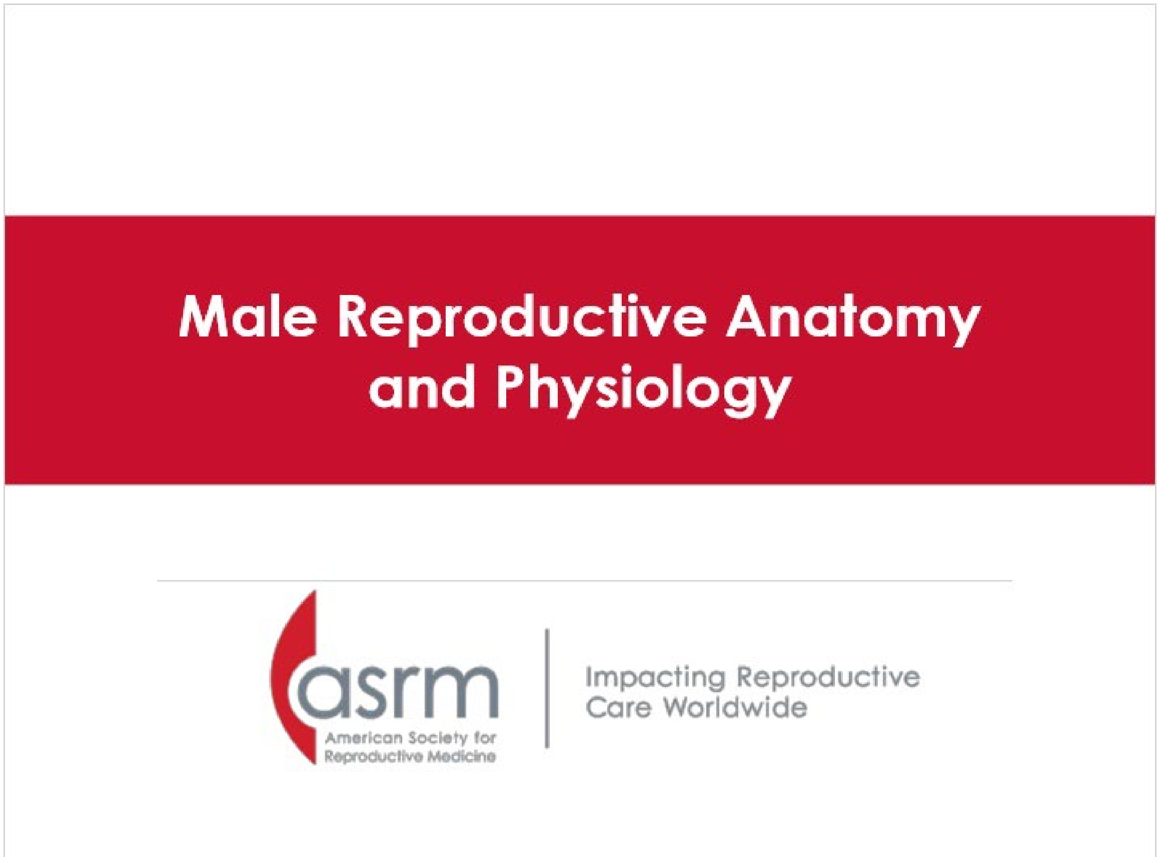
LABCC100 Lesson 2

1.1 Male Reproductive Anatomy and Physiology



Notes:

Welcome to the American Society for Reproductive Medicine’s eLearning modules in reproductive endocrinology. This presentation addresses male reproductive anatomy and physiology.

1.2 Learning Objectives

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At the conclusion of this presentation, participants should be able to:

- Describe origins and development of male reproductive tract
- Identify male reproductive tract anatomy
- Discuss the process of spermatogenesis
- Describe how testosterone is synthesized and regulated
- Explain the process of erection and ejaculation

asrm American Society for Reproductive Medicine

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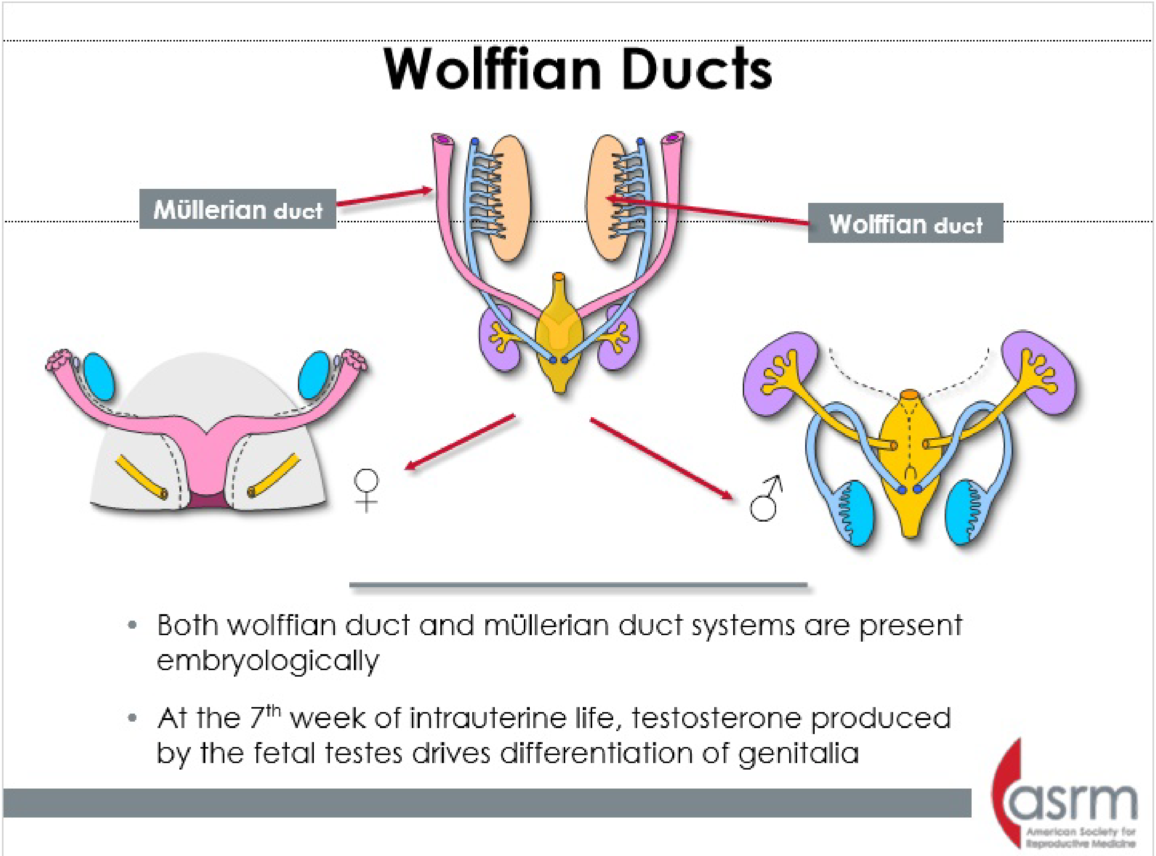
1.3 Wolffian Ducts



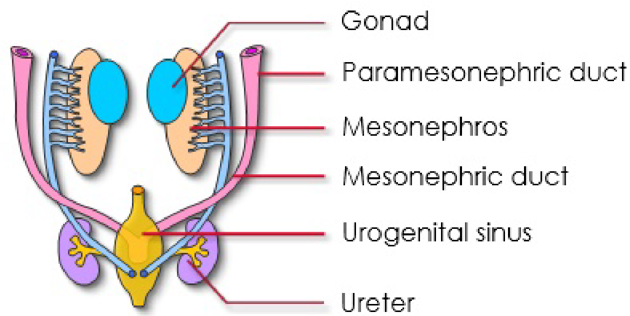
Notes:

Both wolffian and müllerian duct systems are present embryologically. Wolffian ducts form the male genitalia, and müllerian ducts form the female reproductive tract. At the 7th week of intrauterine life under the influence of testosterone, wolffian ducts are enhanced. A substance secreted by the developing gonad (müllerian inhibiting factor) causes the müllerian ducts to regress. The wolffian ducts develop into the epididymis, vas deferens, ejaculatory duct and seminal vesicles.

1.4 Urogenital Development

Urogenital Development

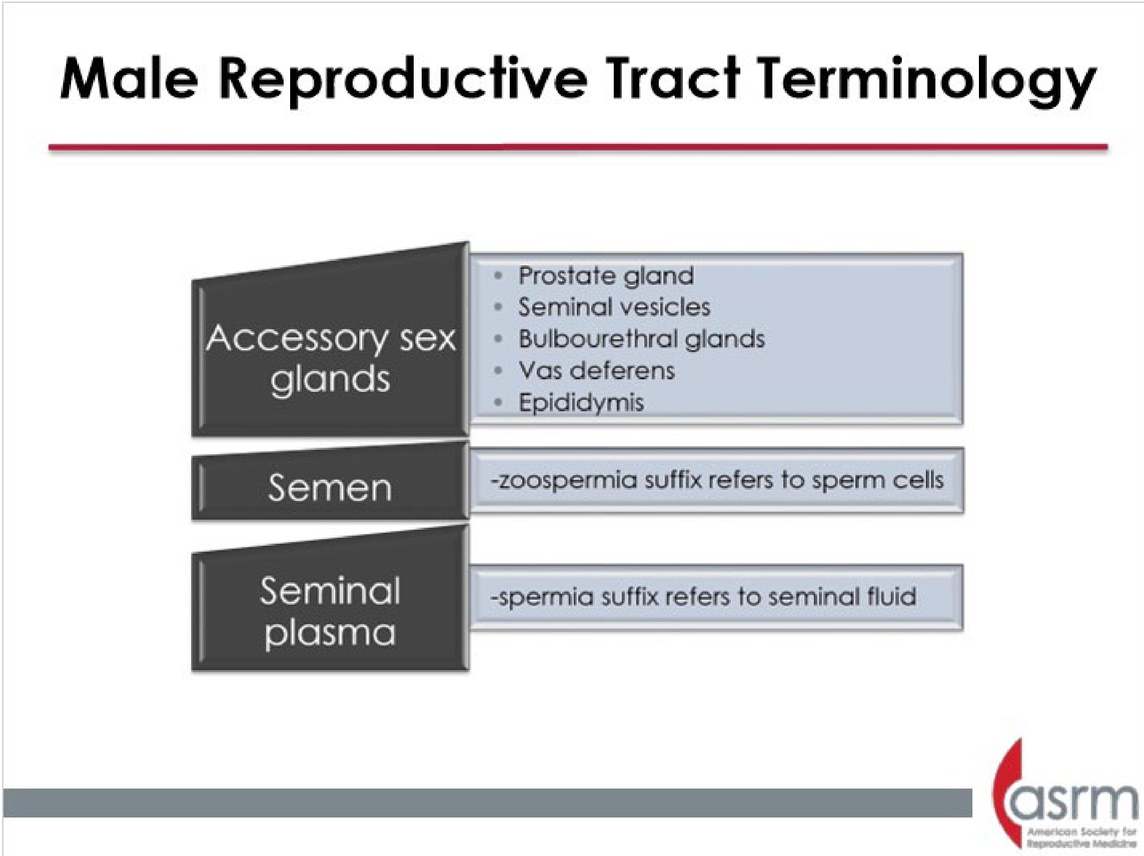
- The external genitalia and prostate are derived embryologically from the urogenital ridge
- Conversion of testosterone to dihydrotestosterone (DHT) required
- Urogenital sinus →
  - prostate gland and urethra
- Urogenital tubercle →
  - penis and scrotum



Notes:

In certain structures, male development requires testosterone to be converted to dihydrotestosterone. With the conversion of testosterone, the urogenital sinus develops into the prostate gland and urethra. The urogenital tubercle becomes the penis and scrotum.

