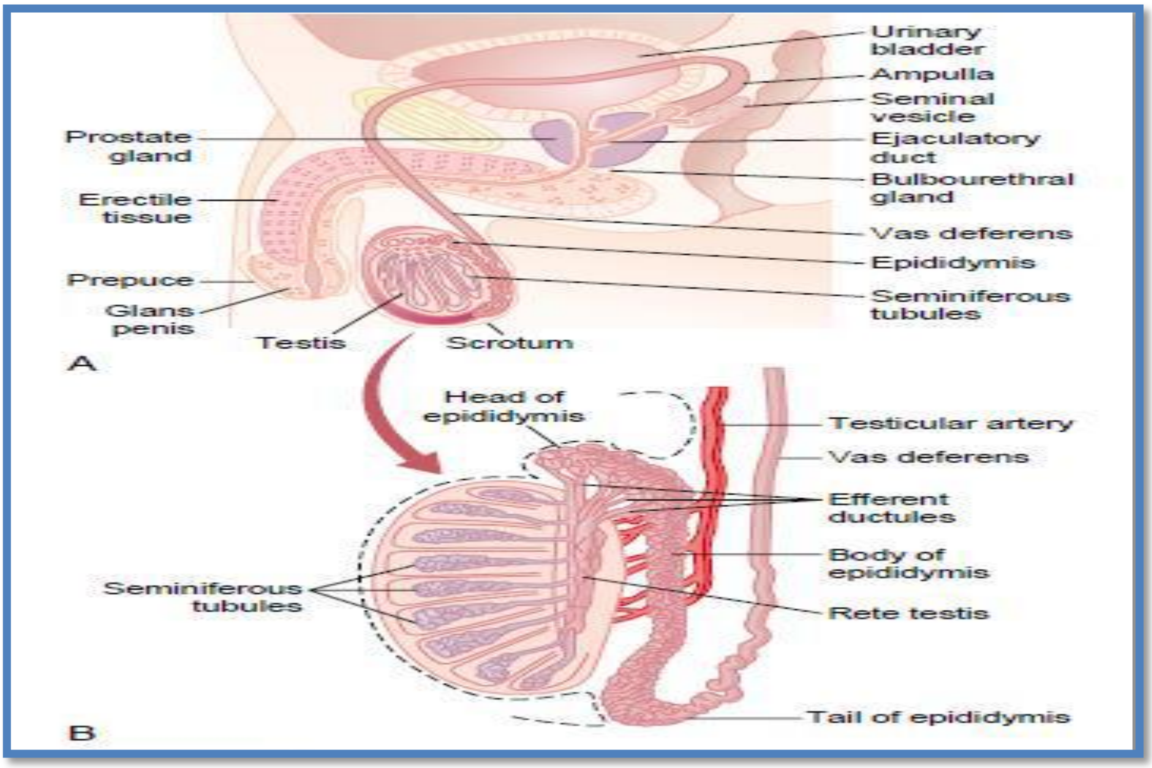
Testicle

The testicle or testis is the male reproductive gland in all animals, including humans. It is homologous to the female ovary. The functions of the testes are to produce both sperm and androgens, primarily testosterone. Testosterone release is controlled by the anterior pituitary luteinizing hormone; whereas sperm production is controlled both by the anterior pituitary follicle-stimulating hormone and gonadal testosterone.

