Male Reproductive System

The Reproductive System

The male reproductive system consists of a pair of testes, numerous excurrent ducts, and different accessory glands that produce a variety of secretions that are added to sperm to form semen. The **testes** contain spermatogenic **stem cells** that continuously divide to produce new generations of cells that are eventually transformed into **spermatozoa,** or **sperm.** From the testes, the sperm move through excurrent ducts to the **epididymis** for storage and maturation. During sexual excitation and ejaculation, sperm leave the epididymis via the **Ductus (vas) deferens** and exit the reproductive system through the penile **urethra.**

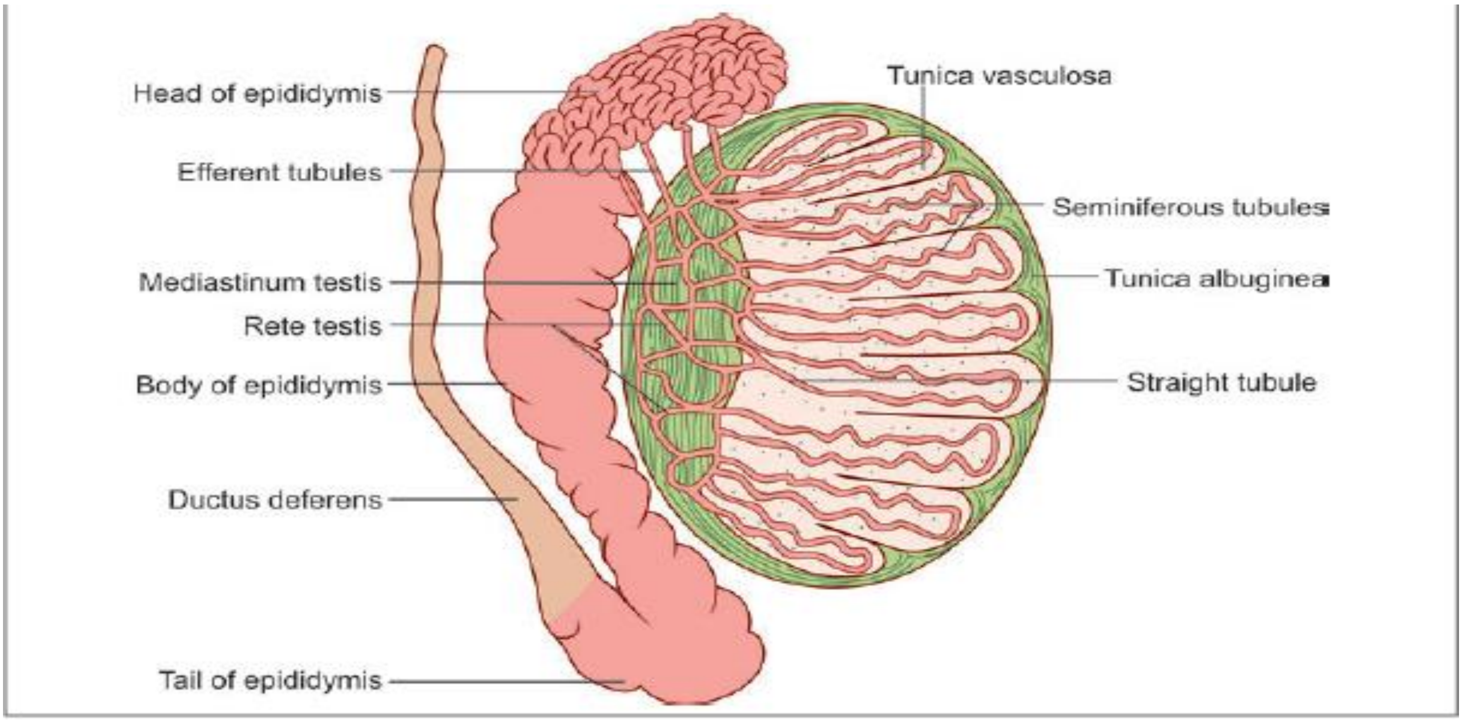
The **accessory glands**—prostate gland, seminal vesicles, and bulbourethral glands

Scrotum

The paired testes are located outside the body cavity in the **scrotum.** In the scrotum, the temperature of the testes is about 2° to 3°C lower than normal body temperature. This lower temperature is vital for normal functioning of the testes and **spermatogenesis,** or sperm production. Perspiration and evaporation of sweat from the scrotal surface maintains the testes in a cooler environment. Equally important in lowering testicular temperature is the special arrangement of blood vessels that supply the testes. Testicular arteries that descend into the scrotum are surrounded by a complex plexus of veins that ascend from the testes and form the **Pampiniform plexus.** Blood returning from the testes in the pampiniform plexus is cooler than the blood in the testicular arteries. By a **countercurrent heat-exchange mechanism,** arterial blood is cooled by venous blood before it enters the testes, helping to maintain a lower temperature in testes.