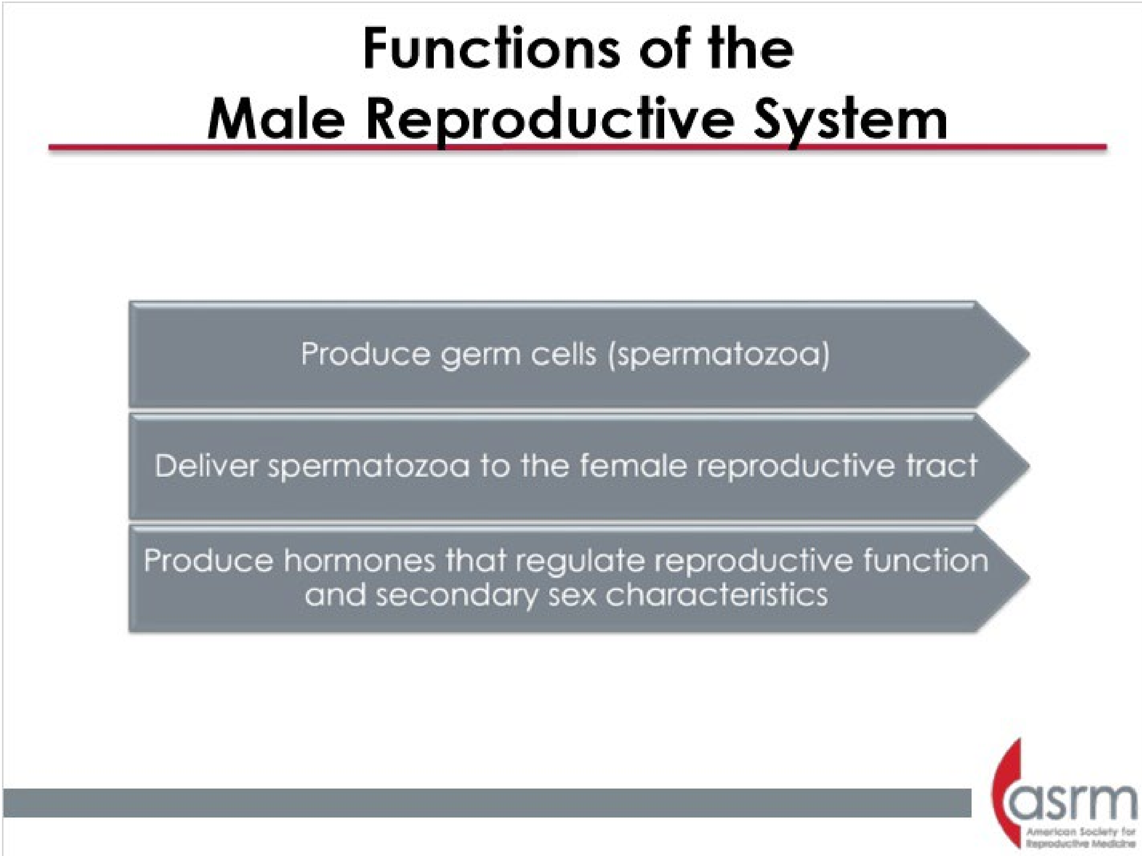
1.5 Male Reproductive Tract Terminology



Notes:

The accessory sex glands in males are the prostate gland, seminal vesicles, bulbourethral glands, vas deferens, and epididymis. Semen is an admixture of sperm cells and secretions from the male accessory sex glands that combine at the time of ejaculation. Seminal plasma is the fluid component of semen and is composed of secreted fluids, cells and cellular components from several male accessory sex glands.

1.6 Functions of the

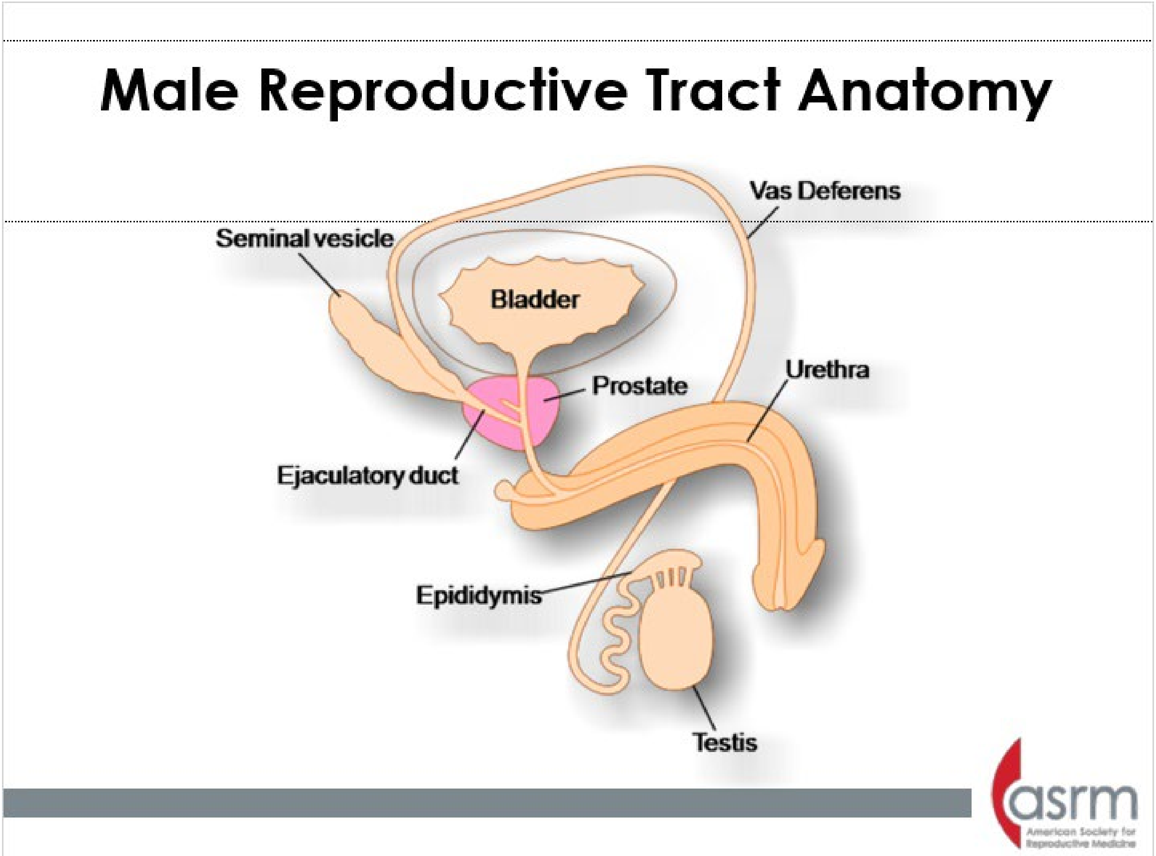


Notes:

The male reproductive system has the following three major functions: produce germ cells, called spermatozoa, for sexual reproduction; deliver the male germ cells to the female reproductive tract; and produce hormones that regulate reproductive function and secondary sex characteristics.

Beginning at puberty, testes produce spermatozoa continuously, not cyclically as in the female.

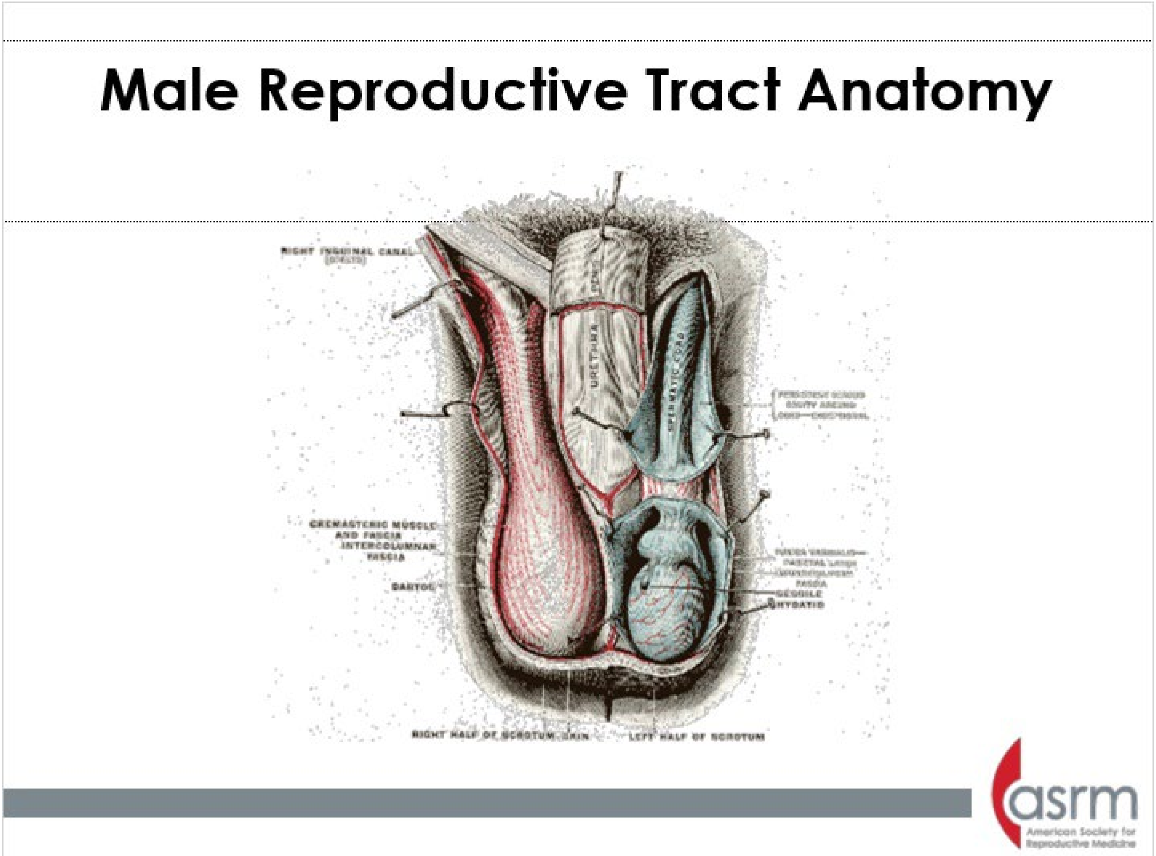
1.7 Male Reproductive Tract Anatomy



Notes:

Male gonads are the testes, which produce sperm, fluid, and hormones. Fluid discharged into the duct system is an exocrine function and hormones represent an endocrine function. The ducts receive, store, and transport sperm. Accessory sex glands support sperm and the supporting structures have various reproductive functions.

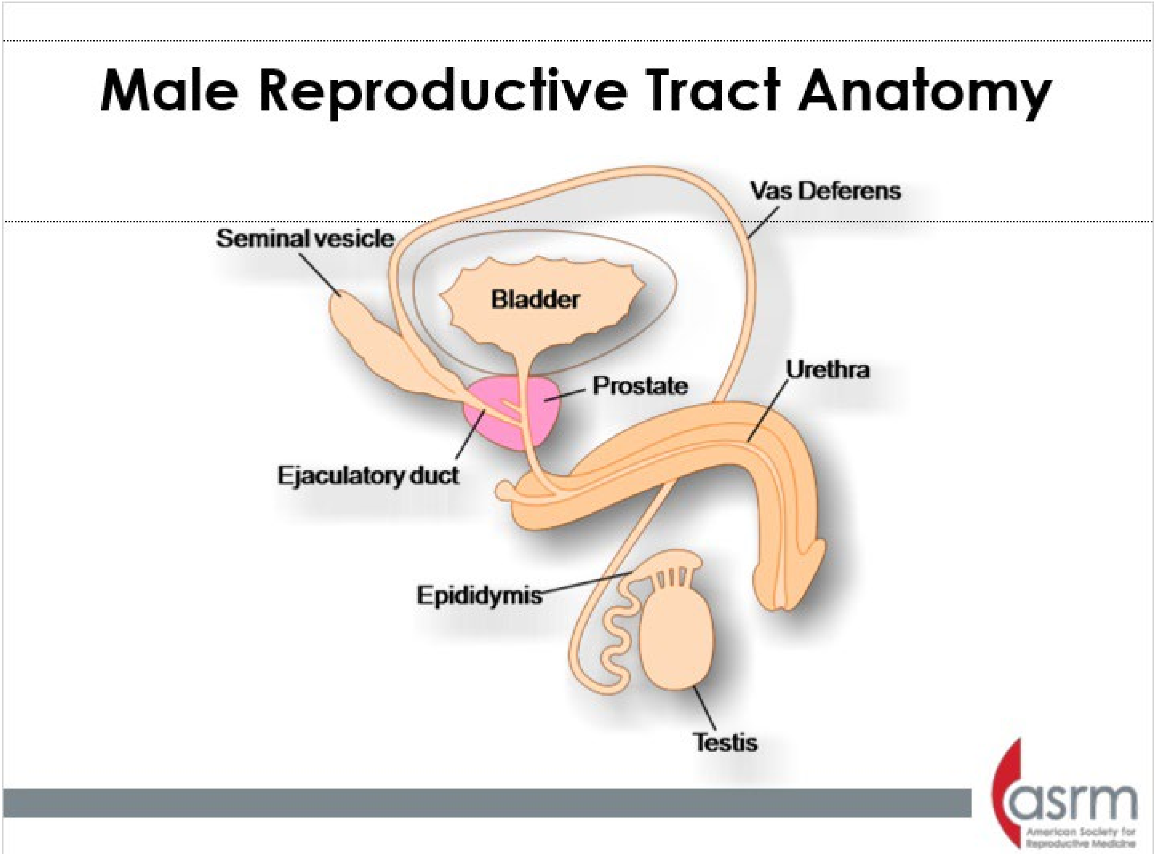
1.8 Male Reproductive Tract Anatomy



Notes:

The male reproductive tract serves as a conduit to transport sperm from the testis to the urethral opening of the penis. It also serves as a storage depot for spermatozoa. For each testis there is a duct system. The function of these ducts is testosterone-dependent. The cells absorb fluid from the testis and remove particulate matter by endocytosis. The epididymis is the major storage site of spermatozoa, which spend five to six days in this segment of the tract. The epididymis is androgen-dependent, although it responds preferentially to dihydrotestosterone. The tall columnar cells of the epididymis secrete ions, nutrients, proteins, and glycoproteins, and they absorb fluid. Epididymal fluid is enriched in potassium relative to semen and rich in glycerophosphorylcholine, a major energy source for spermatozoa. The luminal fluid becomes acidic as it moves from caput to cauda. The vas deferens is a secondary storage site for spermatozoa. Its epithelium has important absorptive and secretory functions.

