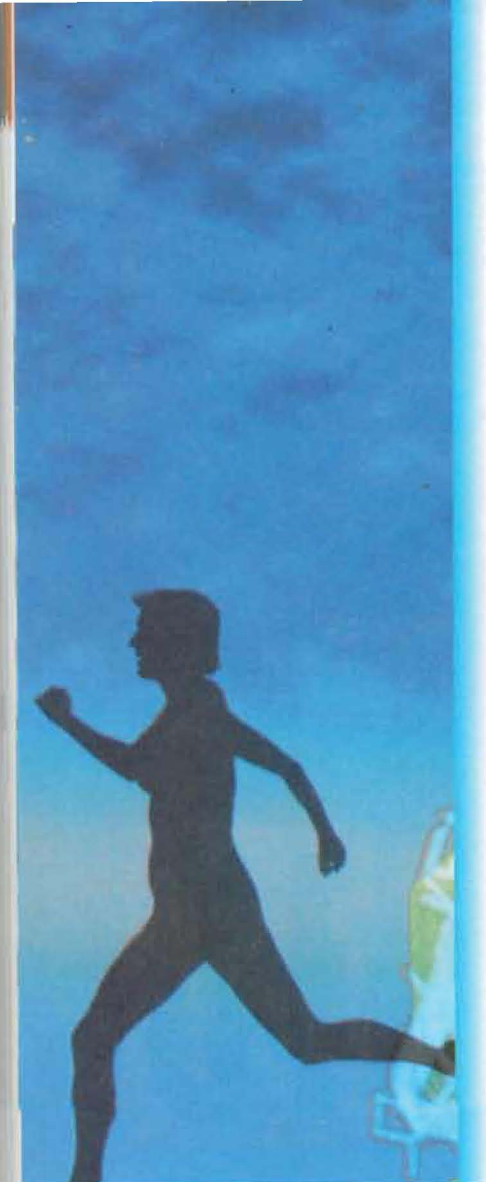


(Objective Checklist, continued)

FEMALE REPRODUCTIVE FUNCTIONS AND CYCLES (pp. 516–520)

- Define *oogenesis*.
- Describe the influence of FSH and LH on ovarian function.
- Describe the phases and controls of the menstrual cycle.

MAMMARY GLANDS (pp. 520–521)

- Describe the structure and function of the mammary glands.

SURVEY OF PREGNANCY AND EMBRYONIC DEVELOPMENT (pp. 522–529)

- Define *fertilization* and *zygote*.
- Describe implantation.
- Distinguish between an embryo and a fetus.
- List the major functions of the placenta.
- Indicate several ways that pregnancy alters or modifies the functioning of the mother's body.
- Describe how labor is initiated and briefly discuss the three stages of labor.
- List several agents that can interfere with normal fetal development.

DEVELOPMENTAL ASPECTS OF THE REPRODUCTIVE SYSTEM (pp. 529, 530, 532)

- Describe the importance of the presence/absence of testosterone during embryonic development of the reproductive system organs.
- Define *menarche* and *menopause*.
- List common reproductive system problems seen in adult and aging males and females.

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 **primary sex organs,** or **gonads** (go′nadz; "seeds"), are the *testes* in males and the *ovaries* in females. The gonads produce sex cells, or **gametes** (gam′ēts; "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 male is to manufacture male gametes called **sperm** and deliver them to the female reproductive tract. The female, in turn, produces female gametes, called **ova,** or *eggs.* If the time is suitable, the 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

As already noted, the primary reproductive organs of the male are the **testes** (tes′tēz), or *male gonads,* which have both an exocrine (sperm-

