Chapter 18
Male Reproductive System

18.1. Introduction

The male reproductive system is composed of Primary Sex Organs and Secondary Sex Organs. The primary sex organs are the Testes. The testes are composed of many very small, convoluted tubules, called Seminiferous Tubules, and abundant interstitial tissue. The various cells of the testes perform the following tasks: [1] production of spermatozoa, the male gametes [2] isolate, protect, nurture, and support the developing gametes [3] production of the hormones of the male reproductive system
[4] phagocytosis.
The secondary, or accessory, sex organs are a series of excurrent ducts having numerous glandular modifications which will ultimately terminate in the penis. The excurrent duct system includes: tubuli recti, rete testes, efferent ductules, ductus epididymides, vas deferens, ampulla, ejaculatory duct, and the urethra. These ducts have three purposes: {a} They store sperm.{b} They serve as the site for sperm maturation.{c} They transport the sperm.

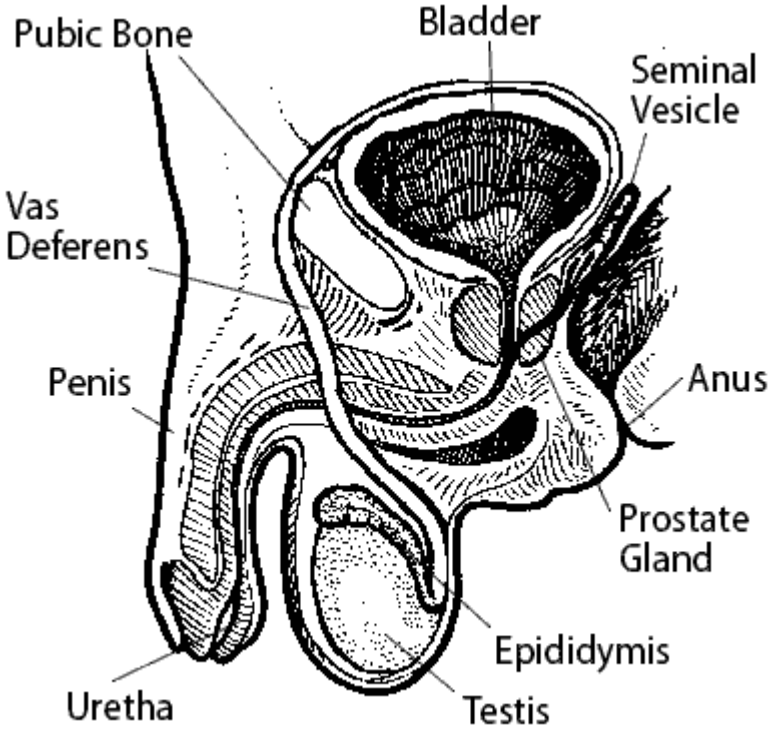

Fig.18.1. The Male Reproductive System

The glandular modifications include: ampullary diverticula, seminal vesicles, prostate, bulbourethral glands, urethral glands, and the preputial glands of Tyson. Primarily these glands produce the fluid component of the ejaculate, Semen. Semen aids in reproduction by the following functions: {1} It serves as the medium for transport of the spermatozoa. {2} It provides factors required for sperm metabolism and energetics. {3} It serves to

lubricate the excurrent ducts. {4} It contains secretions which may well improve sperm effectiveness in the female reproductive tract.

18.2. The Testes

The testes are both exocrine and endocrine in nature. The exocrine function is to produce the male gametes. This process is called Spermatogenesis and occurs in the seminiferous tubules. The seminiferous tubules are a portion of the testis parenchyma. The endocrine function is mainly to produce the male androgens, especially testosterone. The endocrine cells of the testis are the Interstitial cells of Leydig. These epithelial endocrine cells are located in the stroma of the testis. So, in the testis the stroma has both a supportive and a secretory role. Like all epithelial organs the testes consist of a parenchyma and a stroma. The parenchyma is the germinal epithelium of male reproduction. It includes the seminiferous tubules and the supportive Sertoli Cells. The stroma is a connective, supportive, and secretory structure. Each testis is surrounded by a dense, fibrous connective tissue capsule called the Tunica Albuginea. Within the tunica albuginea are fibroblasts, collagen fibers, and some smooth myofibers. From the tunica albuginea thin connective tissue extensions, called Septa, radiate into the testis dividing it into lobules. Each lobule will contain between one to three seminiferous tubules. The seminiferous tubules will drain into one rete testis per lobule. The innermost portion of this testicular capsule is composed of a thin, delicate layer of loose connective tissue and blood vessels called the Tunica Vasculosa.

