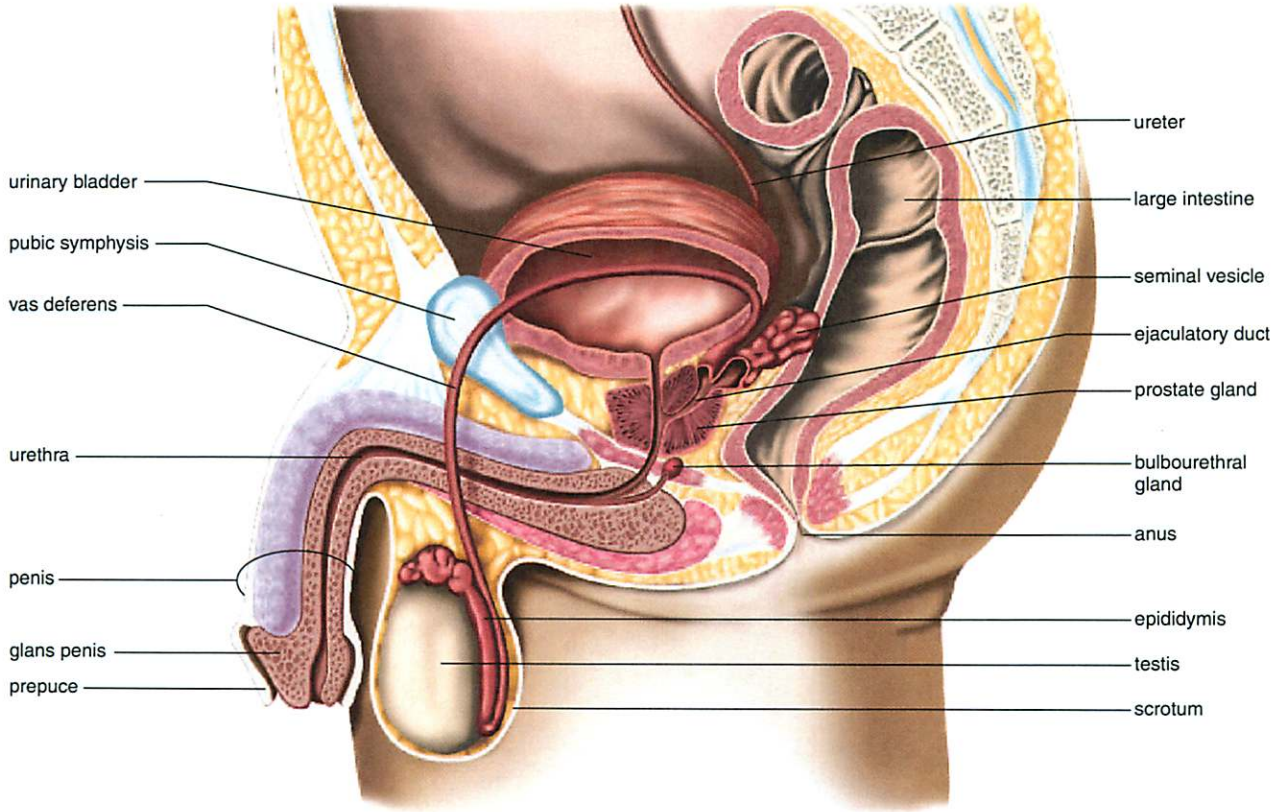
Figure 17.2 The male reproductive system. The testes produce sperm. The seminal vesicles, the prostate gland, and the bulbourethral glands provide a fluid medium for the sperm, which move from a testis to an epididymis to a vas deferens and through the ejaculatory duct to the urethra in the penis. The foreskin (prepuce) is removed when a penis is circumcised.



17.2 Male Reproductive System

The male reproductive system includes the organs depicted in Figure 17.2. The *primary sex organs* of a male are the paired testes (sing., **testis**), which are suspended within the sacs of the **scrotum.** The testes are the primary sex organs because they produce sperm and the male sex hormones (**androgens**).