Appearance

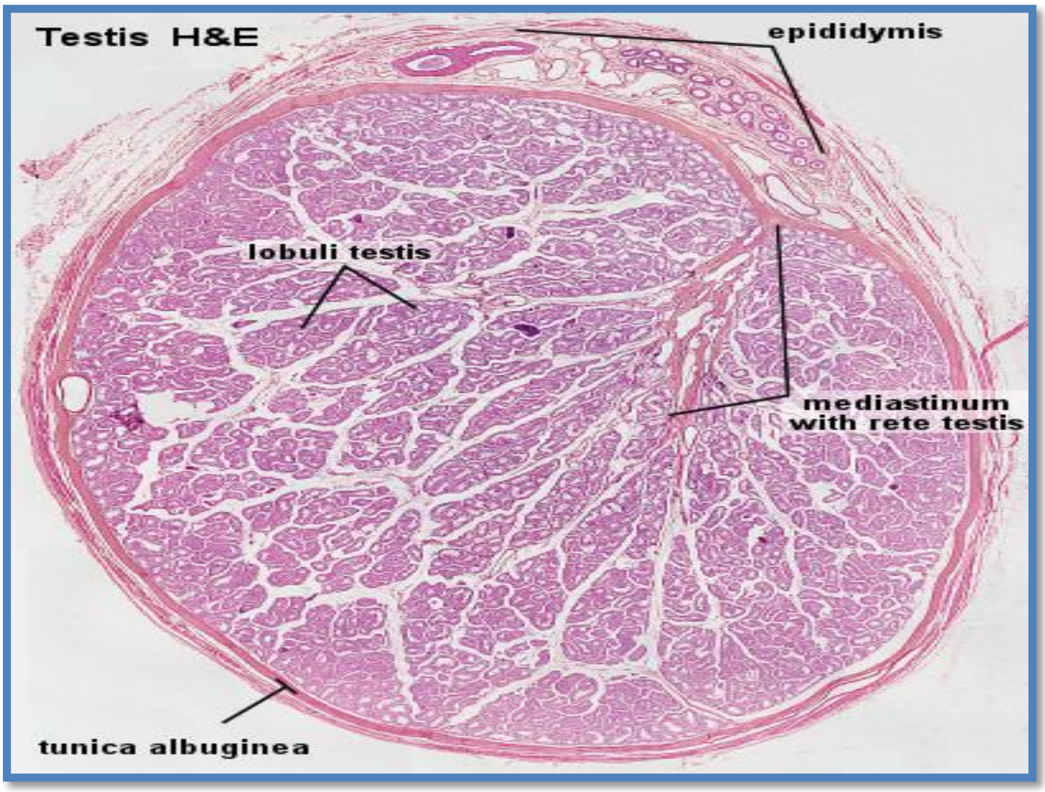
Males have two testicles of similar size contained within the scrotum , which is an extension of the abdominal wall. Scrotal asymmetry is not unusual: one testicle extends further down into the scrotum than the other due to differences in the anatomy of the vasculature.