Testes

A thick connective tissue capsule, the **tunica albuginea,** surrounds each testis. Posteriorly, the tunica albuginea thickens and extends inward into each testis to form the **Mediastinum testis.** A thin connective tissue **septum** extends from the mediastinum testis and subdivides each testis into about 250 incomplete compartments or **Testicular lobules,** each containing one to four coiled **seminiferous tubules.** Each seminiferous tubule is lined by stratified **germinal epithelium,** containing proliferating **spermatogenic (germ) cells** and non-proliferating **Supporting (sustentacular**) or **Sertoli cells.** In the seminiferous tubules, spermatogenic cells divide, mature, and are transformed into sperm. Surrounding each seminiferous tubule are fibroblasts, muscle-like cells, nerves, blood vessels, and lymphatic vessels. In addition, between the seminiferous tubules are clusters of epithelioid cells, the **Interstitial cells (of Leydig).** These cells are steroid-secreting cells that produce the male sex hormone **Testosterone.**



Formation of Sperm: Spermatogenesis

The process of sperm formation is called **spermatogenesis.** This includes mitotic divisions of spermatogenic cells, which produce replacement stem cells and other spermatogenic cells that eventually give rise to **primary spermatocytes** and **secondary spermatocytes.** Both primary and secondary spermatocytes undergo **meiotic divisions** that reduce the number of chromosomes and the amount of DNA. Division of secondary spermatocytes produces cells called **spermatids** that contain 23 single chromosomes (22_X or 22_Y). Spermatids do not undergo any further divisions, but instead are transformed into sperm by a process called **spermiogenesis.**

Once the spermatogenic cells in the germinal epithelium differentiate, they are held together by **intercellular bridges** during further differentiation and development. The intercellular bridges are broken when the developed spermatids are released into the seminiferous tubules as mature sperm.

Transformation of Spermatids: Spermiogenesis

Spermiogenesis is a complex morphologic process by which the spherical spermatids are transformed into elongated sperm cells. During spermiogenesis, the size and shape of the spermatids are altered, and the nuclear chromatin condenses. In the **Golgi phase,** small granules accumulate in the Golgi apparatus of the spermatid and form an **acrosomal granule** within a membrane-bound **acrosomal vesicle.** During the **acrosomal phase**, both the acrosomal vesicle and acrosomal granule spread over the condensing spermatid nucleus at the anterior tip of the spermatid as an **acrosome.** The acrosome functions as a specialized type of lysosome and contains several hydrolytic enzymes, such as hyaluronidase and protease with trypsin-like activity, that assist the sperm in penetrating the cells (corona radiata) and the membrane (zona pellucida) that surround the ovulated oocyte. During the **maturation phases,** the plasma membrane moves posteriorly from the nucleus to cover the developing **flagellum** (sperm tail). The mitochondria migrate to and form a tight sheath around the middle piece of the flagellum. The final maturation phase is characterized by the shedding of the excess or residual cytoplasm of the spermatid and release of the sperm cell into the lumen of the seminiferous tubule. Sertoli cells then phagocytose the residual cytoplasm.

The mature sperm cell is composed of a **head** and an acrosome that surrounds the anterior portion of the nucleus, a **neck,** a **middle piece** characterized by the presence of a compact mitochondrial sheath, and a main or **principal piece or tail.**

Structure of a mature Spermatozoon

The spermatozoa are motile male gametes. With their tails projecting into the lumen of seminiferous tubules, they are found in close association with the sertoli cells.

The spermatozoon has a **head**, a **neck**, and a **principal piece** or **tail**. The tail is made of three pieces i: e middle piece, principal piece and end piece.

The **head** is covered by a cap called the **Acrosomic cap**, **Anterior nuclear cap**, or **Galea Capitis** (Fig. 19.5). It is flattened and oval when seen from the front, but appears to be pointed (some what like a spear-head) when seen from one side, or in section. It consists of chromatin (mostly DNA) that is extremely condensed and, therefore, appears to have a homogeneous structure even when examined by EM. This condensation makes it highly resistant to various physical stresses.