The other organs depicted in Figure 17.2 are the *accessory* (or secondary) *sex organs* of a male. Sperm produced by the testes are stored within the **epididymis** (pl., epididymides). Then they enter a **vas deferens** (pl., vasa deferentia), which transports them to an **ejaculatory duct.** The ejaculatory ducts enter the **urethra.** (The urethra in males is a part of both the urinary system and the reproductive system.) The urethra passes through the penis and transports sperm to outside the body.

At the time of **ejaculation**, sperm leave the penis in a fluid called **semen** (seminal fluid). The seminal vesicles, the prostate gland, and the bulbourethral glands (Cowper glands) add secretions to seminal fluid. The **seminal vesicles** lie lateral to the vas deferens, and their ducts join to form an ejaculatory duct. The **prostate gland** is a single, donut-shaped gland that surrounds the upper portion of the urethra just inferior to the bladder. **Bulbourethral glands** are pea-sized organs that lie inferior to the prostate on either side of the urethra.

Each component of seminal fluid seems to have a particular function. Sperm are more viable in a basic solution, and seminal fluid, which is milky in appearance, has a slightly basic pH (about 7.5). Swimming sperm require energy, and seminal fluid contains the sugar fructose, which presumably serves as an energy source. Semen also contains prostaglandins, chemicals that cause the uterus to contract. Uterine contractions help propel the sperm toward the egg.