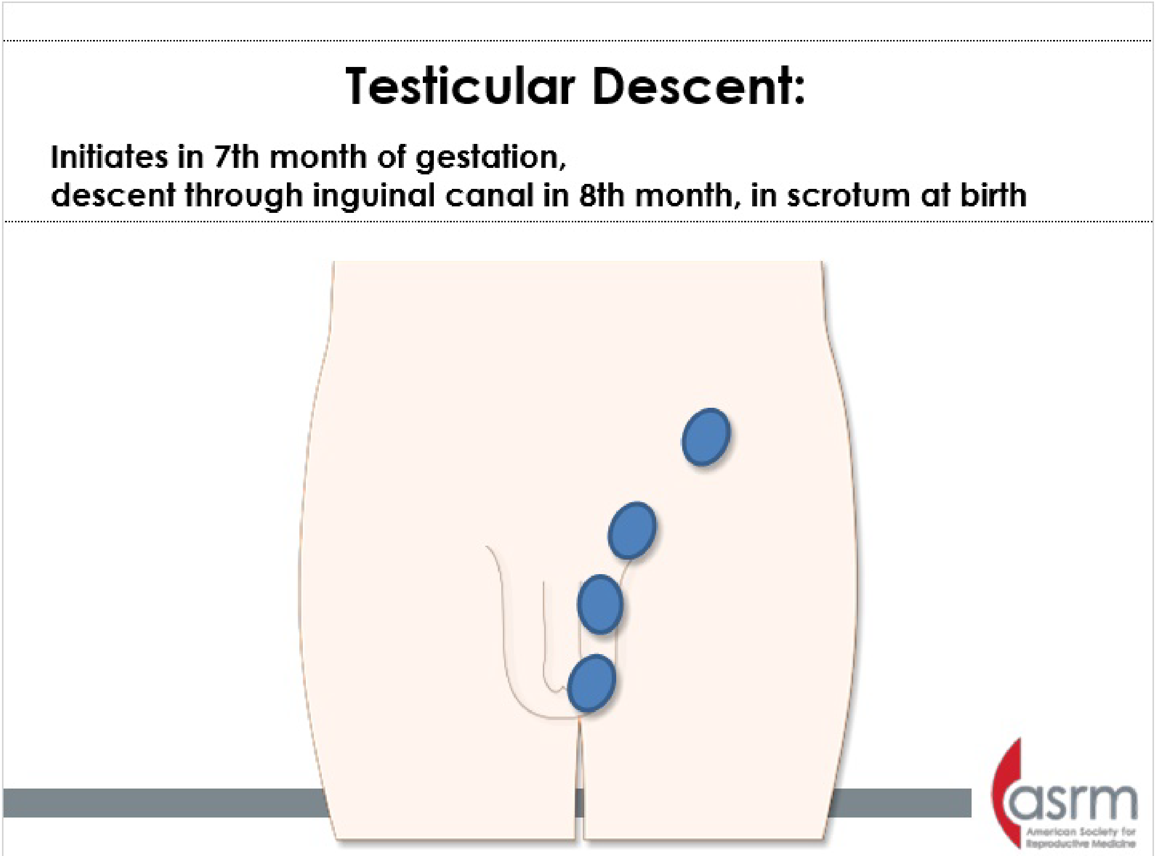
1.9 Male Reproductive Tract Anatomy



Notes:

The other components of the duct system are the ejaculatory duct and the urethra. The paired seminal vesicles are important secretory glands, but they have little storage capacity. They produce a very alkaline secretion and fibrin, which is responsible for coagulation of semen after ejaculation. The seminal vesicles are testosterone-dependent. The prostate gland, which is dihydrotestosterone-dependent, produces a slightly acidic (pH 6.5), colorless, thin secretion, rich in minerals and sodium. The prostate gland produces the enzyme fibrinolysin, which degrades the fibrin clot in coagulated semen. The remaining glands of the male reproductive tract are the bulbourethral glands and glands of Littré within the urethra, which all secrete a small amount of mucus prior to ejaculation.

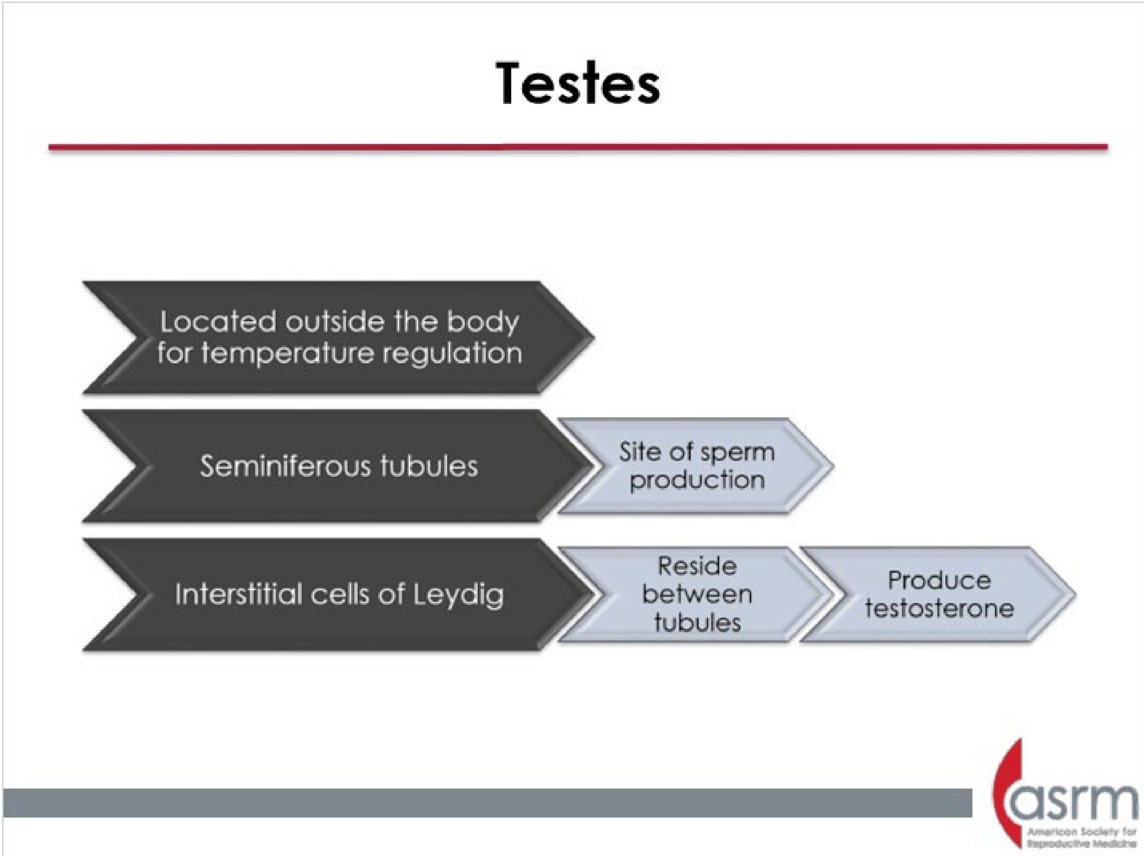
1.10 Testicular Descent:



Notes:

Testes are paired oval glands about 5 cm x 2.5 cm in size. Their development is influenced by the presence of the Y sex chromosome and by maternal hormonal levels. The testes develop in the fetal abdomen and begin descent during the 7th month of pregnancy. Failure to descend, called cryptorchidism, results in sterility, which is a lack of spermatozoa, and, frequently, abnormally low testosterone biosynthesis.

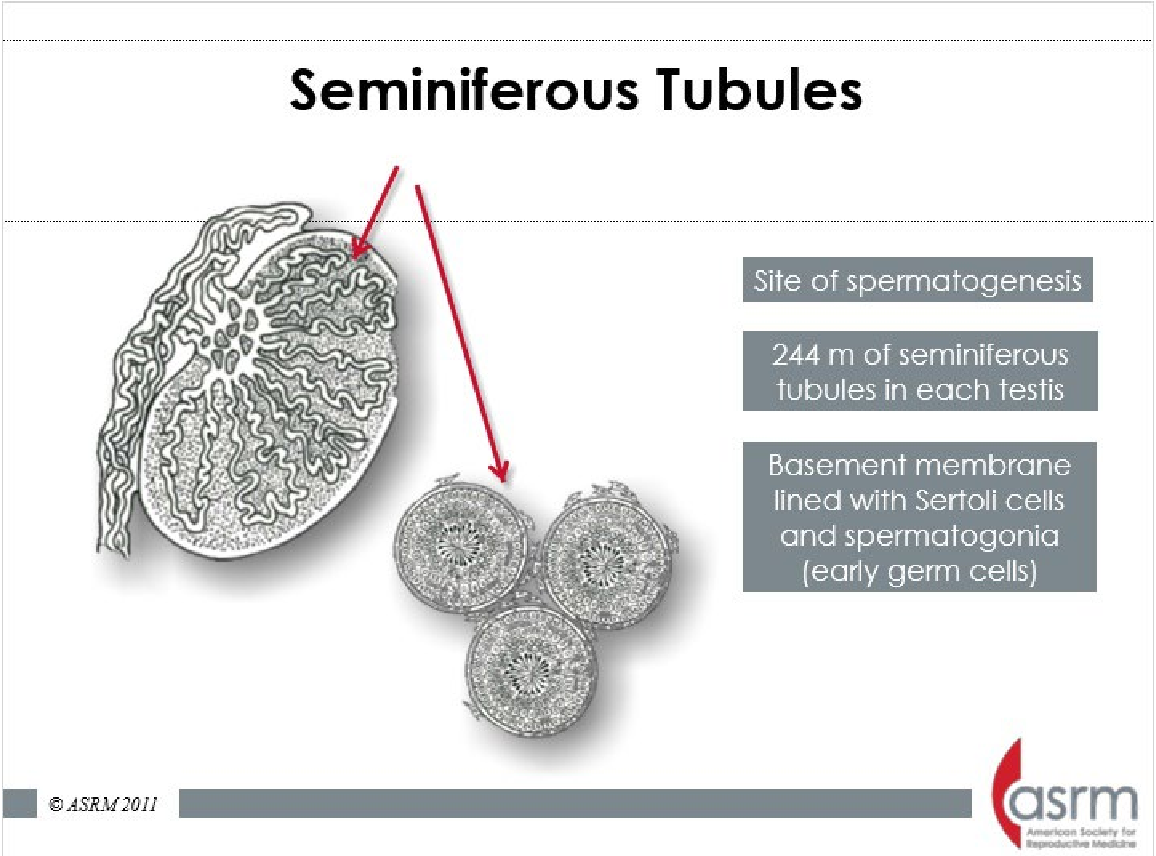
1.11 Testes



Notes:

The fibrous sacs of the scrotum support and protect the testes. Suspension outside the body cavity permits spermatogenesis to occur at 36°C. Scrotal muscles include the cremaster and dartos muscles, which contract in response to temperature. The paired male gonads, the testes, consist of seminiferous tubules surrounded by clusters of interstitial cells of Leydig. The testes also secrete substances such as inhibin that, along with testosterone, exert a negative feedback effect on the hypothalamic-pituitary unit.

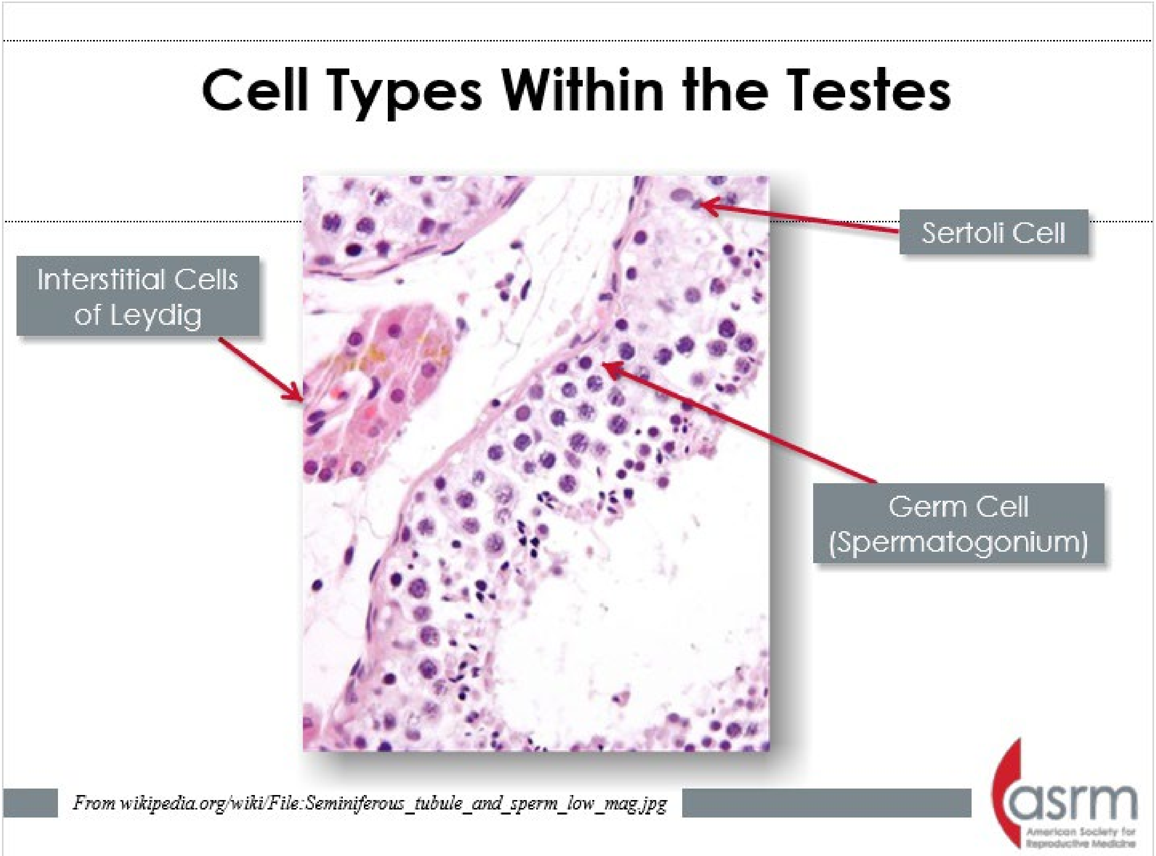
1.12 Seminiferous Tubules



Notes:

The seminiferous tubules are the site of spermatogenesis. There are approximately 244 meters (800 feet) of seminiferous tubules in each testis. Each tubule consists of a basement membrane, lined with germ cells that become spermatozoa, and Sertoli cells. These tubules increase in diameter and tortuosity with hormonal changes of puberty.