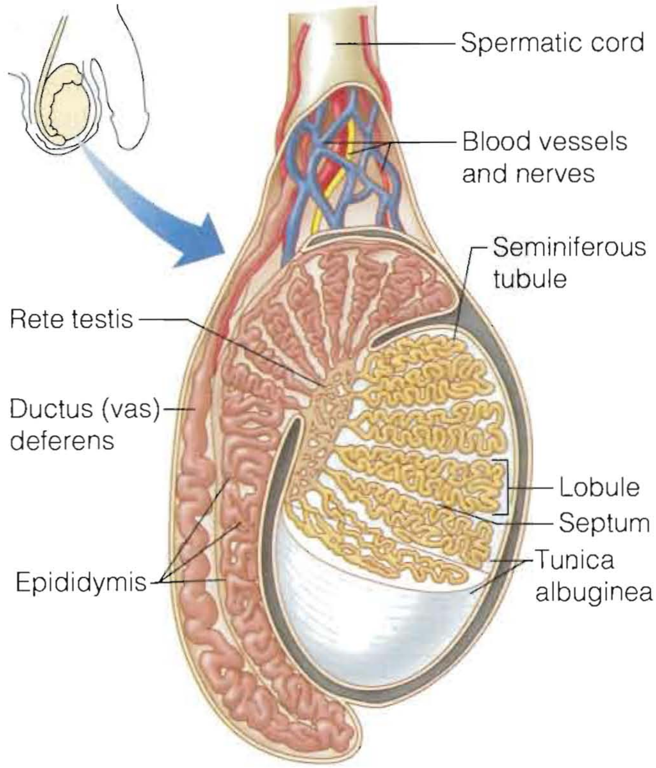


Figure 16.1 Sagittal section of the testis and associated epididymis.

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 olive-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'nĭ-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 lobules. Each lobule contains one to four tightly coiled **seminiferous** (sem"in-if'er-us) **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"ĭ-did'ĭ-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—most importantly, *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 comma-shaped **epididymis** is a highly coiled tube about 6 m (20 feet) long that caps the superior part 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 snaking course of the epididymis (a trip that takes about 20 days), they mature, gaining the ability to swim. When a male is sexually stimulated, 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 bladder. This tube is enclosed, along with blood vessels and nerves, in a connective tissue sheath called the **spermatic cord** (see Figure 16.1). The end of the ductus deferens 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 (*ejac* = 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 scrotal sac, which hangs outside