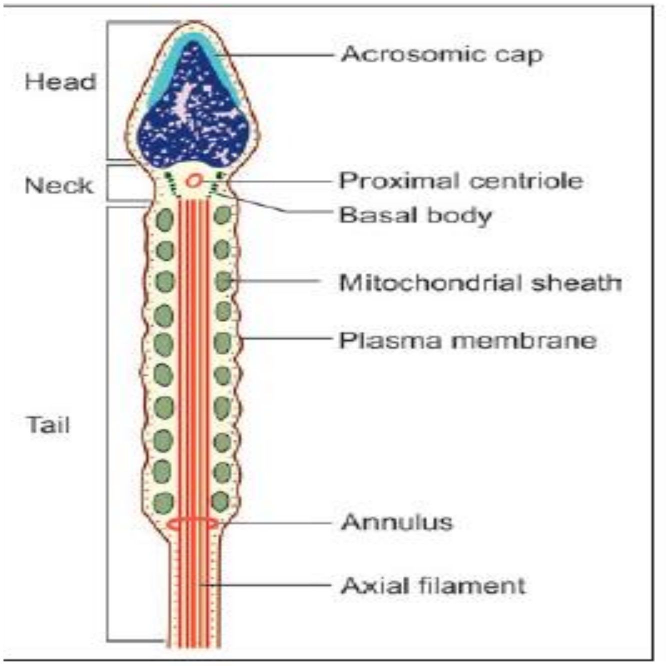


Fig. 19.5: Structure of spermatozoon as seen by electron microscope (Schematic representation)

Note: The acrosome is made up of glycoprotein. It can be regarded as a large lysosome containing numerous enzymes (proteases, acid phosphatase, neuraminidase and hyaluronidase).

The **neck** of the spermatozoon is narrow. It contains a funnel-shaped **basal body** and a spherical **centriole**. The chief structure to be seen in the neck is the **basal body**. It is also called the **connecting piece** because it helps to establish an intimate union between the head and the remainder of the spermatozoon. The basal body is made up of nine segmented rod-like structures each of which is continuous distally with one coarse fiber of the axial filament. On its proximal side (i.e., towards the head of the spermatozoon) the basal body has a convex **articular surface** that fits into a depression (called the **Implantation fossa**) present in the head. An **axial filament** (or **axoneme**) begins just behind the centriole. It passes through the middle piece and extends into the tail. At the point where the middle piece joins the tail, this axial filament passes through a ring-like **annulus**. That part of the axial filament that lies in the middle piece is surrounded by a **spiral sheath** made up of mitochondria.

Pathological Correlation

Tumours of Testis

Testicular tumours can arise from germ cells (Germ cell tumours); stroma (sex cord stromal tumours) or both (combined germ cell-sex cord stromal tumours). Examples of germ cell tumours are seminoma, embryonal carcinoma, teratoma and choriocarcinoma; sex cord stromal tumours are Leydig cell tumour, Sertoli cell tumour and granulosa cell tumour. Gonadoblastoma is an example of combined germ cell-sex cord-stromal tumours.

Germ cell tumours comprise approximately 95% of all testicular tumours and are more frequent before the age of 45 years. Testicular germ cell tumours are almost always malignant.

Clinical Correlation

Varicocele: is an enlargement of the veins within the loose bag of skin that holds the testicles (scrotum). These veins transport oxygen-depleted blood from the testicles. A varicocele occurs when blood pools in the veins rather than circulating efficiently out of the scrotum. Varicoceles usually form during puberty and develop over time. They may cause some discomfort or pain, but they often result in no symptoms or complications. A varicocele may cause poor development of a testicle, low sperm production or other problems that may lead to infertility. Surgery to treat varicocele may be recommended to address these complications.

Fructose content in seminal fluid: In cases of male infertility, on semen analysis absence of fructose suggests congenital absence of seminal vesicle or portion of the ductal system or both.

Excurrent Ducts

Newly released sperm pass from the seminiferous tubules into the inter-testicular excurrent ducts that connect each testis with the overlying epididymis. These excurrent ducts consist of the **straight tubules** (tubuli recti) and the **rete testis,** the epithelial-lined spaces in the mediastinum testis. From the rete testis, the sperm enter approximately 12 short tubules, the **Ductuli efferent** (efferent ducts), which conduct sperm from the rete testis to the initial segment or the head of the **epididymis.**

The extra-testicular duct that conducts the sperm to the penile urethra is the **ductus epididymis,** which is continuous with the **ductus (vas) deferens** and **ejaculatory ducts** in the prostate gland. During sexual excitation and ejaculation, strong contractions of the **smooth muscle** that surrounds the **ductus epididymis** expel the sperm.