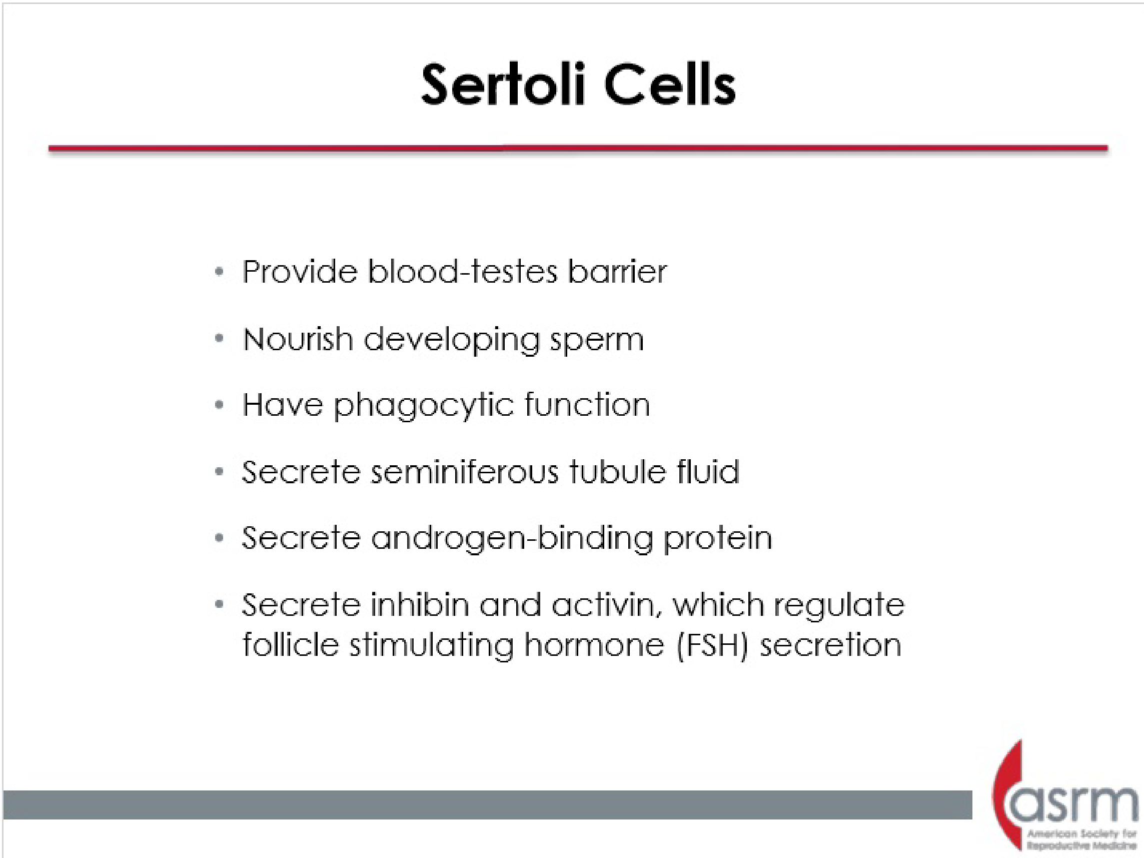
1.13 Cell Types Within the Testes



Notes:

There are three unique cell types within the testes. Germ cells, the cells that divide and mature to become sperm; Sertoli cells, which provide crucial support for spermatogenesis; and the interstitial cells of Leydig that produce the androgenic hormone testosterone, which maintains the reproductive tract and secondary sex characteristics. All germ cells and Sertoli cells are within the seminiferous tubule, while Leydig cells are outside the tubules. The stem cell of the germ-cell line is the spermatogonium.

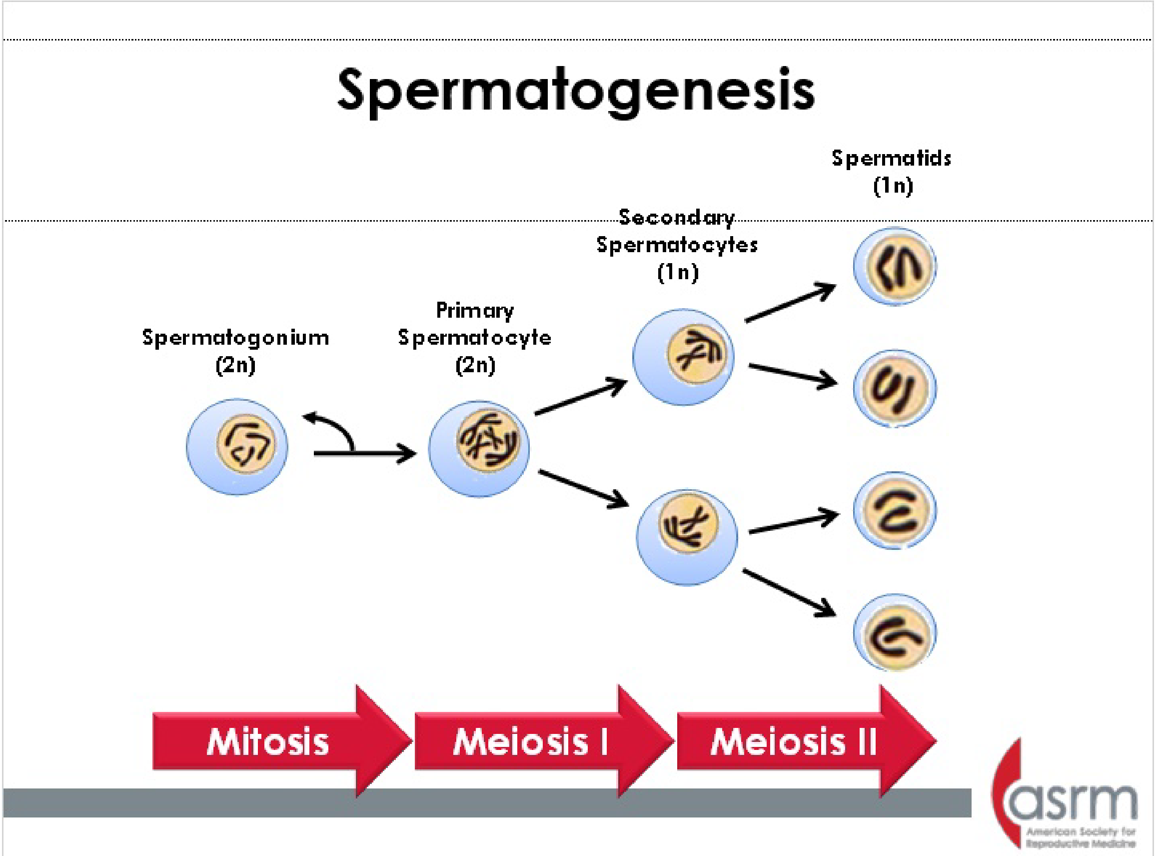
1.14 Sertoli Cells



Notes:

The Sertoli cells of the testes are joined together by tight junctions that form the blood-testis barrier, which prevents diffusion of plasma constituents into the tubular lumen. The blood-testis barrier also prevents contact between germ cells and blood, which is important because spermatozoa are antigenic. Sertoli cells nourish developing sperm, and have a phagocytic function to destroy defective germ cells and engulf extruded cytoplasm from spermatids during remodeling. Sertoli cells secrete seminiferous tubule fluid, androgen-binding protein and inhibin and activin, which regulate FSH secretion.

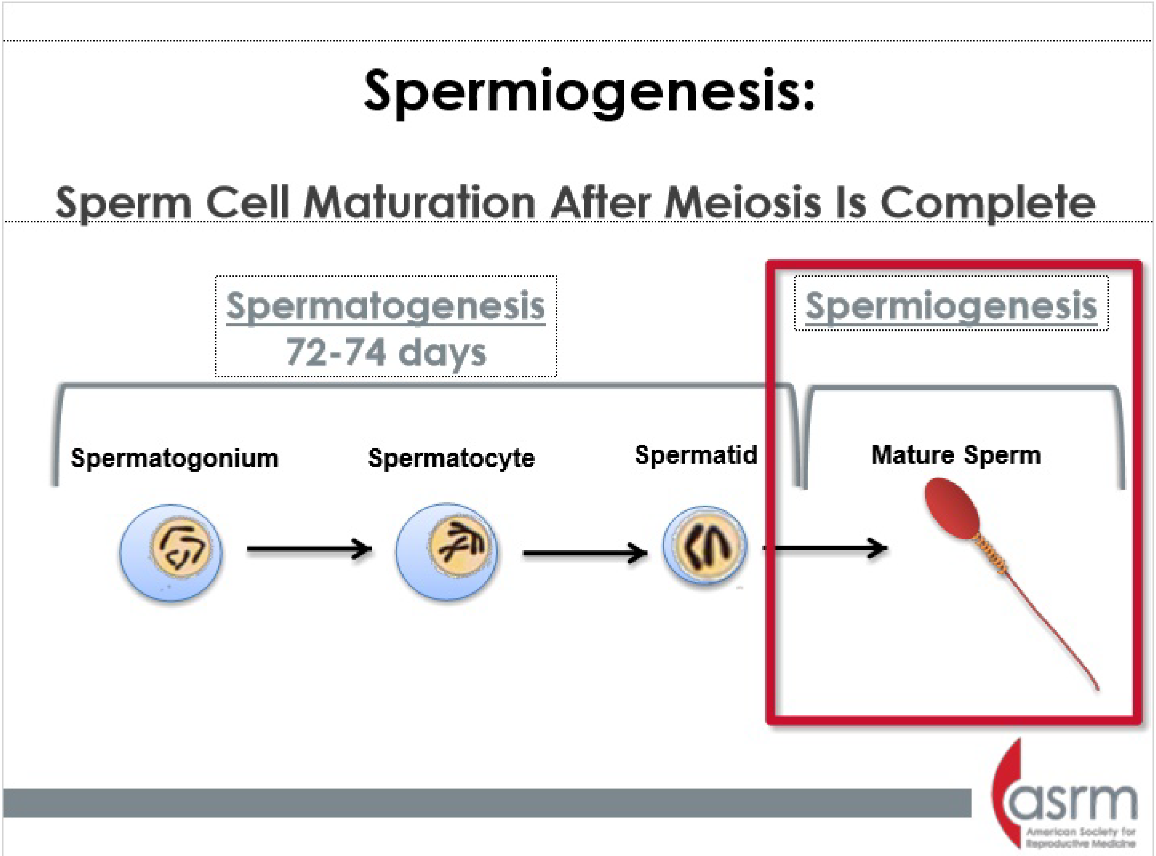
1.15 Spermatogenesis



Notes:

Beginning at puberty, spermatogenesis occurs continuously and repeatedly within folds of the Sertoli cells. Spermatogonia (the sperm stem cells) lie at the base of the Sertoli cells and proliferate through mitosis to maintain themselves and produce daughter cells that enter spermatogenesis. In the two-step reduction division process of meiosis, spermatocytes and spermatids develop. Spermatids are haploid, containing only one copy of each chromosome. As the germ cells divide and mature, they move away from the base of the tubule toward the apical surface of Sertoli cells.
Spermatogenesis takes 74 days, with several hundred million sperm reaching maturity daily. The process is temperature sensitive, occurring only at temperatures less than or equal to 36^{o}C.