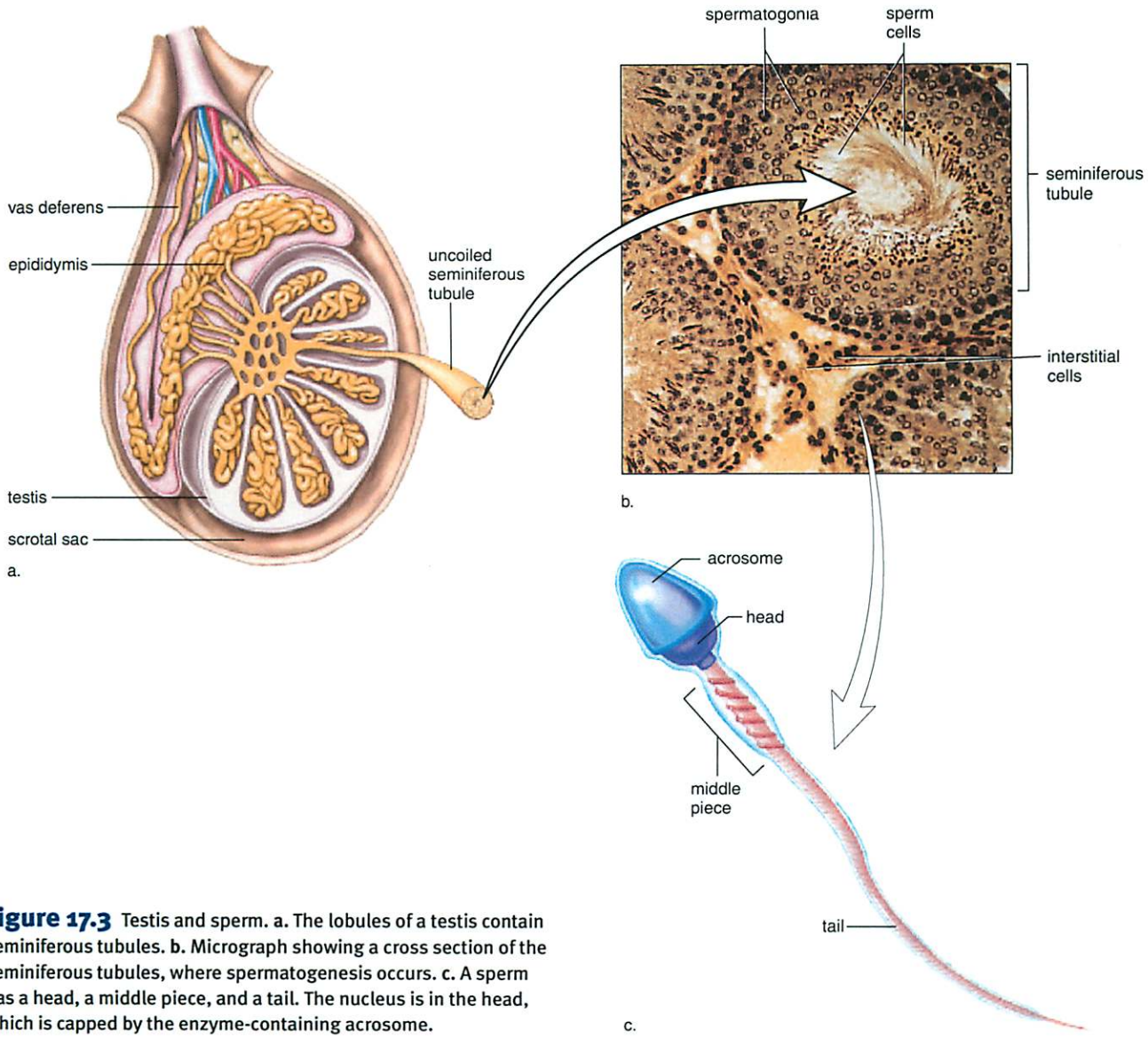


Figure 17.3 Testis and sperm. **a.** The lobules of a testis contain seminiferous tubules. **b.** Micrograph showing a cross section of the seminiferous tubules, where spermatogenesis occurs. **c.** A sperm has a head, a middle piece, and a tail. The nucleus is in the head, which is capped by the enzyme-containing acrosome.

The Testes

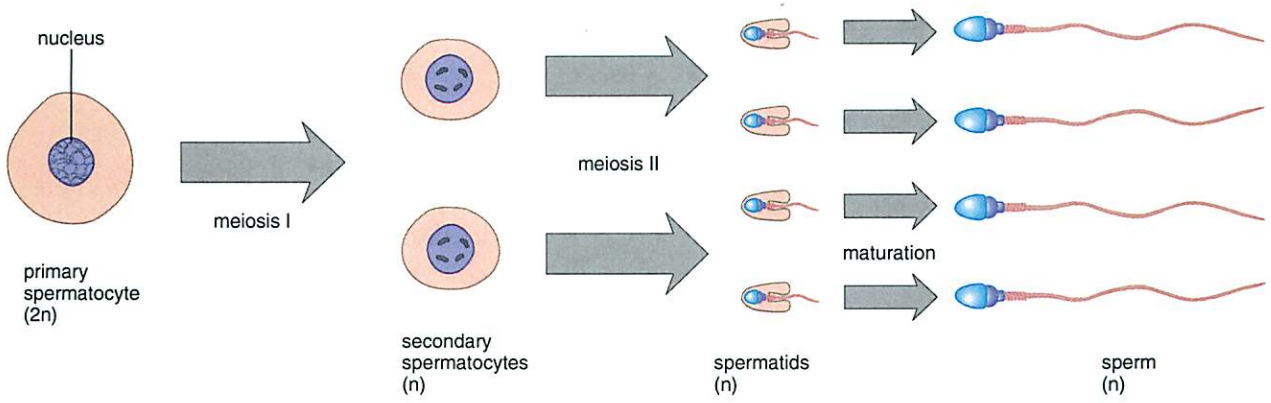
The testes, which produce sperm and also the male sex hormones, lie outside the abdominal cavity of the male within the scrotum. The testes begin their development inside the abdominal cavity but descend into the scrotal sacs during the last two months of fetal development. If, by chance, the testes do not descend and the male is not treated or operated on to place the testes in the scrotum, sterility—the inability to produce offspring—usually follows. This is because the internal temperature of the body is too high to produce viable sperm. A subcutaneous muscle along with an adjoining muscle raise the scrotum during sexual excitement and when a higher temperature is need to warm the testes.

Anatomy of a Testis

A sagittal section of a testis shows that it is enclosed by a tough, fibrous capsule. The connective tissue of the capsule extends into the testis, forming septa that divide the testis into compartments called lobules. Each lobule contains one to three tightly coiled **seminiferous tubules** (Fig. 17.3*a*). Altogether, these tubules have a combined length of approximately 250 m. A microscopic cross section of a seminiferous tubule reveals that it is packed with cells undergoing spermatogenesis (Fig. 17.3*b*), the production of sperm.

Delicate connective tissue surrounds the seminiferous tubules. Cells that secrete the male sex hormones, the androgens, are located here between the seminiferous tubules.