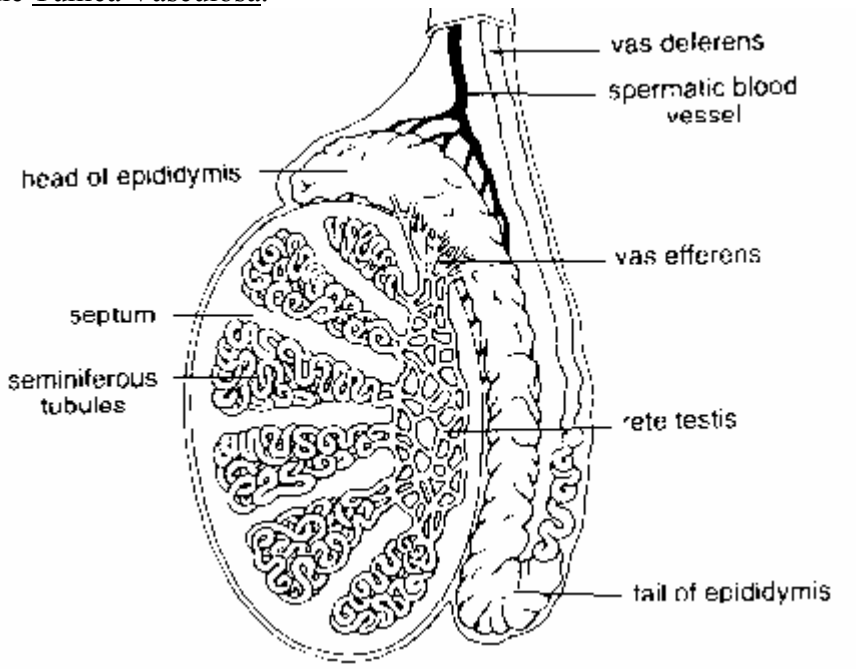

Fig.18.2. CS of Testis showing seminferous tubules and position of epididymis

18.2.1. The Seminiferous Tubules

The seminiferous tubules are highly convoluted tubules lined by a highly specialized epithelium called the Germinal/Seminiferous Epithelium. The seminiferous epithelium consists of two cell populations: spermatogenic cells and Sertoli cells.

a) Spermatogenic Cells

The spermatogenic cells show many characteristics typical of a renewing epithelium (ex;

the epidermis): The most immature elements are located at the basement membrane and as the cells mature they move towards the surface/lumen. The epithelium contains stem cells, proliferating cells, differentiating cells, and exfoliating cells. The successive orders of spermatogenic cells are: spermatogonia, spermatocytes, spermatids, and spermatozoa. Spermatogenesis is the process by which spermatogonia develop into spermatozoa. There are three major stages: spermatocytogenesis, meiosis, and spermiogenesis. Spermatocytogenesis is the stage when spermatogonia, the stem cells, generate the spermatocytes and replace themselves. The spermatogonia rest on the basement membrane. They will give rise to new cells by mitosis. The spermatogonia have a diploid (2N) nucleus.

Meiosis is a special form of cell division resulting in haploid (1N) cells. In spermatogenesis meiosis 1 and meiosis 2 occur in the primary and secondary spermatocytes respectively. Primary and secondary spermatocytes can be distinguished by location relative to the basement membrane, size, and nuclear characteristics.

Primary spermatocytes are large cells, located closer to the basement membrane, with distinct chromatin "threads" in the nucleus.

Secondary spermatocytes are smaller cells, located further from the basement membrane, with less distinct chromatin "granules" in the nucleus. The result of the meiosis stage is the production of four haploid spermatids from each primary spermatocytes that begins meiosis 1.

Spermiogenesis is the stage that produces the actual spermatozoa. This is not a stage of cellular division but rather a stage of cellular transformation where the spermatids undergoes a series of changes to become the spermatozoa. Spermiogenesis occurs in the upper layers of the germinal epithelium. Spermiogenesis has four events: {1} formation of the Acrosome, {2} condensation and elongation of the nucleus, {3} formation of the flagellum,{4} and the discharge of nonessential organelles from the cytoplasm.

b] The Mature Sperm Cell, The Spermatozoa

The spermatozoa are the principle exocrine product of the testes. On average 95 million spermatozoa are produced per testicle per day. The cellular anatomy of the sperm cell can be divided into: a head and a tail.