Internal structure

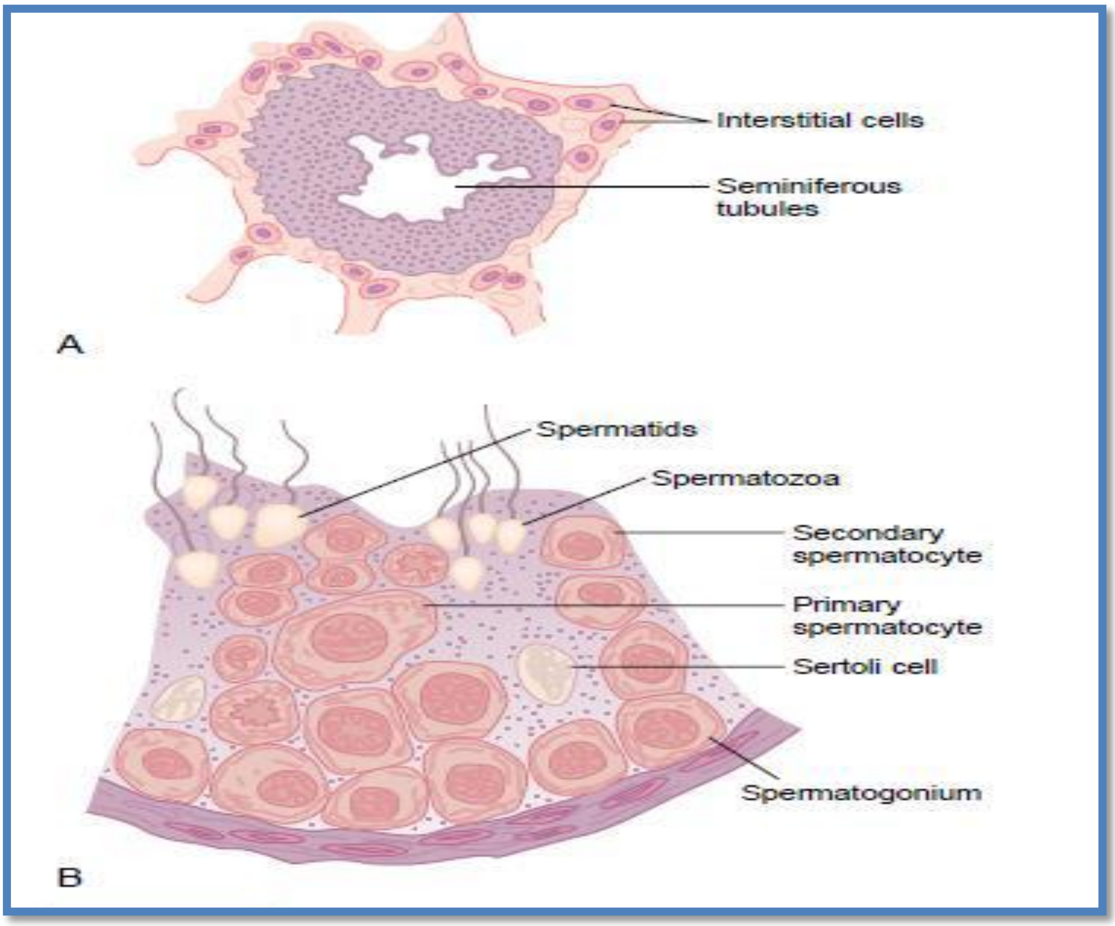
Duct system

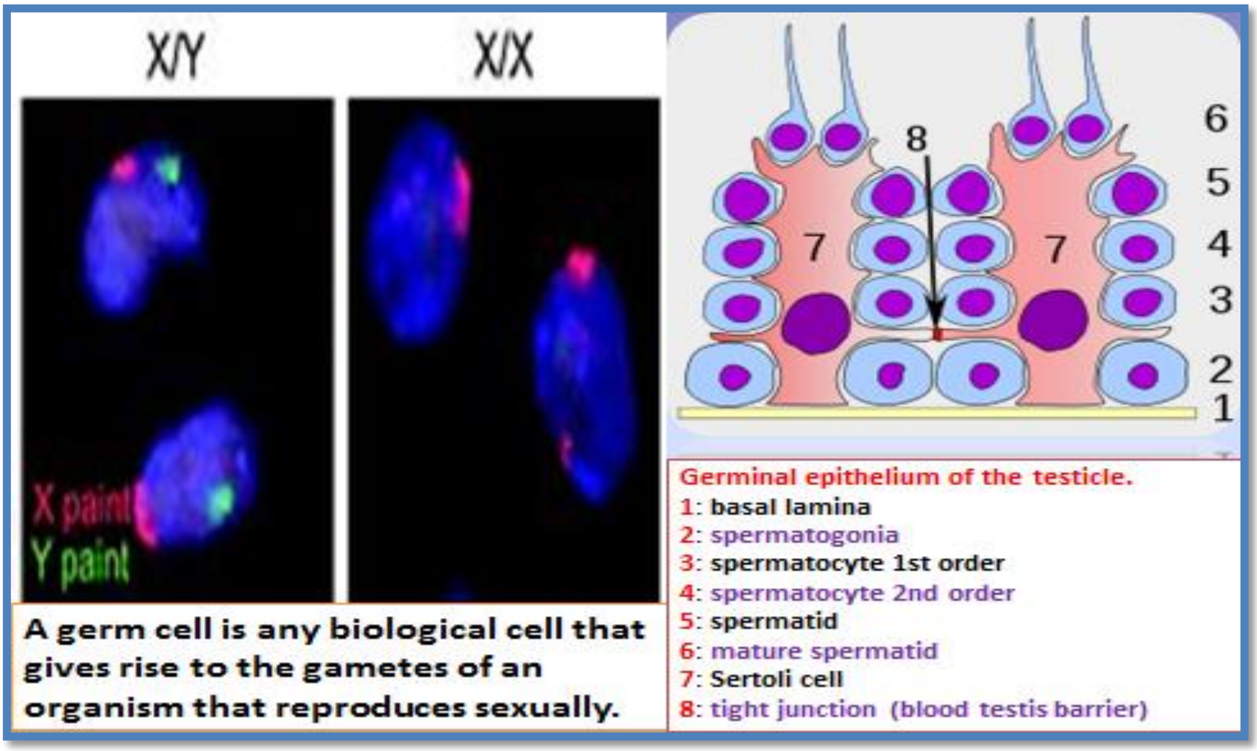
The testes are covered by a tough membranous shell called the tunica albuginea . Within the testes are very fine coiled tubes called seminiferous tubules. The tubules are lined with a layer of cells (germ cells) that develop from puberty through old age into sperm cells (also known as spermatozoa or male gametes). The developing sperm travel through the seminiferous tubules to the rete testis located in the mediastinum testis , to the efferent ducts , and then to the epididymis where newly created sperm cells mature (spermatogenesis). The sperm move into the vas deferens, and are eventually expelled through the urethra and out of the urethral orifice through muscular contractions.



Primary cell types within the seminiferous tubules

- **Germ cells** develop into **spermatogonia**, **spermatocytes**, **spermatids** and **spermatozoon** through the process of **spermatogenesis**. The gametes contain DNA for fertilization of an ovum
- **Sertoli cells** – the true epithelium of the seminiferous epithelium, critical for the support of **germ cell** development into **spermatozoa**. **Sertoli cells** secrete **inhibin**.
- **Peritubular myoid cells** surround the **seminiferous tubules**.