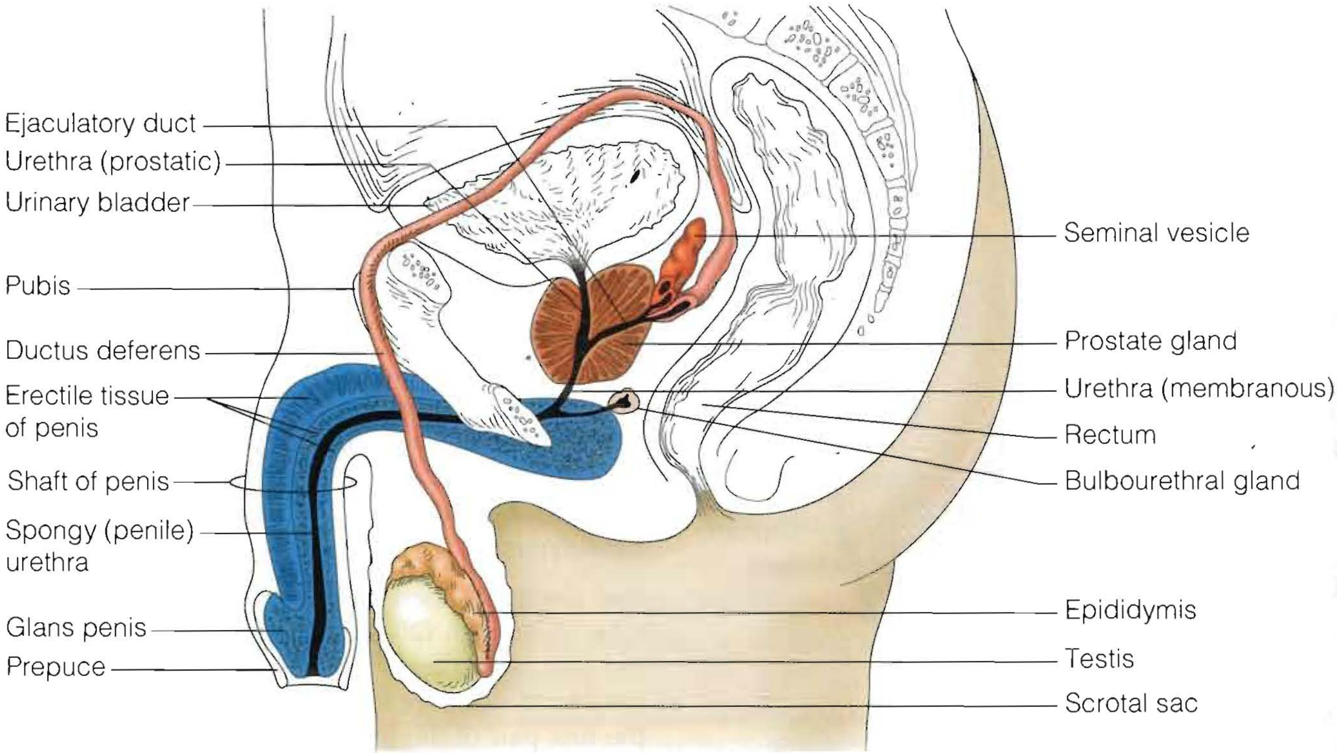


Figure 16.2 Reproductive organs of the male (sagittal view).

the body cavity. Some men voluntarily opt to take full responsibility for birth control by having a **vasectomy** (vah-sek'to-me). In this relatively minor operation, the surgeon makes a small incision into the scrotum and then cuts through or cauterizes the ductus deferens. Sperm are still produced, but they can no longer reach the body exterior and eventually they deteriorate and are reabsorbed. A man is sterile after this procedure, but because testosterone is still produced, the sex drive and secondary sex characteristics are retained.

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 the penis; and (3) the **spongy (penile) urethra,** running within the length of the penis. 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 constricts. This event not only prevents the passage of urine into the urethra, but also prevents sperm from entering the urinary bladder.

Accessory Glands and Semen

The accessory glands include the paired seminal vesicles, the single prostate gland, 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'ĭ-nul) **vesicles,** located at the base of the bladder, produce about 60 percent of 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 Gland

The **prostate gland** is a single gland about the size and shape of a chestnut (see Figure 16.2). It encircles the upper (prostatic) part of the urethra just below the bladder. Prostate gland secretion is a milky fluid that plays a role in activating sperm. During ejaculation, it enters the urethra through several small ducts. Since 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 gland has a reputation as a health destroyer. Hypertrophy of the prostate gland, which affects nearly every elderly male, strangles the urethra. This troublesome condition makes urination difficult and enhances the risk of bladder infections (*cystitis*) and kidney damage. Traditional treatment has been surgical, but some newer options are becoming more popular. These include

- 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 radio-frequency radiation, which incinerate excess prostate tissue

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 is believed to cleanse the urethra of traces of acidic urine, 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 provides a transport medium and nutrients and contains 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 acid 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 seminal plasmin, a chemical that inhibits bacterial multiplication, the hormone relaxin, and certain enzymes that enhance sperm motility.

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 130 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 **external genitalia** (jen″i-tal′e-ah) of the male include the scrotum and the penis (see Figure 16.2). The **scrotum** (skro′tum; "pouch") is a divided sac of skin 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 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.

Male Reproductive Functions

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'ĕ-sis), begins during puberty and continues throughout life. Every day a man makes millions of sperm. Since only one sperm fertilizes an egg, it seems that nature has made sure that the human species will not be endangered for lack of sperm.