{a} Head - contains the haploid nucleus and is capped by the acrosome. The acrosome is a catlike envelope containing hydrolytic enzymes (hyaluronidase) to penetrate the follicle.

{b} Tail - is an elongated flagellum divided into four portions:

{1} Neck - the point of connection between the head and tail. It contains a pair of centrioles.

{2} Middle Piece/Midpiece - is a portion of the flagellum and an accompanying sheath of numerous mitochondria which will power the gamete.

{3} Principle Piece - is another portion of the flagellum surrounded by a fibrous sheath to support the tail.

{4} End Piece - is the terminal portion of the flagellum and of the tail.

c] Capacitation of The Sperm

When ejaculated into the female reproductive tract the spermatozoa are still in an inactive state. The activation of the spermatozoa is termed capacitiation. Capacitation is due to enzymes located in the seminal fluid.

d) Sertoli Cells

The Sertoli cells are roughly columnar cells of the germinal epithelium. They are large cell extending from the basement membrane to the lumen of the seminiferous tubule. They have cytoplasmic invaginations in which are located the spermatogenic cells. Sertoli cells demonstrate: [1] numerous cytoplasmic invaginations, [2] a large basally oriented nucleus with a prominent nucleolus and highly folded nuclear envelope, [3] well developed smooth endoplasmic reticuli and numerous Golgi, [4] numerous microfilaments and microtubules, [5] numerous mitochondria, [6] and many intercellular junctions with adjacent Sertoli cells including gap junctions and numerous tight junctions.

Sertoli cells are functionally diverse cells: [1] They support, protect, nourish, regulate, and eventually release the gametes. [2] They conduct phagocytosis on degenerative germinal cells and spermiogenic residual bodies. [3] They secrete a variety of products. These products include the fluid which serves as the medium for the passage of sperm through the early portions of the excurrent ducts.

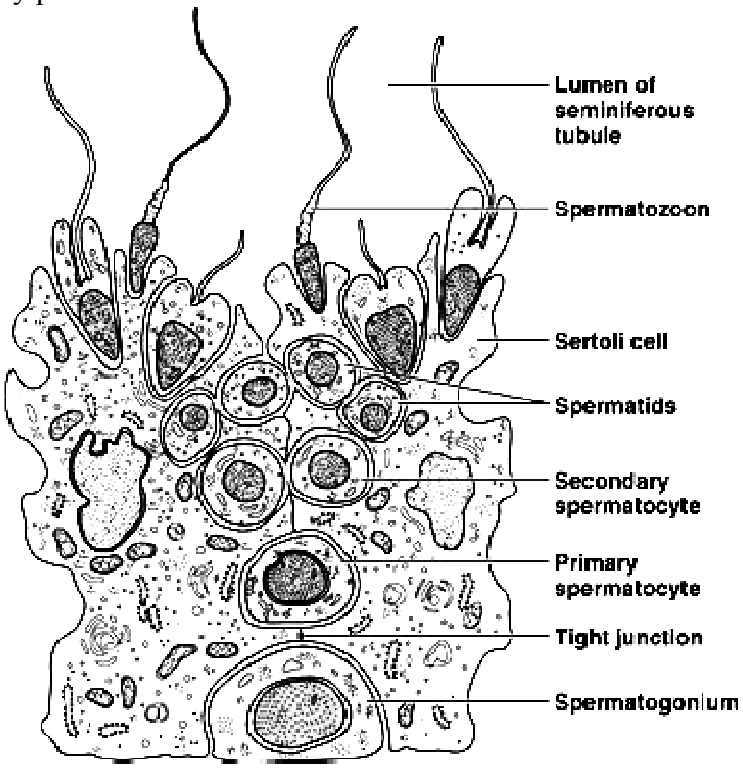

Fig.18.3.Histology of a Testis

18.2.2.The Interstitial Tissue of the Testis

The interstitial tissue of the testis is a delicate, vascular, loose connective tissue called the Intertubular Connective Tissue. It consists of one or more layers being in close association with the seminiferous tubules and looser intermediate regions containing Leydig cells. The blood vessels within this interstitial tissue are continuous with those of the tunica vasculosa (of the testicular capsule). The interstitial tissue will contain: Leydig cells, fibroblasts, fibrocytes, macrophages, mast cells, lymphocytes, collagen fibers, blood vessels, and lymph vessels. One portion of the intertubular connective tissue is the Peritubular Boundary Tissue (aka; PBT). Peritubular boundary tissue could be considered to be the supporting lamina propria of the germinal epithelium (of the seminiferous