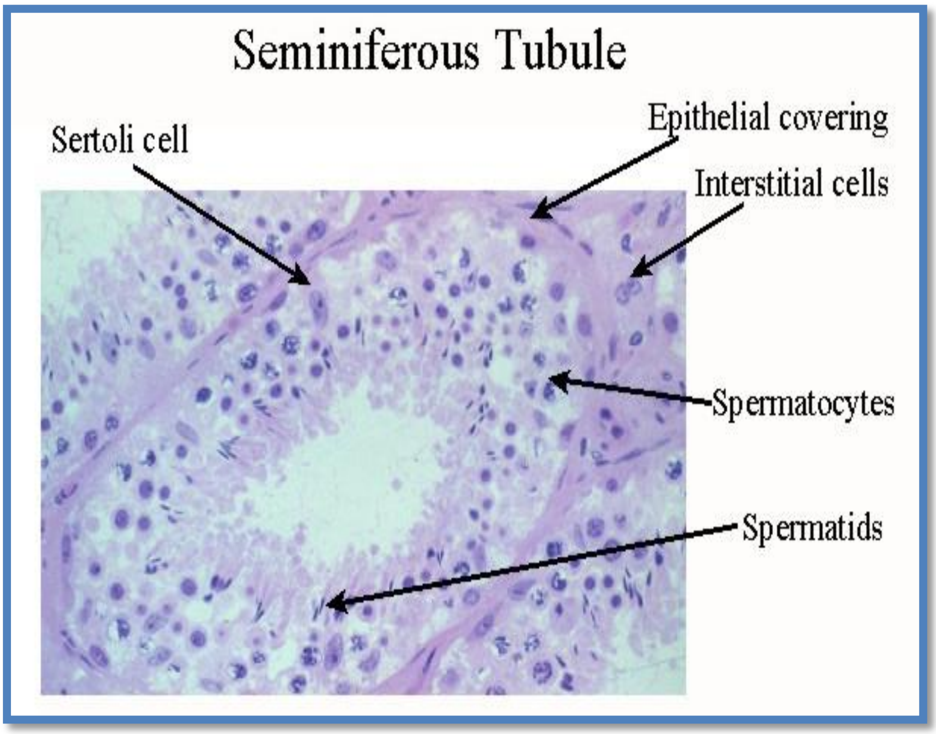


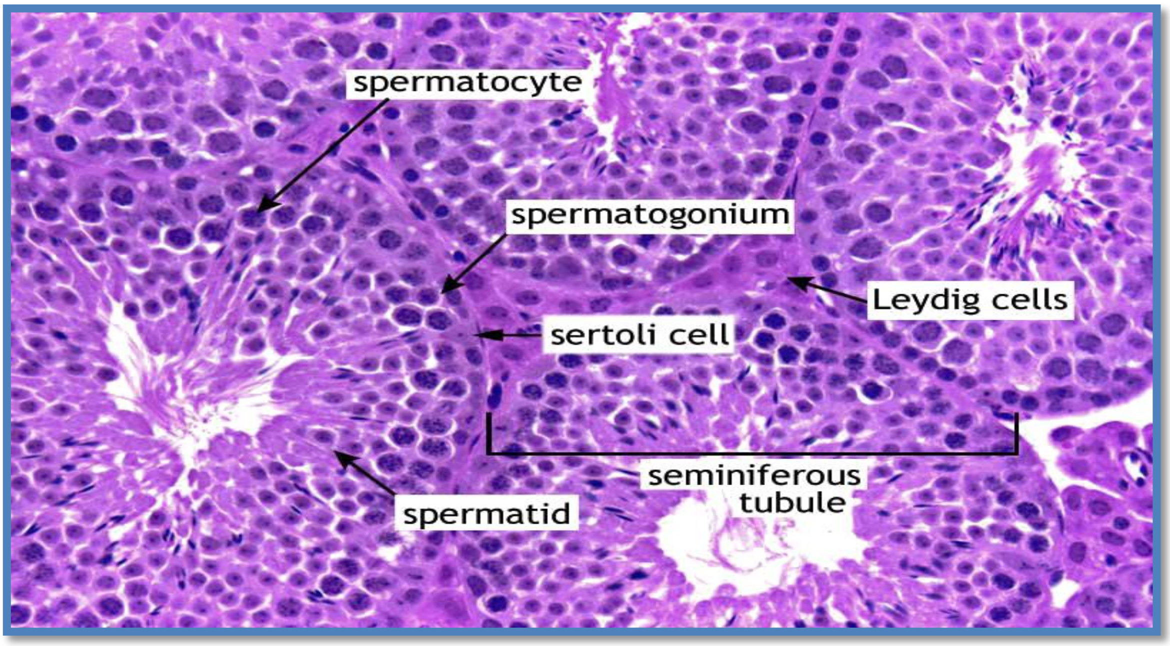
Primary cell types between tubules (interstitial cells)