Figure 17.4 Spermatogenesis.



Therefore, these endocrine cells are called **interstitial cells.** The most important of the androgens is **testosterone,** whose functions are discussed later in this section.

Testicular cancer, or cancer of the testes, is one type of cancer that can be detected by self-examination, as explained in the Medical Focus on page 357.

Spermatogenesis

Spermatogenesis, the production of sperm, includes the process of meiosis as the sperm form. Before puberty, the testes, including the seminiferous tubules, are small and nonfunctioning. At the time of puberty, the interstitial cells become larger and start producing androgens. Then, the seminiferous tubules also enlarge, and they start producing sperm.

The seminiferous tubules contain two types of cells: germ cells, which are involved in spermatogenesis, and sustentacular (Sertoli) cells. Sustentacular cells are large; they extend from the capsule to the lumen of the seminiferous tubule. The sustentacular cells support, nourish, and regulate the development of cells undergoing spermatogenesis.

The germ cells near the capsule are called spermatogonia. The spermatogonia divide, producing more cells by mitosis. Some of these cells remain as spermatogonia, and some are **primary spermatocytes** (Fig. 17.4). The spermatocytes start the process of meiosis, which requires two divisions. Following meiosis I, cells called **secondary spermatocytes** have the reduced, or n, number of chromosomes (i.e., 23 chromosomes). Following meiosis II, there are four spermatids. **Spermatids** then differentiate into sperm.

Mature **sperm,** or spermatozoa, have three distinct parts: a head, a middle piece, and a tail (see Fig. 17.3*c*). Mitochondria in the middle piece provide energy for the movement of the tail, which has the structure of a flagellum. The head contains a nucleus covered by a cap called the **acrosome,** which stores enzymes needed to penetrate the egg. Notice in Figure 17.3*b,* that the sperm are situated so that their tails project into the lumen of the seminiferous tubules.

When formed, the sperm are transported to the epididymis because the seminiferous tubules unite to form a complex network of channels that join, forming ducts. When the ducts join, an epididymis is formed.

The ejaculated semen of a normal human male contains several hundred million sperm, but only one sperm normally enters an egg. Sperm usually do not live more than 48 hours in the female genital tract.

Male Internal Accessory Organs

Table 17.1 lists and Figure 17.5 depicts the internal accessory organs, as well as the other reproductive organs, of the male. Sperm are, transported to the urethra by a series of ducts. Along the way, various glands add secretions to seminal fluid.

Table 17.1 Male Internal Accessory Organs

Organ	Function
Epididymides	Ducts where sperm mature and some sperm are stored
Vas deferentia	Transport and store sperm
Seminal vesicles	Contribute nutrients and fluid to semen
Ejaculatory ducts	Transport sperm
Prostate gland	Contributes basic fluid to semen
Urethra	Transports sperm
Bulbourethral glands	Contribute mucoid fluid to semen

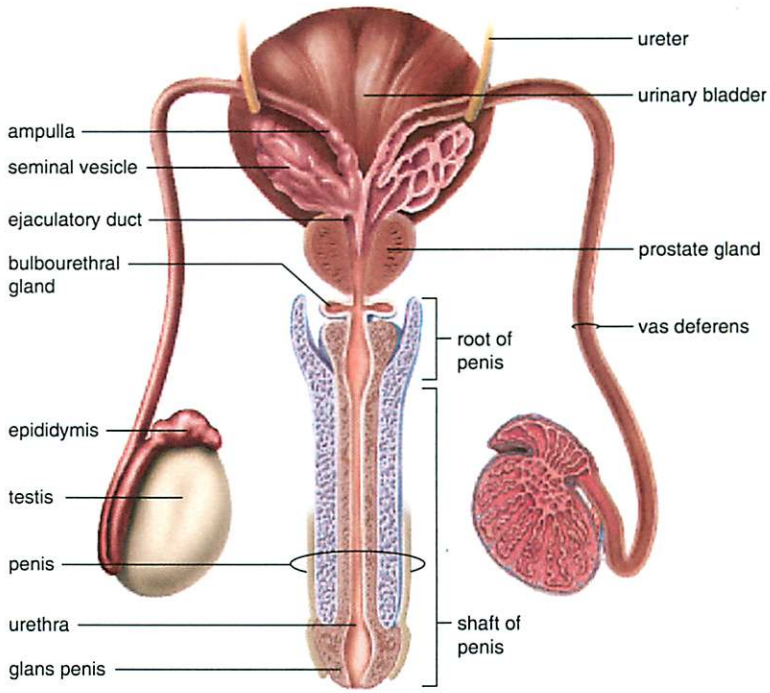


Figure 17.5 Male reproductive system, posterior view. This view shows the duct system that transports sperm from each testis to the urethra, which continues in the penis.