Sperm formation occurs 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

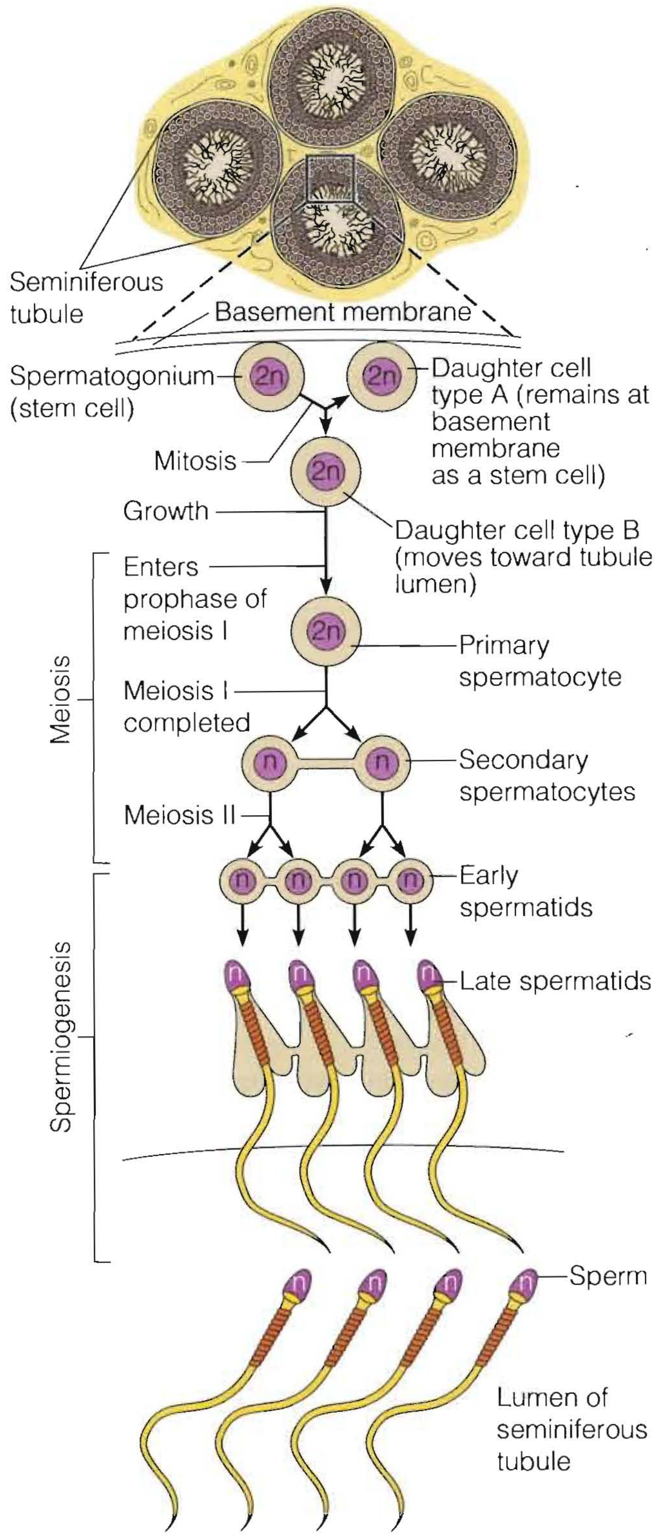


Figure 16.3 Spermatogenesis. Flowchart showing the relative position of the spermatogenic cells in the wall of the seminiferous tubule. Although the stem cells and the primary spermatocytes have the same number of chromosomes (46, designated as 2*n*) as other body cells, the products of meiosis (spermatids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

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 (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) and 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, the progress of meiosis can be followed from the tubule periphery to the lumen. The spermatids, which are the products of meiosis, are *not* functional sperm. They are nonmotile cells 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'ĕ-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.