- **Leydig cells** – cells localized between **seminiferous tubules** that produce and secrete testosterone and other androgens important for **sexual development** and **puberty**, **secondary sexual characteristics** like **facial hair**, **sexual behavior** and **libido**, supporting **spermatogenesis** and **erectile function**. Testosterone also controls testicular volume.
- **Also present are**:

❖ **Immature Leydig cells**

❖ **Interstitial macrophages** and **epithelial cells**



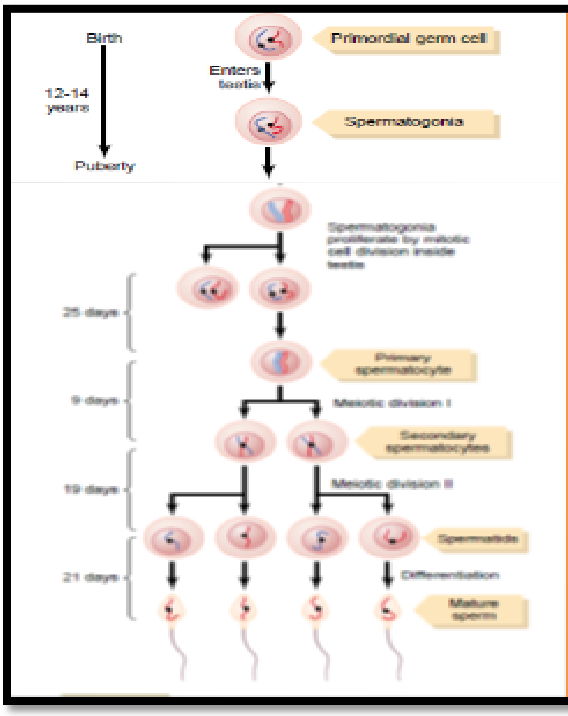


Layers

Many anatomical features of the adult testis reflect its developmental origin in the abdomen. The layers of tissue enclosing each testicle are derived from the layers of the anterior abdominal wall. Notably, the cremasteric muscle arises from the internal oblique muscle.

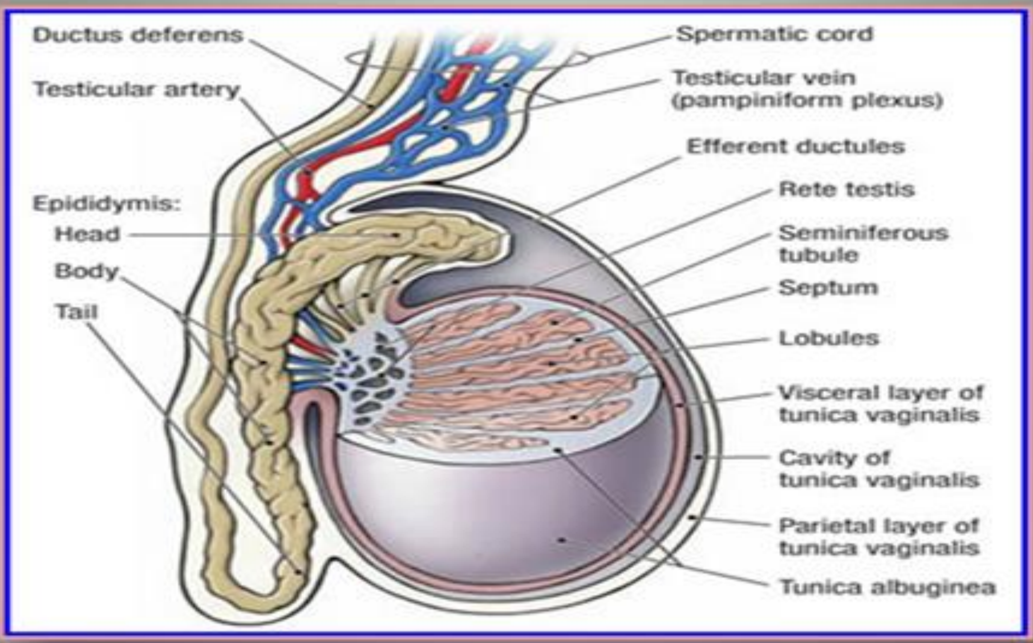
The blood–testis barrier

Large molecules cannot pass from the blood into the lumen of a **seminiferous tubule** due to the presence of tight junctions between adjacent **Sertoli cells**. The **spermatogonia** are in the basal compartment (deep to the level of the tight junctions) and the more mature forms such as primary and secondary **spermatocytes** and **spermatids** are in the **adluminal compartment**.