Epididymides

Each epididymis is a tightly coiled, threadlike tube that would stretch about 6 meters if uncoiled. A epididymis runs posteriorly down along a testis and becomes a vas deferens that ascends a testis medially.

The lining of an epididymis consists of pseudostratified columnar epithelium with long cilia. Sperm are stored in the epididymides, and the lining secretes a fluid that supports them. The wall of an epididymis contains a thin layer of smooth muscle. Peristaltic contractions move the sperm along as they mature. By the time the sperm leave the epididymides, they are capable of fertilizing an egg even though they do not "swim" until they enter the vagina.

Vas Deferens

Each vas deferens is a continuation of an epididymis. As the vas deferens ascends into the abdomen, it passes through an inguinal canal. This is the passageway by which a testis descended from the abdomen into the scrotum. The canal contains the *spermatic cords*, which consist of connective tissue and muscle fibers that enclose a vas deferens, blood vessels, and nerves. The inguinal canal remains a weak point in the adominal wall. As such, it is frequently a site of hernias. A **hernia** is an opening or separation of some part of the abdominal wall through which a portion of an internal organ, usually the intestine, protrudes.

After the vas deferens enters the abdomen, it crosses over to reach the posterior side of the urinary bladder. The vas deferens is lined by pseudostratified columnar epithelium that is ciliated at the testicular end. A vas deferens has an expanded portion called the ampulla, but it is slender again when it joins with the duct of a seminal vesicle to form an ejaculatory duct. The ejaculatory ducts pass through the prostate gland to join the urethra.

Seminal Vesicles

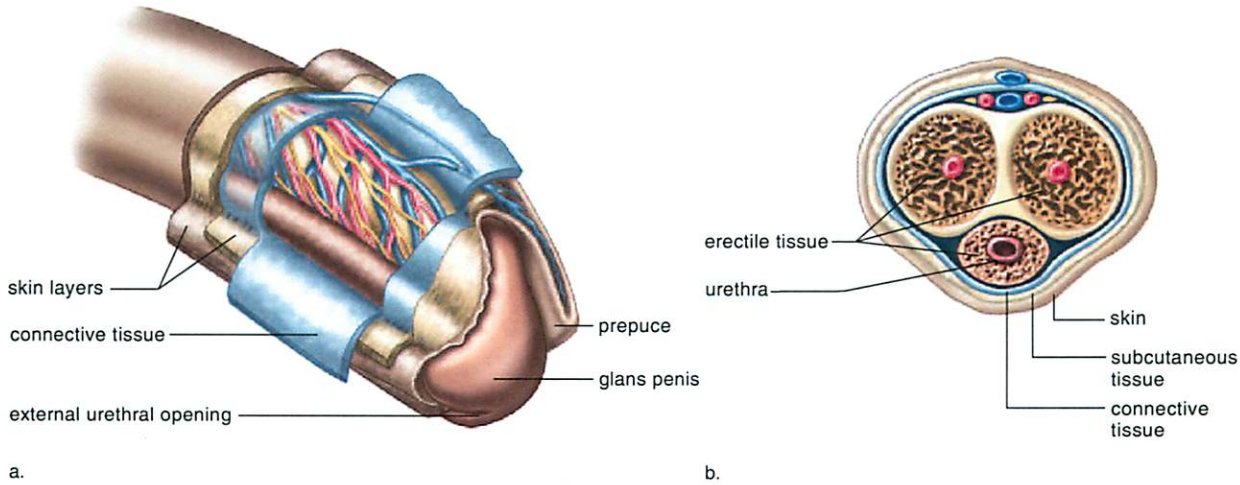
The seminal vesicles lie lateral to the vas deferens on the posterior side of the bladder. They are coiled, membranous pouches about 5 cm long. The glandular lining of the seminal vesicles secretes an alkaline fluid that contains fructose and prostaglandins into an ejaculatory duct. The pH of the fluid helps modify the pH of seminal fluid; the fructose provides energy for sperm; and the prostaglandins promote muscular contractions of the female genital tract that help move sperm along.