tubules). It consists of collagen fibers embedded in an amorphous ground substance. It will also contain myoid cells. The myoid cells of the peritubular boundary tissue are elongated cells resembling fibroblasts containing prominent actin filaments. The myoid cells are contractile and **may** be involved in the movements of the seminiferous tubules.

18.2.3. The Interstitial Cells of Leydig

The interstitial tissue is an endocrine component of the testis due to the presence of Leydig cells. Leydig cells are polyhedral, epitheliod cells. They have large nuclei having 1 or 2 prominent nucleoli. They have an eosinophilic cytoplasm. They have the typical steroid secretory adaptations such as extensive smooth endoplasmic reticuli, numerous mitochondria and Golgi, and the presence of lipid droplets. They also have highly structures crystals of undetermined function called the Crystals of Reinke. The Leydig cells produce the androgenic steroid hormones responsible for male sexual characteristics and, in particular, testosterone. Leydig cells are under hormonal control by the gonadotropic hormone leutinizing hormone (LH). LH is produced by the anterior pituitary.

18.3. The Excurrent Ducts and Accessory Sex Glands

18.3.1. Seminiferous Termini

The seminiferous termini are the start of the excurrent duct system. They are the modified terminal portion of the seminiferous tubules and will drain into the Tubuli Recti. Unlike the seminiferous tubule, the seminiferous termini are straight, not convoluted, and are sometimes referred to as Straight Tubules. The seminiferous termini lack the spermatogenic elements of the seminiferous tubules. So they are lined only by the columnar shaped Sertoli cells. Seminiferous termini also have a narrower lumen than do the seminiferous tubules.

a) Tubuli Recti: These are straight tubules which connect the seminiferous termini to the rete testis. They have a narrower lumen than do the seminiferous termini. The are lined by a simple cuboidal epithelium.

b) Rete Testis: The rete testis is a network of labyrinthian channels head and superior portion of the body of the posterior testis. It serves to connect the ducts of the testis to those of the epididymis. They are described as being lined by a simple cuboidal epithelium. Although the cells are variable in height ranging from squamous-like to a low columnar. Each epithelial cell possesses a single flagellum. Their underlying connective tissue is loose and highly vascularized.

c) Ductuli Efferentes/Efferent Ductules of the Epididymides: The efferent ductules are a series of approximately 12 delicate, convoluted tubules located in the head of the epididymis. Each efferent duct is lined by a simple epithelium composed of cells of varying height. Due to the varying cell heights, the epithelium gives the lumen of the duct a "stellate" or "festooned" appearance. There are two epithelial cell types present:

a} Principle Cells - columnar cells having numerous short microvilli on their lumenal surface.

b} Ciliated Cells - columnar cells having numerous long cilia on their lumenal surface. The cilia beat towards the ductus epididymis and allow for transport of the spermatozoa.

Immediately below the basement membrane is a loose connective tissue containing elastic fibers. Surrounding the loose connective tissue is a circularly arranged band of smooth muscle.

The efferent ductules are responsible for the movement/transport of the sperm. The efferent ductules are also responsible for the absorption of a portion of the fluid produced by the testis. This is the purpose for the microvilli on the principle cells.

d) Ductus Epididymides: The ductus epididymis is a single highly coiled tubule making up the body and tail of the epididymis. (A small portion of it may be found in the head.) It runs posteriolateral to the testis. It's uncoiled length is 6 meters.

The ductus epididymis is lined by a pseudostratified columnar epithelium having two cell types:

1] Principle Cells - columnar epithelial cells possessing very long microvilli called Stereocilia.

2] Basal Cells - short cells resting on the basement membrane that do not extend to the lumen.