Cell division during spermatogenesis. During embryonic development the primordial germ cells migrate to the testis where they become spermatogonia. At puberty (usually 12 to 14 years after birth), the spermatogonia proliferate rapidly by mitosis. Some begin meiosis to become primary spermatocytes and continue through meiotic division 1 to become secondary spermatocytes. After completion of meiotic division 2, the secondary spermatocytes produce spermatids, which differentiate to form spermatozoa.

The function of the **blood–testis barrier** may be to prevent an auto-immune reaction. Mature **sperm** (and their antigens) arise long after immune tolerance is established in infancy. Therefore, since **sperm** are antigenically different from self tissue, a male animal can react immunologically to his own **sperm**. In fact, he is capable of making antibodies against them.



Partial sagittal section of testis

TEMPERATURE REGULATION

Spermatogenesis is enhanced at temperatures slightly less than core body temperature The spermatogenesis is less efficient at lower and higher temperatures than 33 °C. Because the testes are located outside the body, the smooth tissue of the scrotum can move them closer or further away from the body.

The temperature of the testes is maintained at 35 degrees Celsius (95 degrees Fahrenheit) two degrees below the body temperature of 37 degrees Celsius (98.6 degrees Fahrenheit). Higher temperatures affect spermatogenesis. There are a number of mechanisms to maintain the testes at the optimum temperature.

The cremasteric muscle is part of the spermatic cord. When this muscle contracts, the cord is shortened and the testicle is moved closer up toward the body, which provides slightly more warmth to maintain optimal testicular temperature. When cooling is required, the cremasteric muscle relaxes and the testicle is lowered away from the warm body and is able to cool.

DEVELOPMENT

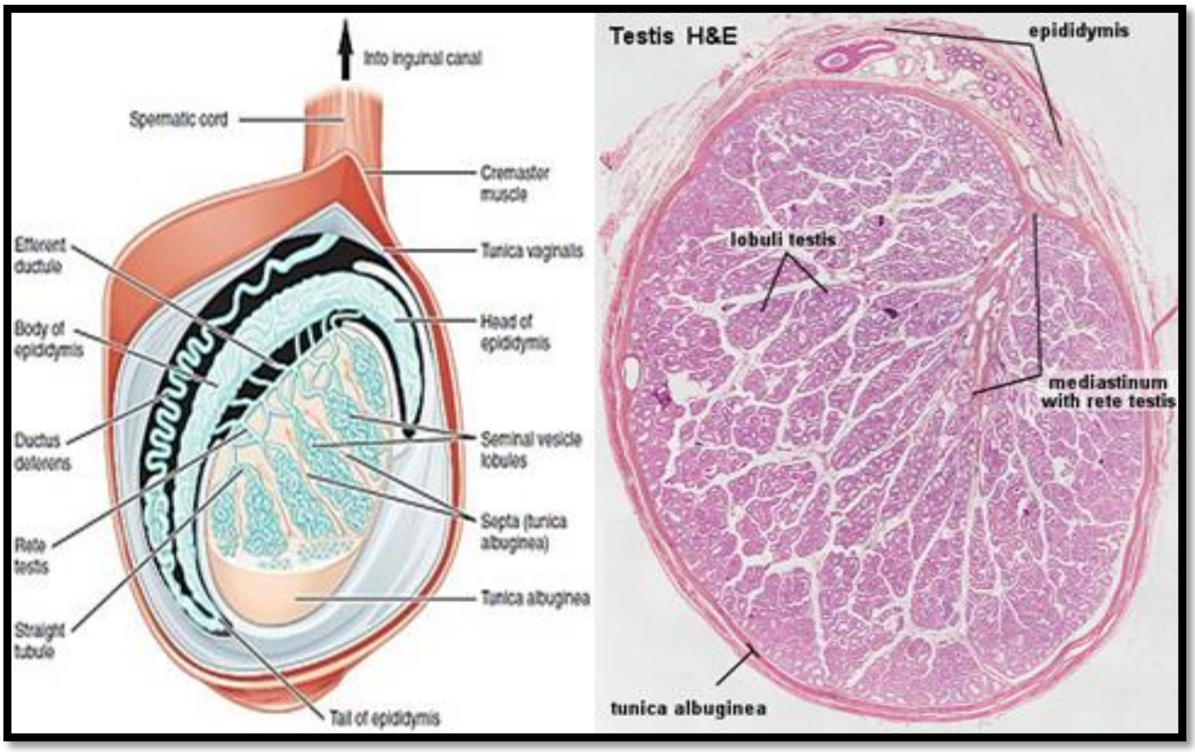
There are two phases in which the testes grow substantially; namely in embryonic and pubertal age.