Prostate

The prostate gland encircles the urethra just inferior to the bladder. The donut-shaped gland is about 4 cm across, 2 cm thick, and 3 cm in length. The fibrous connective tissue of its capsule extends inward to divide the gland into lobes, each of which contains about 40 to 50 tubules. The epithelium lining the tubules secretes a fluid that is thin, milky, and alkaline. In addition to adjusting the pH of seminal fluid, prostatic fluid enhances the motility of sperm. The secretion of the prostate gland enters the urethra when the smooth muscle in its capsular wall contracts.

As discussed in the Medical Focus on page 338, the prostate gland is a frequent site for cancer.

Figure 17.6 Penis anatomy. **a.** Beneath the skin and the connective tissue lies the urethra, surrounded by erectile tissue. This tissue expands to form the glans penis, which in uncircumcised males is partially covered by the foreskin (prepuce). **b.** Two other columns of erectile tissue in the penis are located posteriorly.



Bulbourethal Glands

The bulbourethral glands (Cowper glands) are two small glands about the size of peas. They are located inferior to the prostate gland and enclosed by fibers of the external urethral sphincter. These glands also contain many tubules that secrete a mucuslike fluid. This fluid lubricates the end of the penis preparatory to sexual intercourse.

Male Sexual Response

The **external genitals** are the sex organs that can be easily observed because they are located outside the body. The **penis** and the scrotum are the external genitals of the male. The penis is the male organ of sexual intercourse by which sperm are introduced into the female reproductive tract.

The penis has an internal root and an external shaft (see Fig. 17.5). At the glans penis, the skin folds back on itself to form the *prepuce,* or foreskin (Fig. 17.6*a*). This is the structure that is removed in the surgical procedure called **circumcision.** Internally, it contains three cylindrical bodies of erectile tissue; the urethra passes though one of them. These three columns are supported by fibrous connective tissue, and the whole is covered with a thin, loose skin (Fig. 17.6*b*).

The erectile tissues contain distensible blood spaces. During sexual arousal, autonomic nerve impulses lead to the production of cGMP (cyclic guanosine monophosphate), causing the smooth muscle walls of incoming arteries to relax and the erectile tissue to fill with blood. The veins that take blood away from the penis are compressed, and the penis becomes erect. **Erectile dysfunction** (formerly called impotency) exists when the erectile tissue doesn't expand enough to compress the veins. The drug Viagra inhibits an enzyme that breaks down cGMP, ensuring that a full erection will take place. However, vision problems may occur when taking Viagra because the same enzyme occurs in the retina.

Orgasm (climax) in males is marked by ejaculation, which has two phases: emission and expulsion. During emission, sperm enter the urethra from each ejaculatory duct, and the prostate, seminal vesicles, and bulbourethral glands contribute secretions to the seminal fluid. Once seminal fluid is in the urethra, rhythmic muscle contractions cause seminal fluid to be expelled from the penis in spurts. During ejaculation, a sphincter closes off the bladder so that no urine enters the urethra. (Notice that the urethra carries either urine or semen at different times.)

Male orgasm includes expulsion of seminal fluid from the penis but also the physiological and psychological sensations that occur at the climax of sexual stimulation. The psychological sensation of pleasure is centered in the brain, but the physiological reactions involve the genital organs and associated muscles, as well as the entire body. Marked muscular tension is followed by contraction and relaxation.

Following ejaculation and/or loss of sexual arousal, the penis returns to its normal flaccid state. After ejaculation, a male typically experiences a period of time, called the refractory period, during which stimulation does not bring about an erection. The length of the refractory period increases with age.

There may be in excess of 400 million sperm in the 3.5 ml of semen expelled during ejaculation. The sperm count can be much lower than this, however, and fertilization of the egg by a sperm can still take place.