Surrounding the epithelium is a very vascular loose connective tissue and smooth muscle. The histology of the ductus epidiymus does display regional change: The epithelium diminishes in height between the head and the tail of the epididymis. It goes from tall, columnar principle cells having long stereocilia to cuboidal principle cells having shorter stereocilia. The muscular component thickens from unilaminar in the head to trilaminar in the tail.

The ductus epididymis is responsible for fluid absorption and modification. The ductus epididymis is responsible for sperm storage. It handles the bulk of sperm storage. It serves as the site of sperm maturation. Before maturation in the epididymis the spermatozoa are not capable of full motility and fertilization. The ductus epididymis is responsible for sperm expulsion during the ejaculation.

e) Vas Deferens/Ductus Deferens: The vas deferens picks up sperm from the tail of the epididymis, joins the spermatic cord, enters the abdominopelvic cavity via the inguinal canal, and joins the ejaculatory duct posterior to the urinary bladder. The Spermatic Cord is a combined structure including the vas deferens, testicular artery, testicular vein, nerves, and lymph vessels. These structures are surrounded by longitudinal bundles of skeletal muscle called the Cremaster Muscle. The cremaster will elevate the testes in response to a decrease in ambient temperatures. External to the cremaster muscle is a sheath of fibrous dense connective tissue. The vas deferens is a thick walled structure consisting of three tunics.

a] Tunica Mucosa - pseudostratified columnar epithelium sitting on a lamina propria which is rich in elastic fibers. The epithelium is similar to that of the ductus epididymides.

b] Tunica Muscularis - an exceedingly robust trilaminar smooth muscle sheath. The three sheets are arranged: longitudinal, circular, and longitudinal. This muscular component, in combination with the elastic fibers of the lamina propria, causes the mucosa to be thrown into numerous folds.

c] Tunica Adventitia - a dense fibrous connective tissue continuous with the connective tissue sheath of the spermatic cord.

The vas deferens will propel the sperm during ejaculation. The vas deferens also serves as a secondary site for the storage of sperm. After passing over and behind the urinary bladder the vas deferens dilates into a structure termed the Ampulla of the Vas Deferens. The ampullae could be considered to be an accessory sex gland because: The mucosa shows a great degree of folding (much like that of the seminal vesicles). The principle

cells are secretory in nature. Aside from the degree of mucosal folding, the ampulla is histologically similar to the rest of the vas deferens:
1] Tunica Mucosa - pseudostratified columnar epithelium sitting on a lamina propria which is rich in elastic fibers.
2] Tunica Muscularis - an exceedingly robust trilaminar smooth muscle sheath.
3] Tunica Adventitia - a dense fibrous connective tissue sheath. The duct of the seminal vesicle will open into the ampulla. So this is the first portion of the excurrent duct system where spermatozoa will come in contact with a component of seminal fluid.

f) Seminal Vesicles/Coagulating Glands/Vesicular Glands: The two seminal vesicles are glandular evaginations of the vas deferens located on the posterior bladder. They each are actually a highly coiled tubule embedded in connective tissue and smooth muscle. The mucosa of the seminal vesicle is thrown into a complex series of folds. This result in a "honeycomb" appearance to the gland in cross section. It also will result in occasional outpockets. All, however, will communicate with the lumen of the gland. Histology: is similar to that of the ampulla.
a] Tunica Mucosa - pseudostratified columnar epithelium sitting on a lamina propria which is rich in elastic fibers.The epithelium will have principle and basal cells.The principle cells will be secretory cells in the seminal vesicle and will produce a portion of the semen. The secretion is a viscous fluid containing: fructose, ascorbic acid, citric acid, phosphorylcholine, and prostaglandins. These secretions provide: (a) a medium for sperm transport, (b) for the metabolic needs of the spermatozoa, (c) for the activation of the sperm by the prostaglandins, (d) and may also influence the female reproductive tract through the prostaglandin component.
b] Tunica Muscularis - a bilaminar smooth muscle sheath. The two sheets are arranged: circular inner and longitudinal outer.
c] Tunica Adventitia - a dense fibrous connective tissue having many elastic fibers.

g) Ejaculatory Duct: The ejaculatory duct extends from the ampulla of the vas deferens, through the prostate, to the urethra. The ejaculatory duct has only two tunics and lacks a muscular component.
a] Tunica Mucosa - pseudostratified columnar epithelium sitting on a lamina propria which is rich in elastic fibers. The mucosa is arranged into folds.
b] Tunica Adventitia - a dense fibrous connective tissue.