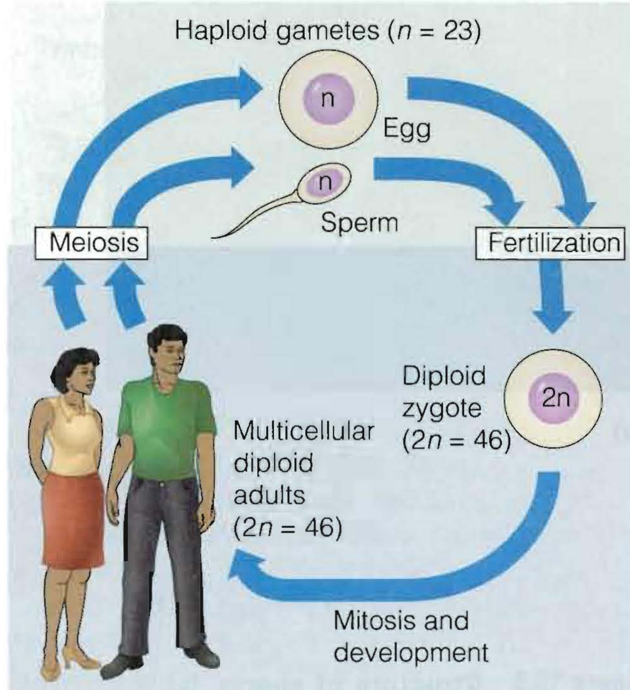
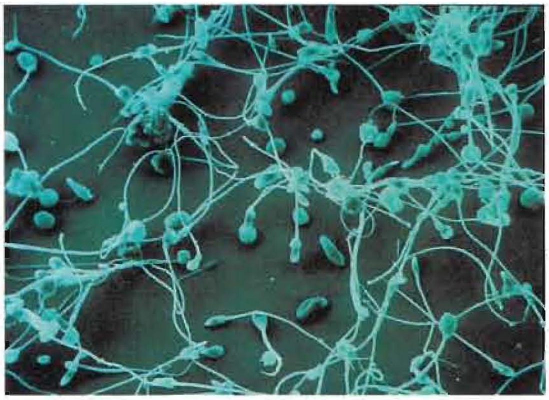


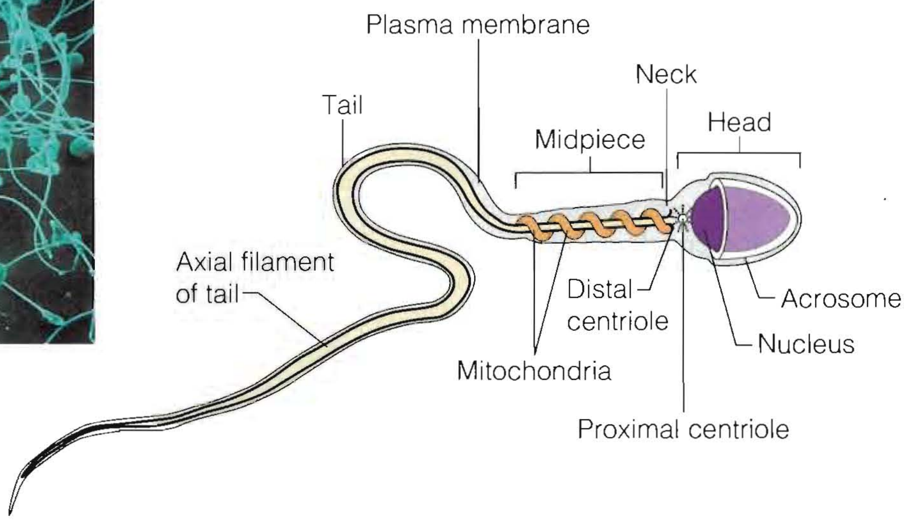
Figure 16.4 **The human life cycle.**

The sperm head contains 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 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 enzymes that help the sperm penetrate through the follicle cells that surround the egg. Filaments, which form the 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.

The entire process of spermatogenesis, from the formation of a primary spermatocyte to release of immature sperm in the tubule lumen, takes 64 to 72 days. Sperm in the lumen are unable to "swim" and 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.



(a)



(b)

Figure 16.5 Structure of sperm. (a) Scanning electron micrograph of mature sperm (430×). **(b)** Diagrammatic view of a sperm.