Spermatogonia

The function of the testes is to produce both sperm and testosterone. Testosterone is an essential hormone for development and maintenance of male sexual characteristics and normal functioning of the accessory reproductive glands.

The spermatogenic cells in the seminiferous tubules divide, differentiate, and produce sperm by a process called **spermatogenesis.** This process involves the following:

• Mitotic divisions of spermatogonia to form stem cells

• Formation of **primary** and **secondary spermatocytes** from spermatogenic cells

• **Meiotic divisions** of primary and secondary spermatocytes to reduce the somatic chromosome numbers by one half and formation of **spermatids,** which are germ cells with only 23 single chromosomes (22_X or 22_Y)

• Morphologic transformation of spermatids into mature sperm by a process called **spermiogenesis**

Sertoli Cells

Sertoli cells are the supportive cells of the testes that are located among the spermatogenic cells in the seminiferous tubules. They perform numerous important functions in the testes, among which are the following:

• Physical support, protection, and nutrition of the developing sperm (spermatids)

• Phagocytosis of excess cytoplasm (residual bodies) from the developing spermatids

• Release of mature sperm, called spermiation, into the lumen of seminiferous tubules

• Secretion of fructose-rich testicular fluid for nourishment and transport of sperm to the excurrent ducts

• Production and release of androgen-binding protein (ABP) that binds to and increases the concentration of testosterone in the lumen of the seminiferous tubules that is necessary for spermatogenesis. ABP secretion is under the control of follicle-stimulating hormone (FSH) from the pituitary gland

• Secretion of the hormone inhibin, which suppresses the release of FSH from the pituitary gland

• Production and release of the anti-müllerian hormone, also called müllerian-inhibiting hormone, that suppresses the development of müllerian ducts in the male and inhibits the development of female reproductive organs.

Blood-Testis Barrier

The adjacent cytoplasm of Sertoli cells are joined by occluding **Tight junctions,** producing a **blood-testis barrier** that subdivides each seminiferous tubule into a **basal compartment** and an **adluminal compartment.** This important barrier segregates the spermatogonia from all successive stages of spermatogenesis in the adluminal compartment and excludes the plasma proteins and blood borne antibodies from the lumen of seminiferous tubules. The more advanced spermatogenic cells can be recognized by the body as foreign and cause an immune response. The barrier protects these cells from the immune system by restricting the passage of membrane **antigens** from developing sperm into the bloodstream. Thus, the blood-testis barrier prevents an autoimmune response to the individual's own sperm, antibody formation, and eventual induction of sterility. The blood-testis barrier also keeps harmful substances in the blood from entering the developing germinal epithelium.

Hormones of Male Reproductive Organs

Normal spermatogenesis is dependent on the action of **Luteinizing Hormone (LH)** and **Follicle**-S**timulating Hormone (FSH)** produced by **Gonadotrophs** in the **Adenohypophysis** of the pituitary gland. LH binds to receptors on **interstitial cells** (of Leydig) and stimulates them to synthesize the hormone **testosterone.** FSH stimulates **Sertoli cells** to synthesize and release **Androgen-Binging Protein (ABP**) into the seminiferous tubules. ABP combines with testosterone and increases its concentration in the seminiferous tubules, which then stimulates spermatogenesis.

Increased concentration of testosterone in the seminiferous tubules is essential for proper **Spermatogenesis.** In addition, the structure and function of the accessory reproductive glands, as well as development and maintenance of male secondary sexual characteristics, are dependent on proper testosterone levels.

The hormone **Inhibin,** also secreted by the Sertoli cells, has an inhibitory effect on the pituitary gland and suppresses or inhibits additional production of FSH.

Ductuli Efferentes (Efferent Ductules)

The motility of cilia in the **ductuli efferentes** creates a current that assists in transporting the fluid and sperm from the seminiferous tubules to the **ductus epididymis.** In addition, contractility of the smooth muscle fibers that surround these tubules provides additional assistance to sperm transport. The non-ciliated cuboidal cells that also line the ductuli efferentes absorb most of the testicular fluid that was produced in the seminiferous tubules by Sertoli cells.