1. **Embryonic**

During mammalian development, the gonads are at first capable of becoming either ovaries or testes. In humans, starting at about week **4** the gonadal rudiments are present within the intermediate mesoderm adjacent to the developing kidneys. At about week **6**, sex cords develop within the forming testes. These are made up of early Sertoli cells that surround and nurture the germ cells that migrate into the gonads shortly before sex determination begins. In males, the sex-specific gene **SRY** that is found on the **Y-chromosome** initiates sex determination by downstream regulation of sex-determining factors, which leads to development of the male phenotype, including directing development of the early bipotential gonad down the male path of development. Testes follow the "path of descent" from high in the posterior fetal abdomen to the inguinal ring and beyond to the inguinal canal and into the scrotum. In most cases both testes have descended by birth. In most other cases, only one testis fails to descend (cryptorchidism) and that will probably express itself within a year.

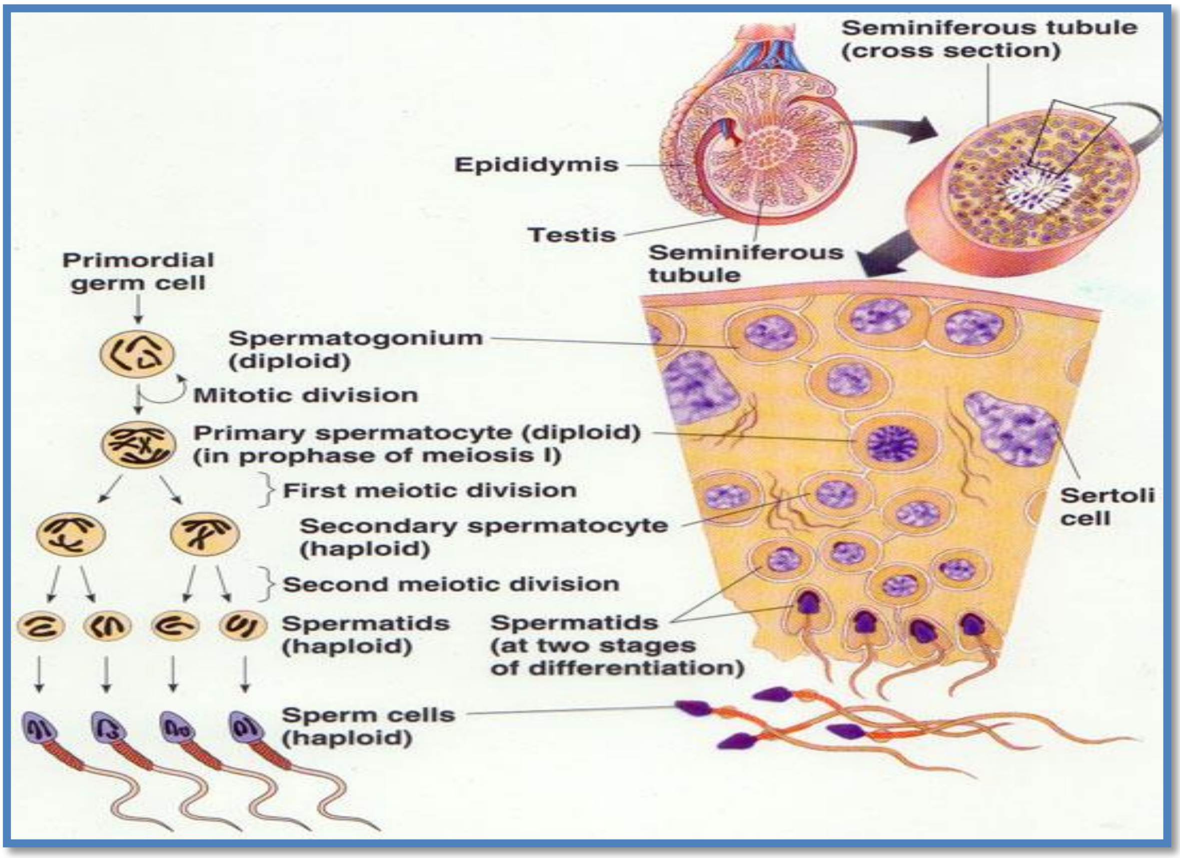
2. Pubertal

The testes grow in response to the start of spermatogenesis. Size depends on lytic function, sperm production, interstitial fluid, and Sertoli cell fluid production. After puberty, the volume of the testes can be increased by over 500% as compared to the pre-pubertal size. Testicles are fully descended before one reaches puberty.