18.3.2. Prostate

The prostate contributes an alkaline fluid rich in enzymes to the seminal fluid. The prostate gland is a histologically complex gland. It is a compact mass of compound tubuloacinar glands that open into the prostatic urethra through numerous ducts. It can be divided into a stroma and a parenchyma. The stroma is composed of dense fibroelastic connective tissue and smooth muscle. It includes a capsule. The parenchyma is a compact mass of tubuloacinar glands supported by an extremely well vascularized loose connective tissue. The epithelium will be variable being either a simple or pseudostratified columnar epithelium depending on the region and degree of glandular activity found in that region. The cells display the typical adaptations found in secretory epithelial cells.

18.3.3. Urethra

The urethra extends from the urinary bladder, through the penis, to the urethral orifice. It serves as a common passageway for both urine and sperm. Small glandular outpocketings

of the epithelium occur throughout the urethra called Urethral Glands. Urethral glands are mucous cell nests which may have a lubricating function. The urethra is divided into three major regions:

1] Prostatic Urethra - the first segment it extends from the base of the bladder, through the prostate, to the base of the prostate.

2] Membranous Urethra - the middle segment it extends from the base of the prostate, through the urogenital diaphragm, to the bulb/base of the penis.

3] Penile Urethra/Cavernous Urethra - the final segment it extends through the penis to open at the urogenital orifice at the distal portion of the glans penis. It has three (minor) segments:

a} Bulbous Segment - passing through the bulb of the penis.

b} Pendulous Segment - passing through the body of the penis.

c} Glandular Segment - passing through the glans penis.

The wall of the urethra is composed of elastic tissue and smooth muscle. The epithelium lining the urethra demonstrates regional variation: It is transitional epithelium in the prostatic urethra. It is stratified to pseudostratified columnar epithelium in the membranous and much of the penile urethra. The glandular segment of the penile urethra is lined by a stratified squamous epithelium which is continuous with the epithelium covering the penis and prepuce. This stratified squamous epithelium is nonkeratinized.

18.3.4. Bulbourethral Glands/Cowper's Glands

The bulbourethral glands are small, paired glandular nodules located at the bulb of the penis. They are located near the junction of the membranous and penile urethra. Their glands will typically open into the penile urethra. Bulbourethral glands are of the tubuloacinar variety. They are lined by a simple cuboidal or columnar epithelium. The glandular cells are similar in appearance to mucus secreting cells. However, their product is a clear, viscous liquid containing numerous carbohydrate compounds. The function of this product is primarily to lubricate the urethra during ejaculation. Surrounding the epithelium of these glands is a fibroelastic connective tissue and strands of both smooth and skeletal muscle.

18.3.5. Preputial Glands/Preputial Glands of Tyson

The preputial glands are sebaceous glands located on the inner aspects of the Prepuce. What differentiates these sebaceous glands from the typical type of the integument is that they **are not** associated with hair follicles.

18.3.6. The Scrotum

The scrotum is a cutaneous outpocketing designed to house the testes and to maintain a fairly constant temperature to facilitate spermatogenesis. Externally it is covered by skin which is consistent for the skin of that region. Internally it has a number of connective tissue layers. The connective tissues divided the scrotum into two chambers and securely hold the testes. They will be a dense irregular connective tissue for the most part. Within the connective tissues of the superficial scrotum are bundles of smooth muscle called the Dartos. The dartos causes the scrotum to wrinkle due to a decrease in ambient temperatures so as to bring the testes closer to the body.

18.3.7. The Penis

The penis is a highly vascularized, cylindrical organ composed of three tissue masses. The three tissue masses are: [a] Corpora Cavernosa Penis - paired dorsolateral masses. [b]

Corpus Cavernosum Urethrae/Corpus Spongiosum - a singular midventral mass containing the urethra. All three corpora cavernosa are surrounded by a fibrous connective tissue capsule called the Tunica Albuginea Penis. The tunica albuginea penis is thicker around the corpora cavernosa penis than it is around the corpus cavernosum urethrae. External to the tunica albuginea penis is skin. Within the corpora cavernosa are numerous modifications designed to assist in the functioning of the penis including: [a] a high degree of vascularization, [b] elastic tissue, [c] smooth muscle, [d] and numerous and various sensory nerve endings.