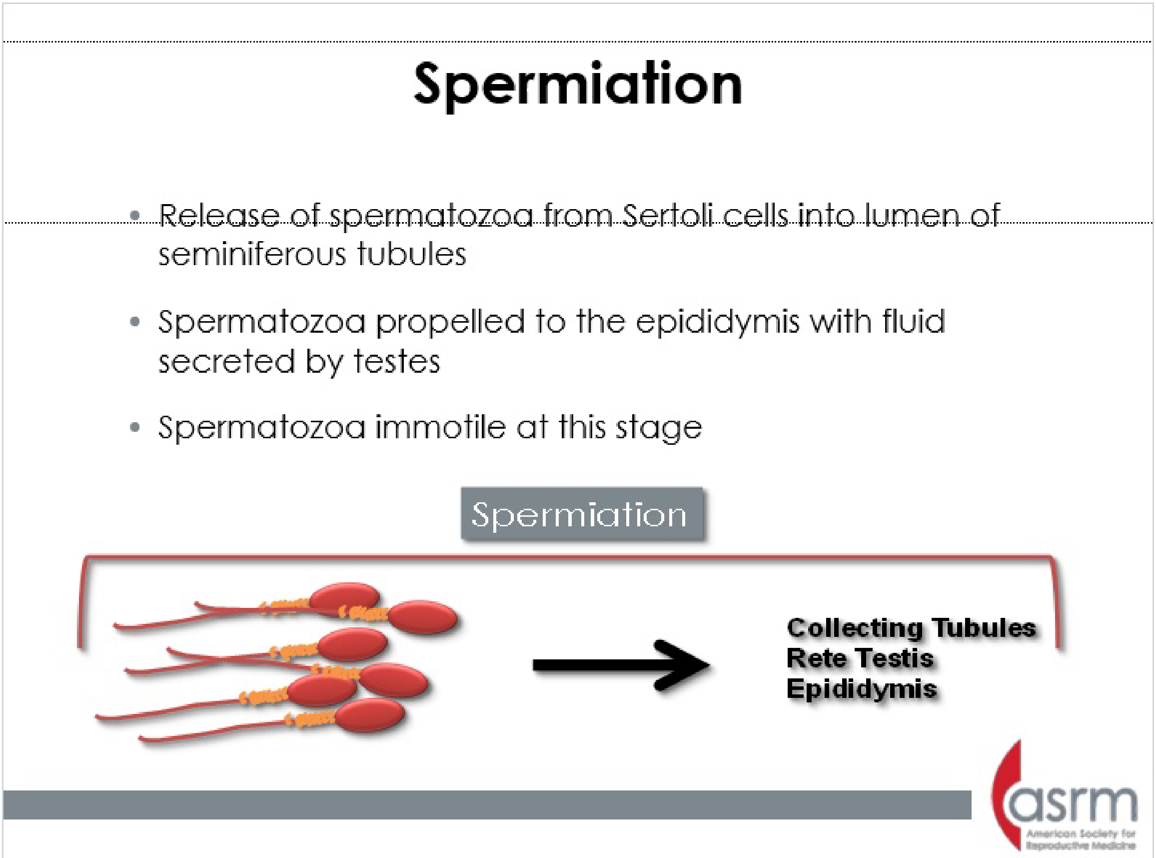
1.16 Spermiogenesis:



Notes:

Following meiosis, spermiogenesis is the maturation process in which the round spermatids are transformed into elongated spermatozoa with tails. The spermatid nucleus condenses and most cytoplasm is lost. The Golgi apparatus moves to one side of the nucleus, forming an acrosome that surrounds the top two thirds of the nucleus (in the head). Cell microtubules organize into a flagellar apparatus to form the tail for motility, and mitochondria to the midpiece of the tail for movement.

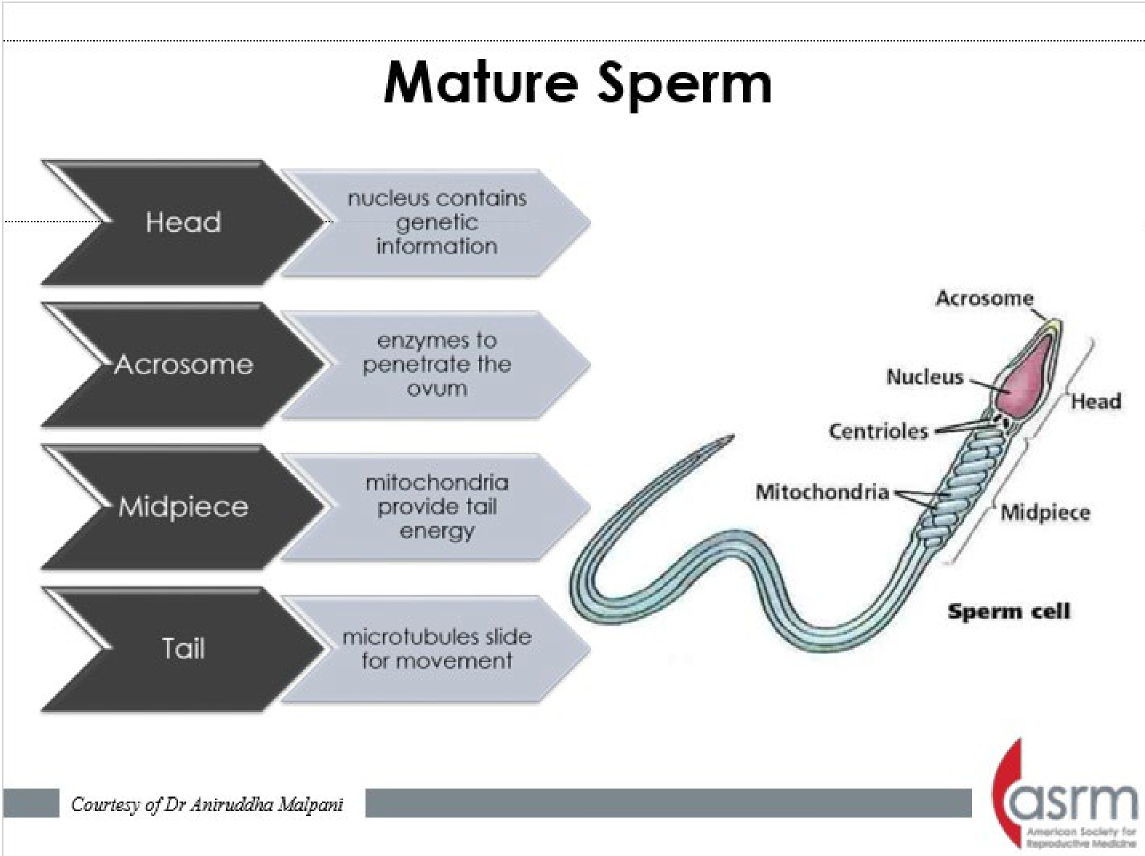
1.17 Spermiation



Notes:

Spermiation is the process in which fully developed but non-motile spermatozoa are released from the Sertoli cells and propelled out of the tubules into the collecting tubules, rete testis and then the epididymis. The spermatozoa are immotile at this stage.

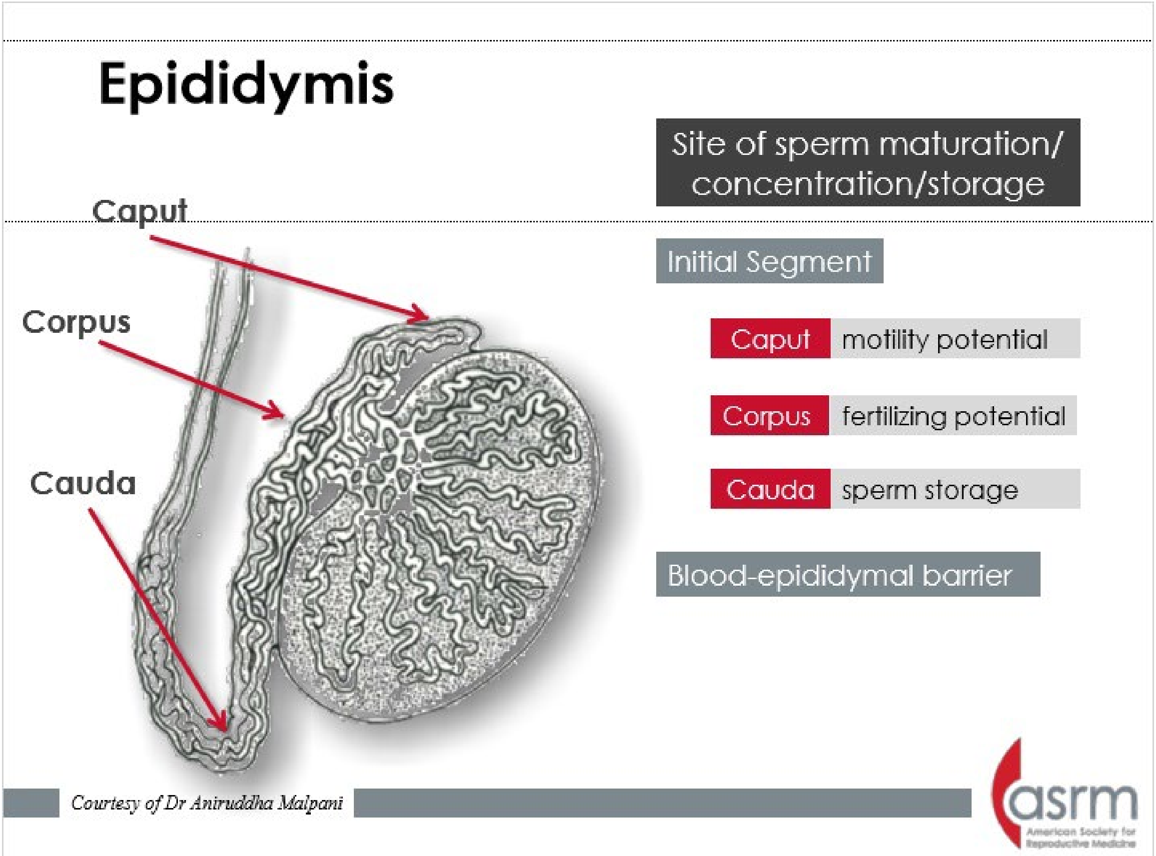
1.18 Mature Sperm



Notes:

Mature sperm have a head, which consists primarily of the nucleus containing genetic information. The acrosome is a specialized lysosome, containing about 20 different enzymes**,** which are needed for penetration of the ovum during fertilization. The acrosome covers the anterior third of the nucleus in a mature sperm cell. In the midpiece are mitochondria to provide the energy required for the movement of the tail. The tail grows out of one of the centrioles. Movement results from the sliding of the microtubules.

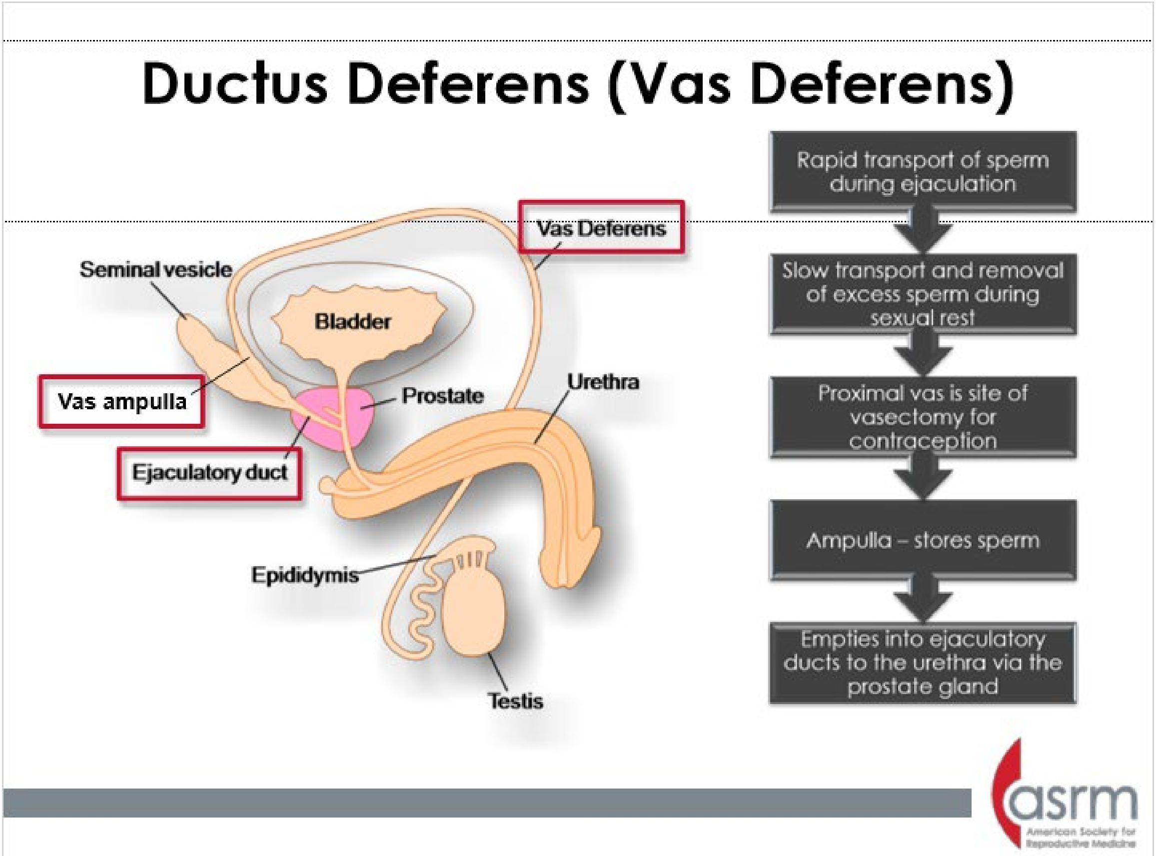
1.19 Epididymis



Notes:

The epididymis is where sperm mature, concentrate and are stored. When sperm initially enter the epididymis, they are immotile and do not have the capacity to fertilize ova. The epididymal histology and function change along its length. The initial segment connects with the rete testis and has tall columnar cells and a narrow lumen for major fluid absorption. In the caput, fluid becomes hyperosmotic and sperm attain motility potential. In the corpus, fertilizing potential is achieved with maturation of the sperm plasma membrane and sperm attain the ability to adhere to the zona pellucida of the ovum. In the cauda are cuboidal cells with a wide lumen for sperm storage. Tight junctions between epididymal epithelial cells maintain the blood-epididymal barrier, which is important for immune protection of sperm cells.

1.20 Ductus Deferens (Vas Deferens)



Notes:

In the ductus deferens, also called the vas deferens, there is rapid transport of sperm during ejaculation and slow transport and removal of excess sperm during sexual rest. The proximal vas is the site of vasectomy for contraception. The distal part near the prostate, called the ampulla, stores sperm and empties into ejaculatory ducts that traverse the prostate gland to enter the urethra.