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). ▲

Testosterone Production

As noted earlier, the interstitial cells produce **testosterone** (tes-tos′tĕ-rōn), the most important hormonal product of the testes. During puberty, as the seminiferous tubules are being prodded to produce sperm by FSH, the interstitial cells are being activated by *luteinizing hormone (LH),* sometimes called *interstitial cell–stimulating hormone (ICSH),* 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 male stimulates his reproductive organs to develop to their adult size, underlies the sex drive, and causes the secondary male sex characteristics to

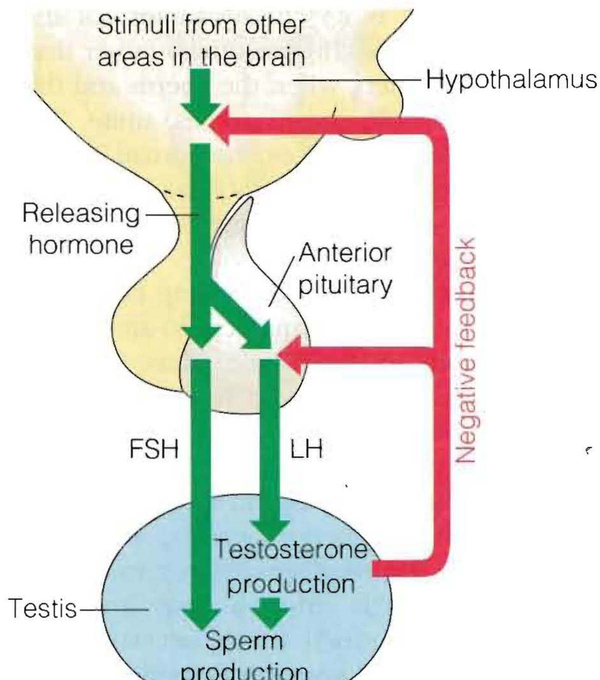


Figure 16.6 Hormonal control of the testis.

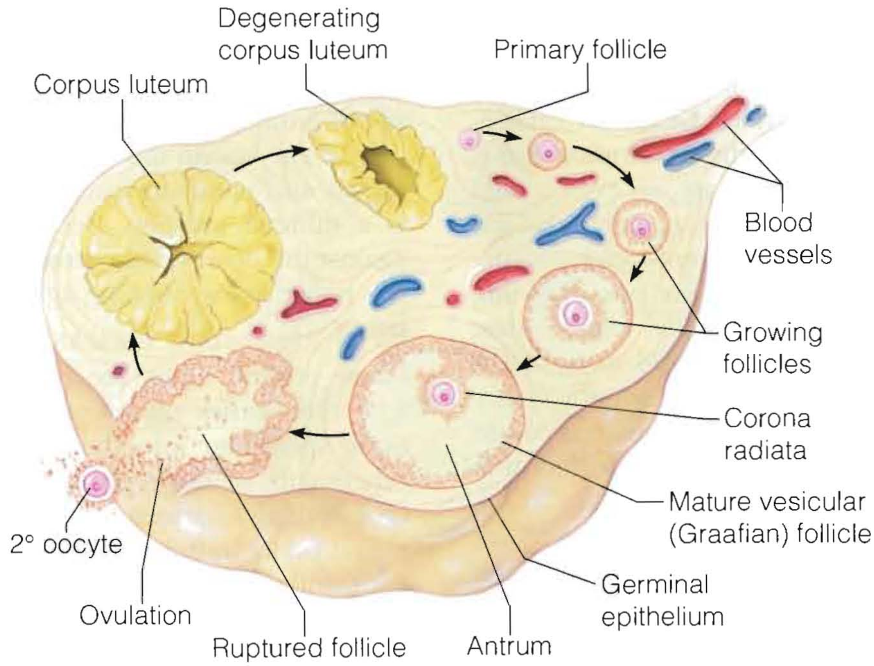


Figure 16.7 **Diagrammatic view of a human ovary.**

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

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

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

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

Anatomy of the Female Reproductive System

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

Ovaries

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