Ductus Epididymis

The highly coiled ductus epididymis is the site for **accumulation, storage,** and further **maturation** of sperm. When sperm enter the epididymis, they are nonmotile and incapable of fertilizing an oocyte. However, about a week later in transit through the ductus epididymis, the sperm acquire motility. The **principal cells** in the ductus epididymis are lined with long branching microvilli, or **stereocilia,** that continue to absorb testicular fluid that was not absorbed in the ductuli efferentes during the passage of sperm from the testes. The principal cells in the epididymis also phagocytose the remaining residual bodies that were not removed by the Sertoli cells in the seminiferous tubules, as well as any abnormal or degenerating sperm cells. These cells also produce a glycoprotein that **inhibits capacitation** or the fertilizing ability of the sperm until they are deposited in the female reproductive tract.

Accessory Reproductive Glands

Seminal Vesicles, Prostate Gland, Bulbourethral Glands, and Penis

The accessory glands of the male reproductive system consist of paired **seminal vesicles,** paired **bulbourethral glands,** and a single **prostate gland.** These structures are directly associated with the male reproductive tract and produce numerous secretory products that mix with sperm to produce a fluid called **semen.** The penis serves as the copulatory organ, and the penile urethra serves as a common passageway for urine or semen.

The seminal vesicles are located posterior to the bladder and superior to the prostate gland. The excretory duct of each seminal vesicle joins the dilated terminal part of each ductus (vas) deferens, the **ampulla,** to form the **ejaculatory ducts.** The ejaculatory ducts enter and continue through the prostate gland to open into the **prostatic urethra.**

The prostate gland is located inferior or down to the neck of the bladder. The **urethra** exits the bladder and passes through the prostate gland as the **prostatic urethra.** In addition to the ejaculatory ducts, numerous excretory ducts from prostatic glands open into the prostatic urethra.

The bulbourethral glands are small, pea-sized glands located at the root of the **penis** and embedded in the skeletal muscles of the urogenital diaphragm; their excretory ducts terminate in the proximal portion of the **penile urethra.**

The **penis** consists of **erectile tissues,** the paired dorsal **corpora cavernosa** and a single ventral **corpus spongiosum** that expands distally into the **glans penis.** Because the penile urethra extends through the entire length of the corpus spongiosum, this portion of the penis is also called the **corpus cavernosum**

urethrae. Each erectile body in the penis is surrounded by the connective tissue layer **tunica albuginea.**

The erectile tissues in the penis consist of irregular vascular spaces lined by vascular endothelium. The trabeculae between these spaces contain collagen and elastic fibers and smooth muscles. Blood enters the vascular spaces from the branches of the **dorsal artery** and **deep arteries of the penis** and is drained by peripheral veins.

The secretory products from the seminal vesicles, prostate gland, and bulbourethral glands mix with sperm and form **semen.** Semen provides the sperm with a liquid transport medium and nutrients. It also neutralizes the acidity of the male urethra and vaginal canal, and activates the sperm after ejaculation.

The **seminal vesicles** produce a yellowish, viscous fluid that contain high concentration of sperm-activating chemicals, such as **fructose,** the main carbohydrate component of semen. Fructose is metabolized by sperm and serves as the main **energy** source for sperm motility.

Seminal vesicles produce most of the fluid found in semen. The **prostate gland** produces a thin, watery, slightly acidic fluid, rich in citric acid, prostatic acid phosphatase, amylase, and prostate-specific antigen (PSA). The enzyme fibrinolysin in the fluid liquefies the congealed semen after ejaculation. PSA is very useful for diagnosis of prostatic cancer because its concentration often increases in the blood during malignancy.

The **bulbourethral glands** produce a clear, viscid, mucouslike secretion that, during erotic stimulation, is released and serves as a lubricant for the penile urethra. During ejaculation, secretions from the bulbourethral glands precede other components of the semen.

Clinical Correlation

Benign nodular hyperplasia of prostate: Non-neoplastic tumour-like enlargement of the prostate, is a very common condition in men and considered by some as normal ageing process. It becomes increasingly more frequent above the age of 50 years and its incidence approaches 75–80% in men above 80 years. The central zone commonly undergoes benign hypertrophy in old persons. Enlargement of the prostate can compress the urethra leading to problems in passing urine.

Carcinoma of prostate: Cancer of the prostate is the second most common form of cancer in males, followed in frequency by lung cancer. It is a disease of men above the age of 50 years and its prevalence increases with increasing age so that more than 50% of men 80 years old have asymptomatic (latent) carcinoma of the prostate. Many a times, carcinoma of the prostate is small and detected as microscopic foci in a prostate removed for benign enlargement of prostate or found incidentally at autopsy. The peripheral zone is often the site of carcinoma.