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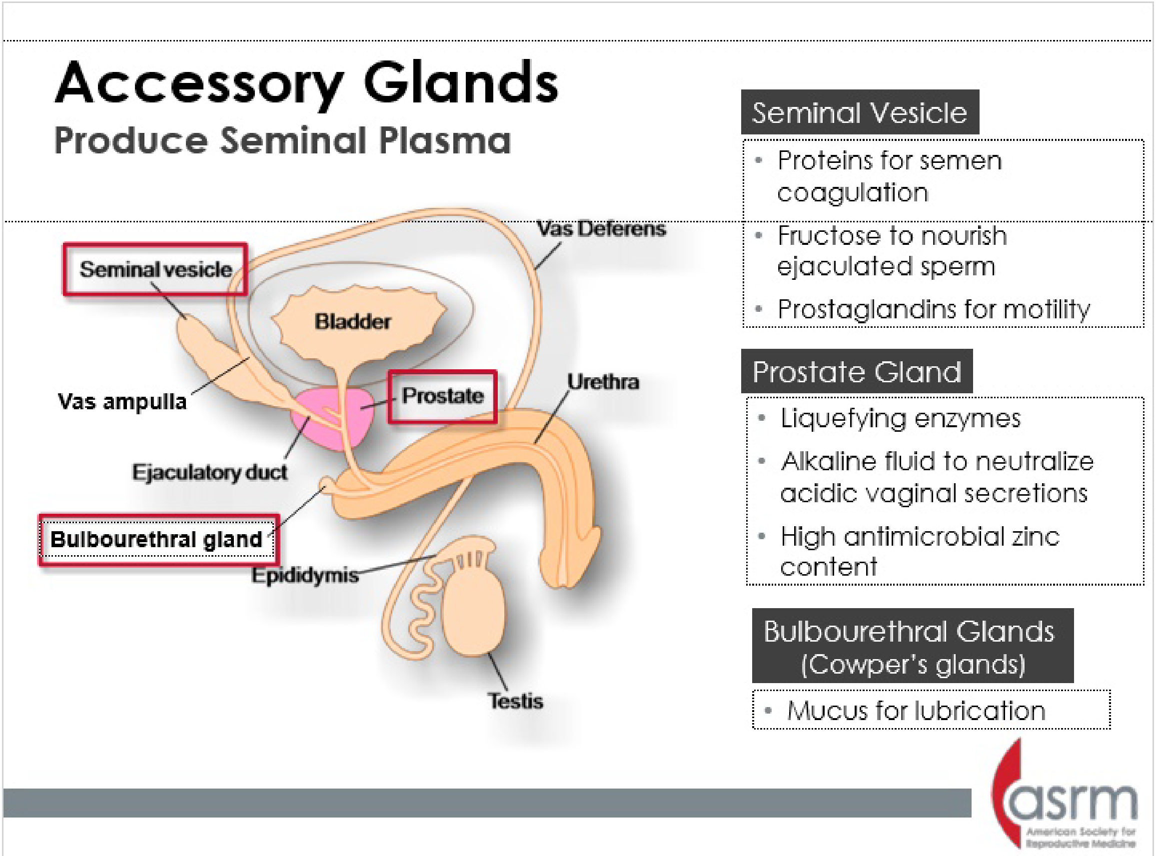
1.21 Accessory Glands



Notes:

Accessory glands include the seminal vesicle, prostate gland and bulbourethral glands. The seminal vesicle provides precursor proteins responsible for semen coagulation, supplies fructose to nourish the ejaculated sperm and secretes prostaglandins that stimulate motility. The prostate gland secretes proteolytic enzymes to liquefy coagulum after ejaculation. It secretes alkaline fluid to neutralize acidic vaginal secretions and the high zinc content is antimicrobial. The bulbourethral glands, also known as Cowper's glands, secrete mucus for lubrication.

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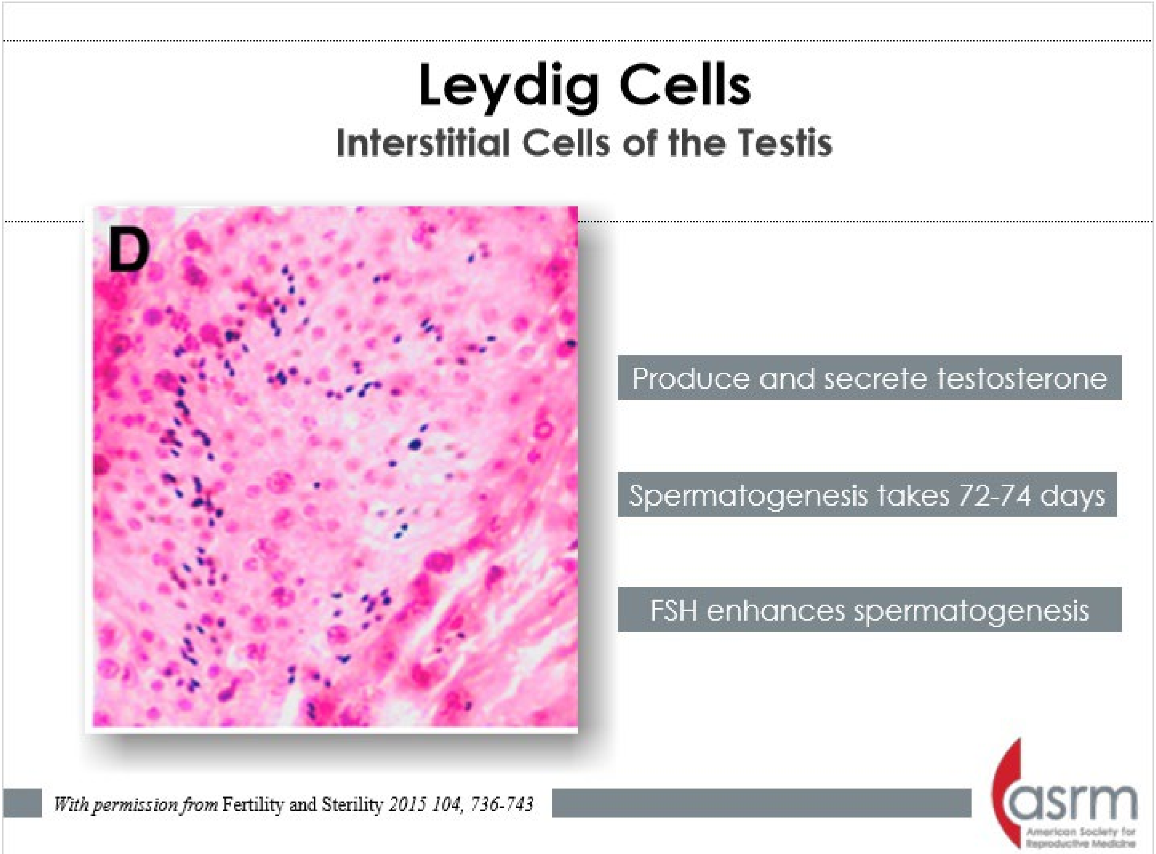
1.22 Leydig Cells



Notes:

The interstitial Leydig cells produce and secrete testosterone. Spermatogenesis takes 72-74 days. Only testosterone from the testicular Leydig cells is absolutely required for spermatogenesis. However, FSH greatly enhances spermatogenesis by stimulating the functions of Sertoli cells and increasing mitoses of spermatogonia. Once mitosis has been initiated in spermatogonia, testosterone alone can maintain spermatogenesis.

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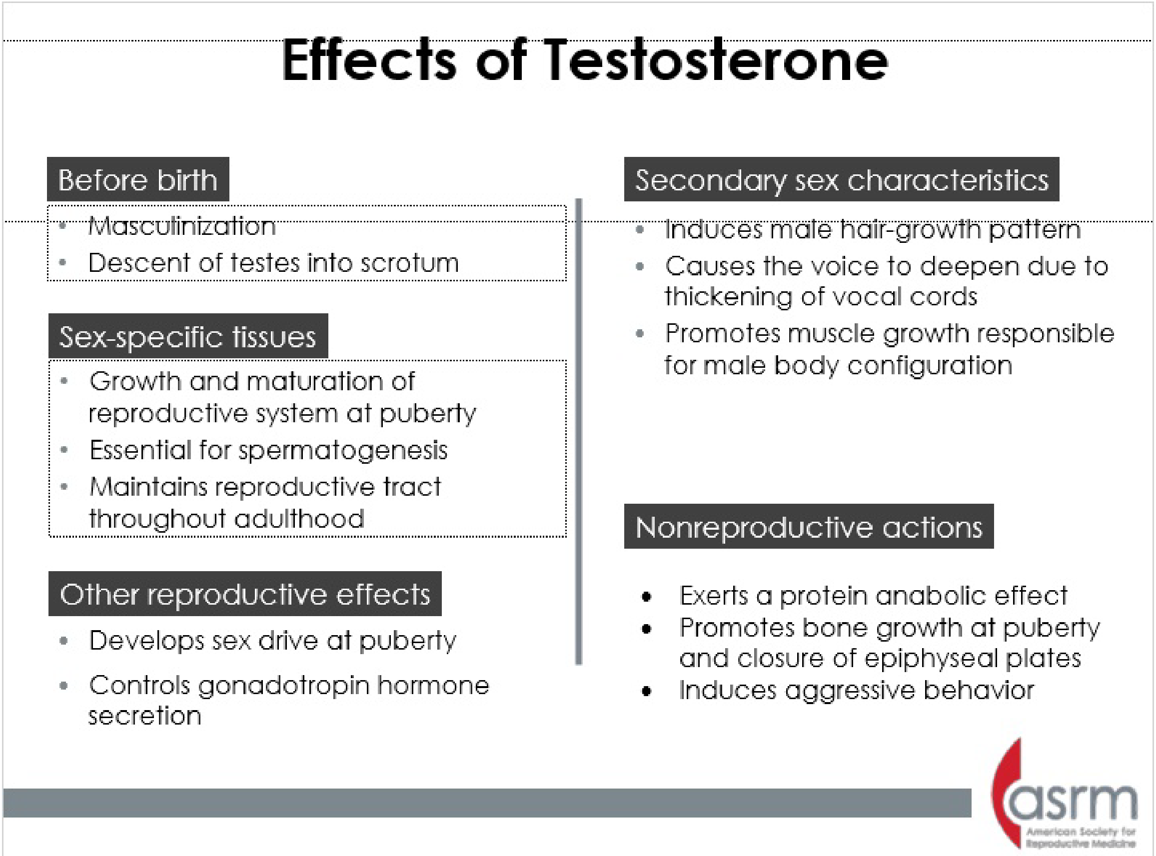
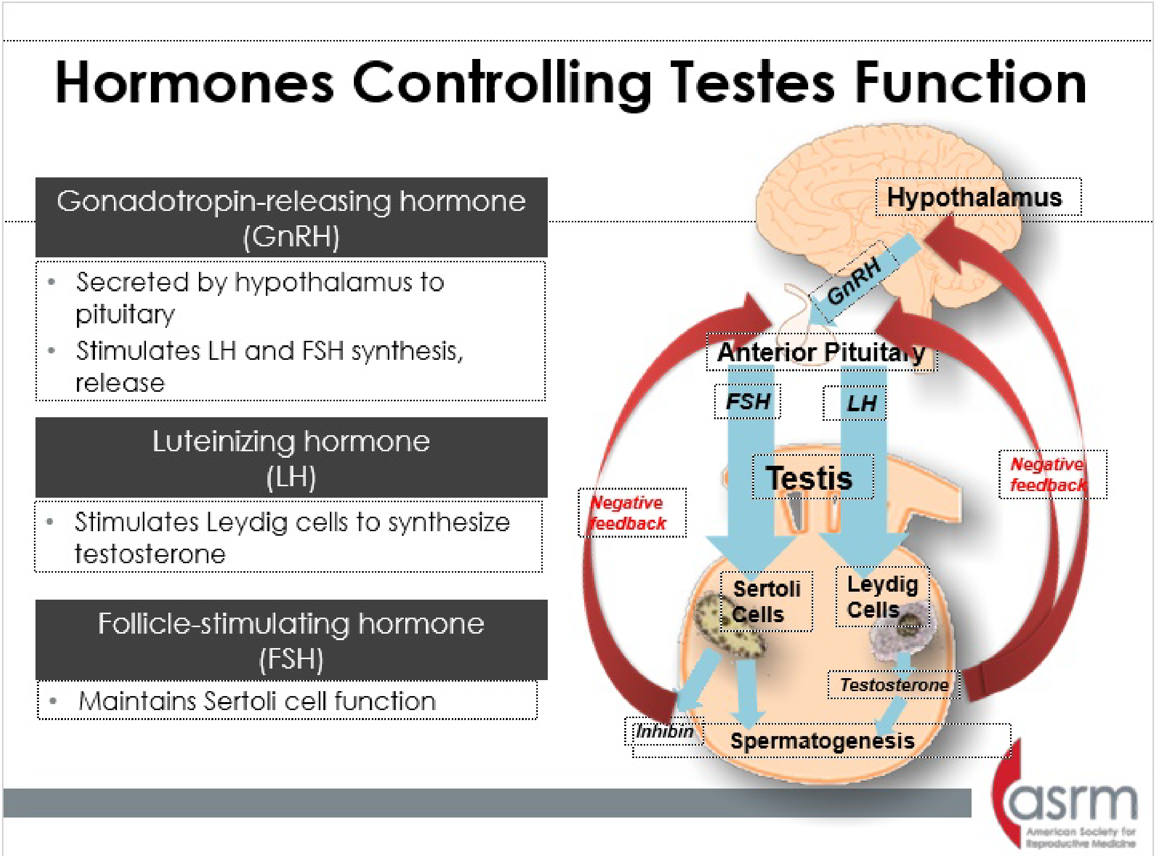
1.23 Effects of Testosterone



Notes:

Testosterone has significant effects throughout the male life cycle. Before birth, testosterone masculinizes the reproductive tract and external genitalia and promotes descent of the testes into the scrotum. For sex-specific tissues, testosterone promotes growth and maturation of the reproductive system at puberty, is essential for spermatogenesis, and maintains the reproductive tract throughout adulthood. Other reproductive effects include development of the sex drive at puberty and control of gonadotropin hormone secretion. Secondary sex characteristics are also testosterone-dependent. Testosterone induces the male pattern of hair growth (such as the beard), causes the voice to deepen due to thickening of the vocal cords, and promotes muscle growth responsible for the male body configuration. Nonreproductive actions of testosterone include a protein anabolic effect, promotion of bone growth at puberty and closure of the epiphyseal plates. Testosterone also induces aggressive behavior.

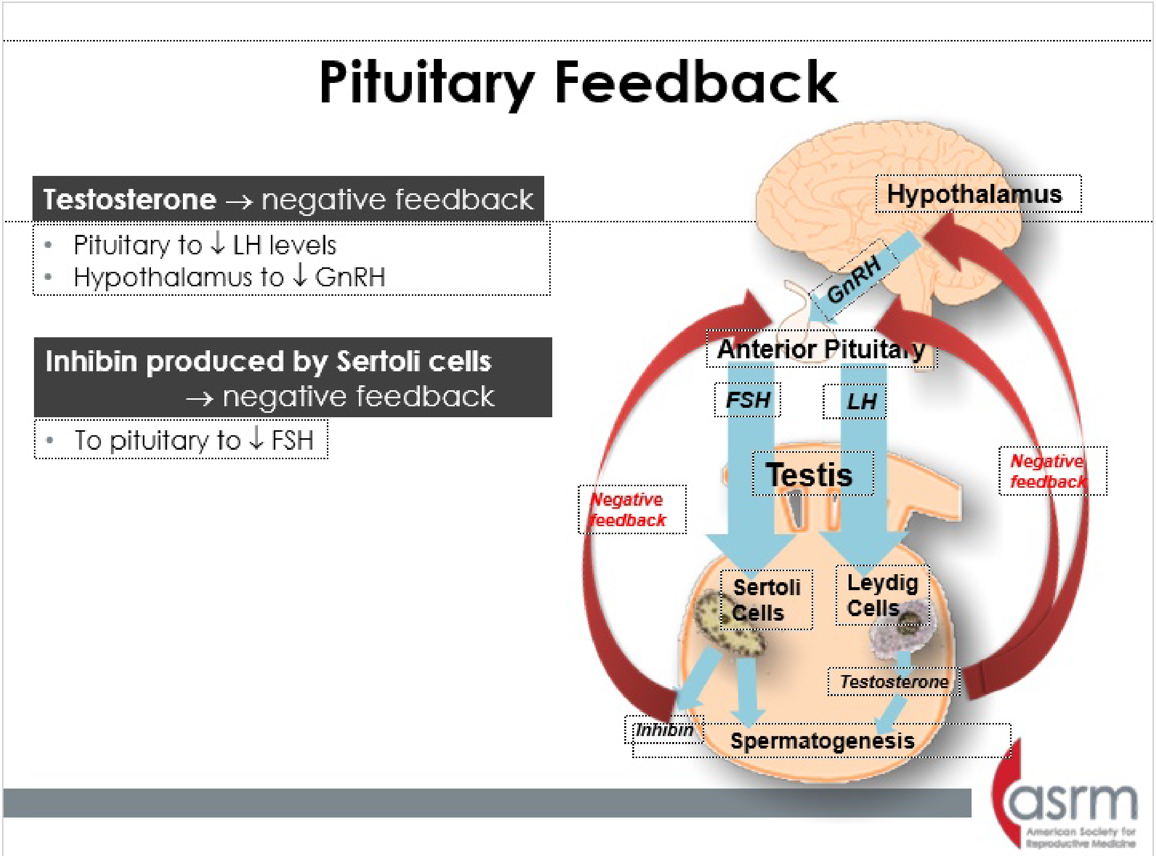
1.24 Hormones Controlling Testes Function



Notes:

Several hormones control testes function. Gonadotropin-releasing hormone (GnRH) is secreted by the hypothalamus and stimulates the pituitary to synthesize and release LH and FSH. Luteinizing hormone (LH) stimulates Leydig cells to synthesize testosterone. Follicle-stimulating hormone (FSH) maintains Sertoli cell function.

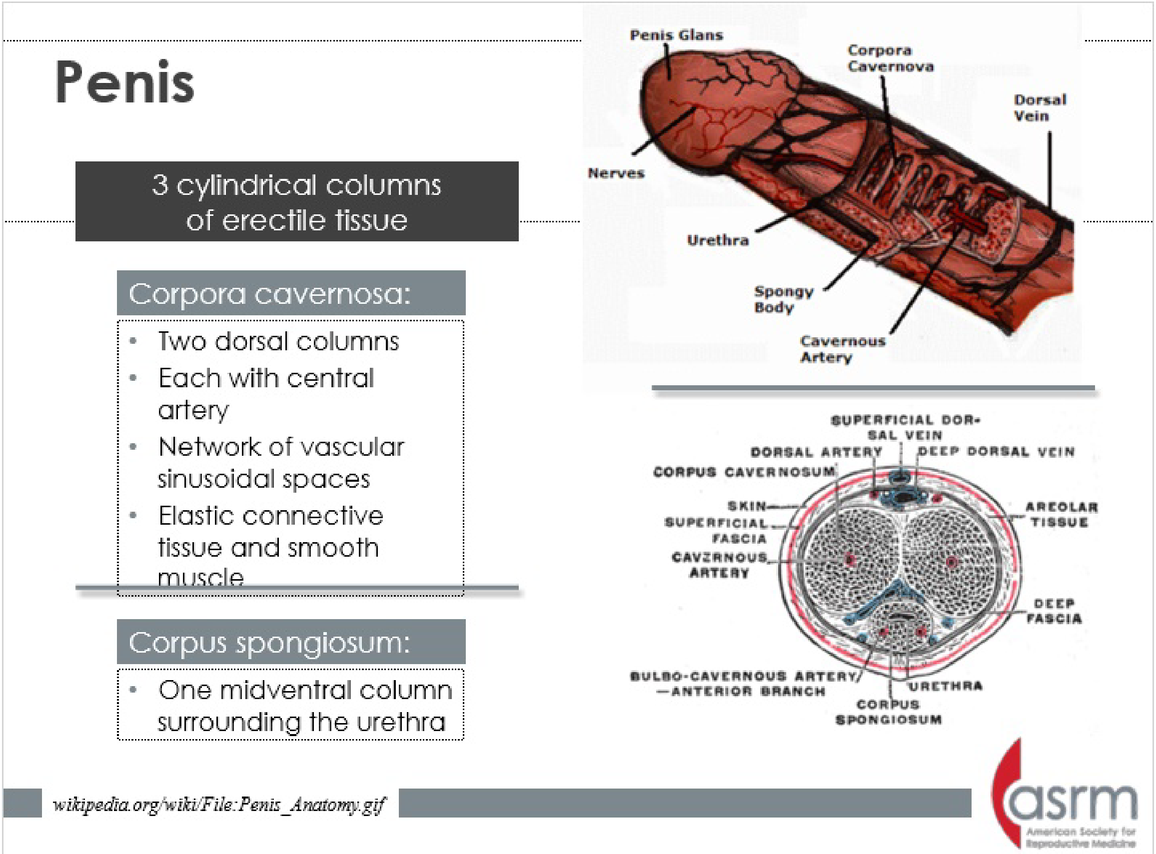
1.25 Pituitary Feedback



Notes:

Testosterone provides negative feedback to the pituitary to decrease LH and FSH levels, and to the hypothalamus to decrease GnRH production. Testosterone only partially decreases FSH production. Inhibin, produced by Sertoli cells, is responsible for the remainder of the inhibition of FSH production.

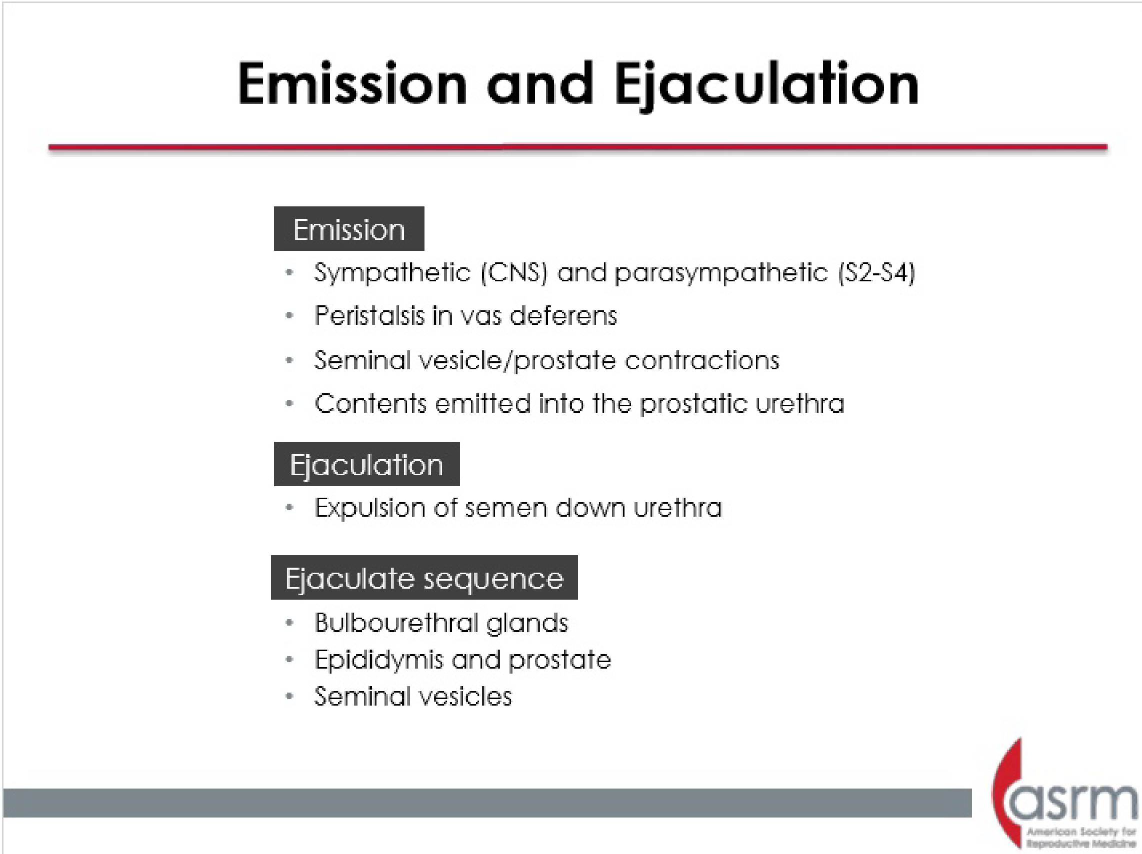
1.26 Penis



Notes:

The penis is made up of 3 cylindrical columns of erectile tissue. Two corpora cavernosa are dorsal columns. Each contains a central artery surrounded by a network of vascular sinusoidal spaces partially separated by elastic connective tissue and smooth muscle. The corpus spongiosum is one midventral column surrounding the urethra. Blood flow through the cavernosal artery regulates erection. In the relaxed state, the central arteries in the cavernosa are constricted, limiting blood inflow. Blood flows through sinusoids, and out through veins. In the aroused state, the central arteries dilate and blood fills the sinusoids to compress the veins, reducing venous outflow and causing an erection.

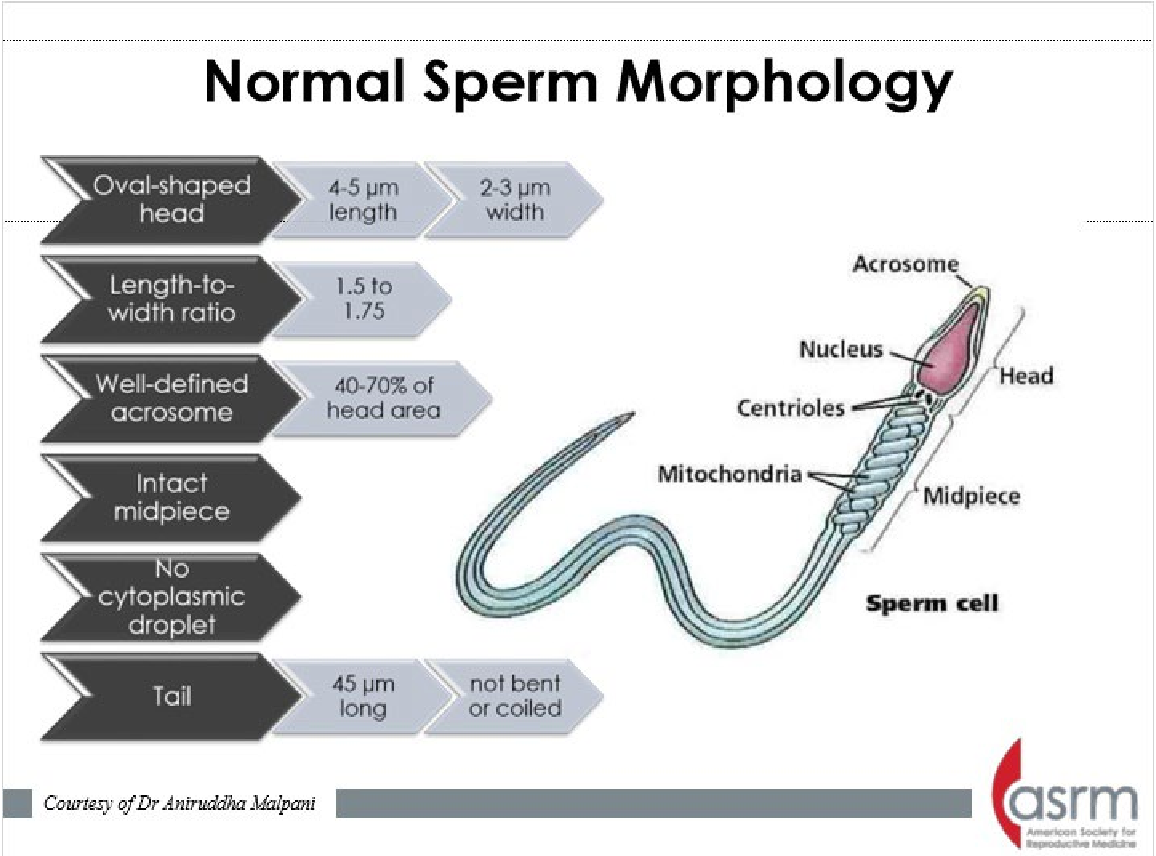
1.27 Emission and Ejaculation



Notes:

Emission is a sympathetic and parasympathetic (S2-S4) event causing peristaltic waves up the vas deferens and contractions from the seminal vesicles and prostate gland to expel contents to the prostatic urethra. Ejaculation is expulsion of the semen in the prostatic urethra distally down the urethra. Ejaculation occurs by expulsion of the contents of the bulbourethral glands, followed by the fluid from the epididymis and prostate, accounting for about 30% of volume and the highest sperm concentration. Lastly, the seminal vesicles empty and produce the largest portion of the seminal volume.

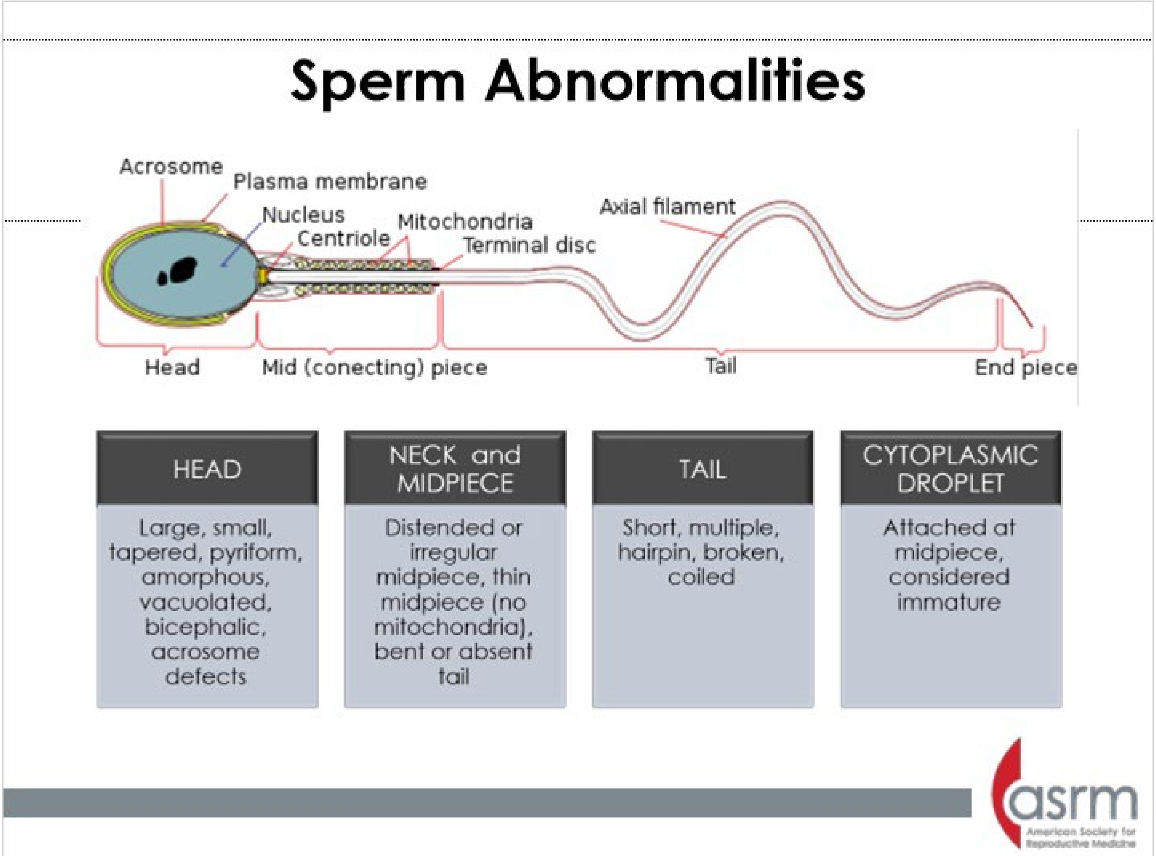
1.28 Normal Sperm Morphology



Notes:

Normal sperm morphology is defined by multiple parameters. The head is oval shaped and is 4-5 microns long and 2-3 microns wide. The length-to-width ratio is 1.5 to 1.75. A well-defined acrosome makes up 40 to 70% of the head area. The midpiece is intact and there is no cytoplasmic droplet. The tail is 45 microns long, and is not bent or coiled.

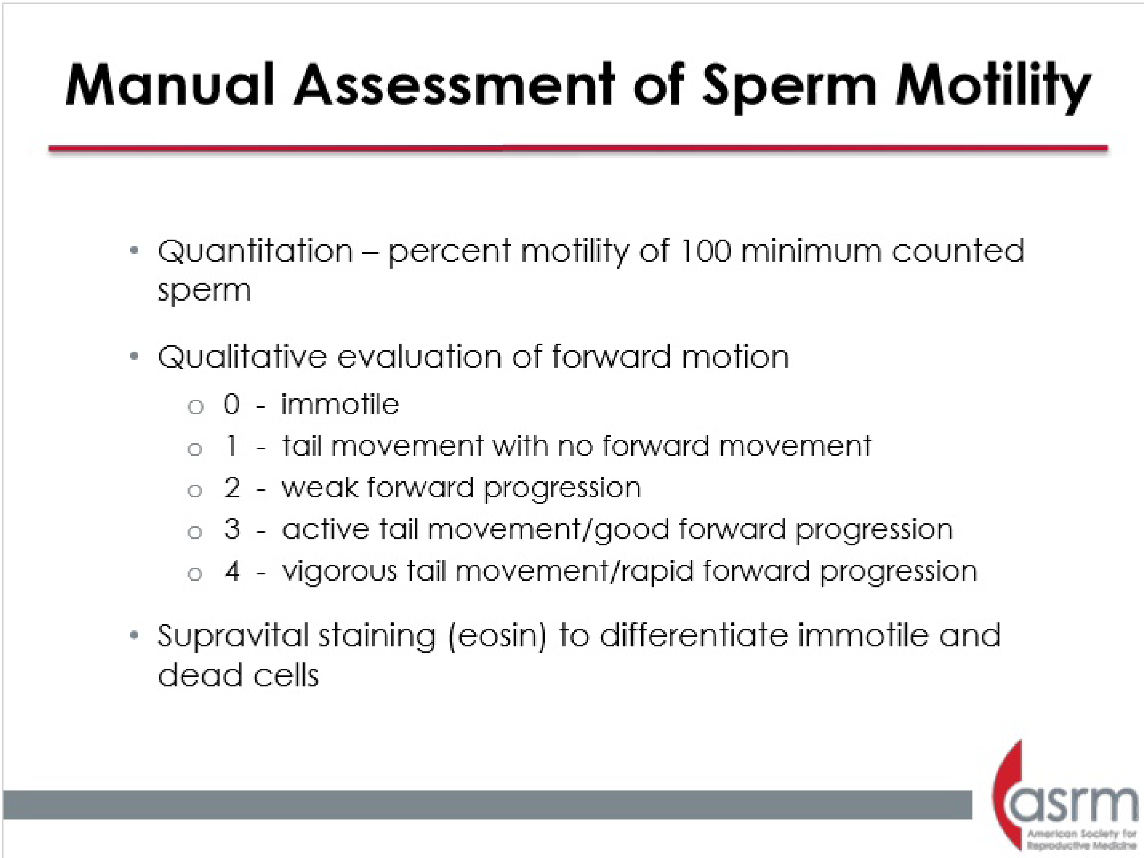
1.29 Sperm Abnormalities



Notes:

Sperm abnormalities are scored in four categories: For the head, abnormal characteristics include large, small, tapered, pyriform, amorphous, vacuolated, bicephalic, and acrosome defects. In the neck and midpiece, a distended or irregular midpiece, thin midpiece (no mitochondria), and bent or absent tail are abnormal. Abnormal tails may be short, multiple, hairpin, broken, or coiled. If there is a cytoplasmic droplet attached at the midpiece, the spermatozoon is considered immature. Clinical assessment is made on the overall percentage of normal forms; however, prevalent defects should be specifically noted.

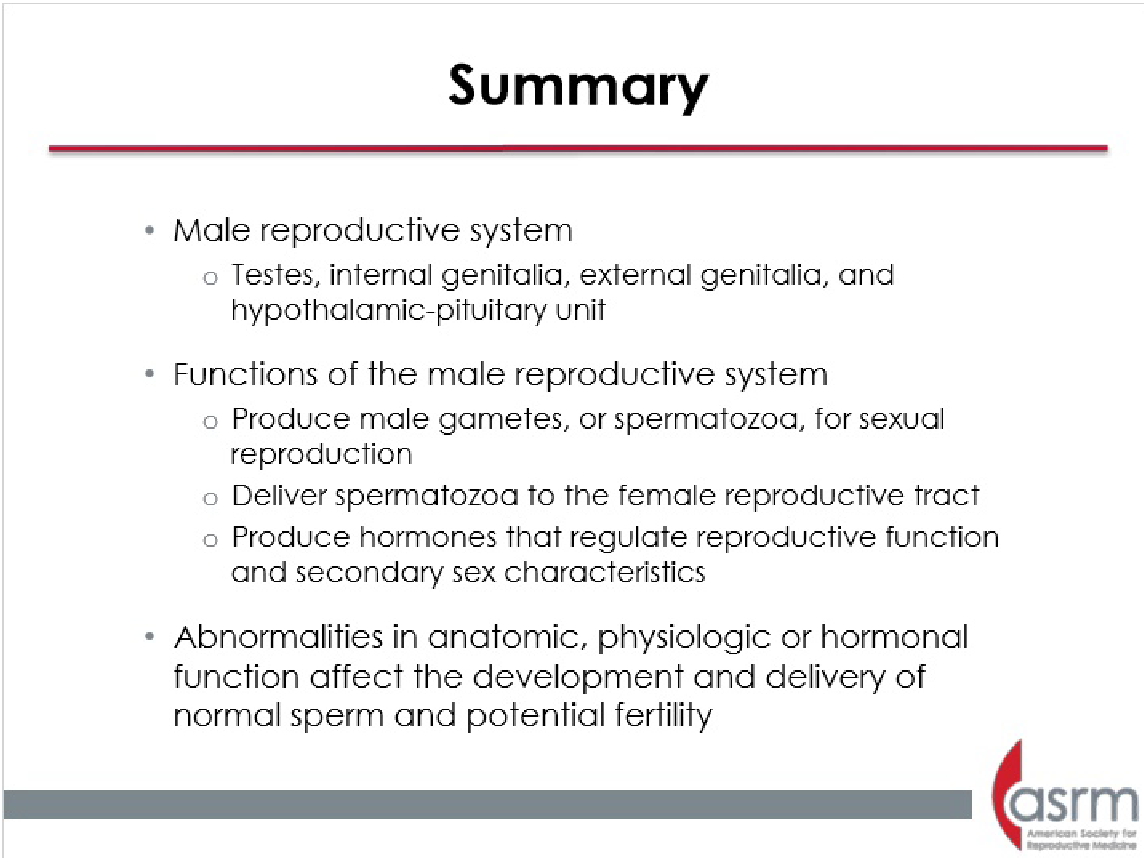
1.30 Manual Assessment of Sperm Motility



Notes:

Manual assessment of sperm motility includes determining the percent of sperm that move by counting motile and immotile cells in a counting chamber; 100 minimum are counted. For qualitative evaluation of forward motion: 0 is immotile, 1 is tail movement with no forward movement of the sperm, 2 is weak forward progression, 3 is for active tail movement with good forward progression, 4 indicates vigorous tail movement with rapid forward progression. Supravital staining using eosin to differentiate immotile and dead cells is used when motility is less than 40%.

1.31 Summary



Notes:

The male reproductive system consists of the testes, the male gonads; the internal genitalia, or reproductive tract; the external genitalia; and the hypothalamic-pituitary unit. The functions of the male reproductive system are to produce male gametes, or spermatozoa, for sexual reproduction; deliver spermatozoa to the female reproductive tract; and produce hormones that regulate reproductive function and secondary sex characteristics. Abnormalities in anatomic, physiologic or hormonal function affect the development and delivery of normal sperm and potential fertility.

1.32 Thank You

Notes:

Hopefully this module has enhanced your knowledge of male anatomy and physiology. By developing a clear understanding of what is normal, you will better understand abnormalities affecting reproduction and the mechanisms behind treatment.