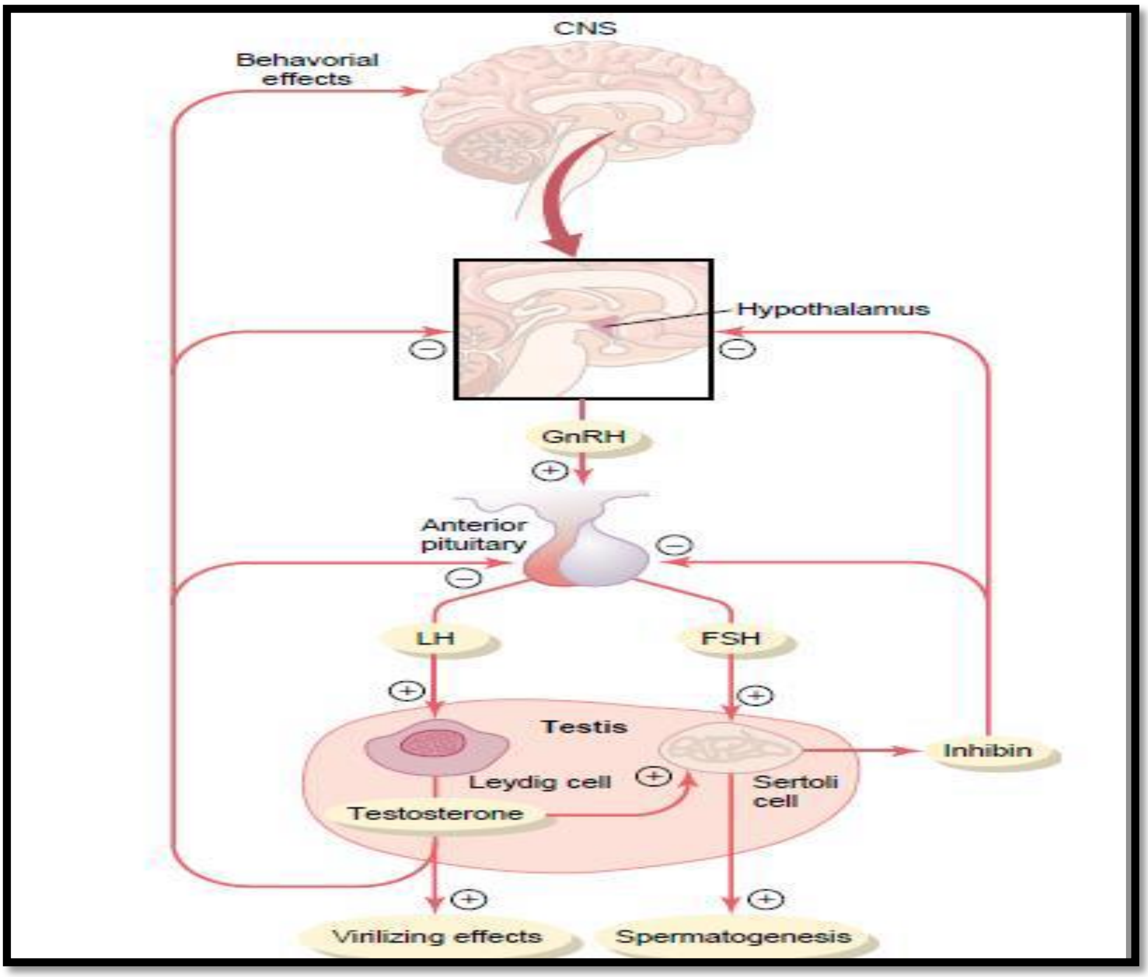
The testes of the male begin to produce testosterone at puberty in response to LH. Testosterone is the primary male sex hormone and an anabolic steroid, it plays a key role in the development of male reproductive tissues such as testes and prostate, it promotes maturation of the male reproductive organs, development of secondary sex characteristics(facial and body hair, also deepens the voice of a male at a certain age and maintaining healthy levels of muscle and bone mass) and production of sperm by the testes.

Testosterone is biosynthesized in several steps from cholesterol and is converted in the liver to inactive metabolites. It exerts its action through binding to and activation of the androgen receptor.

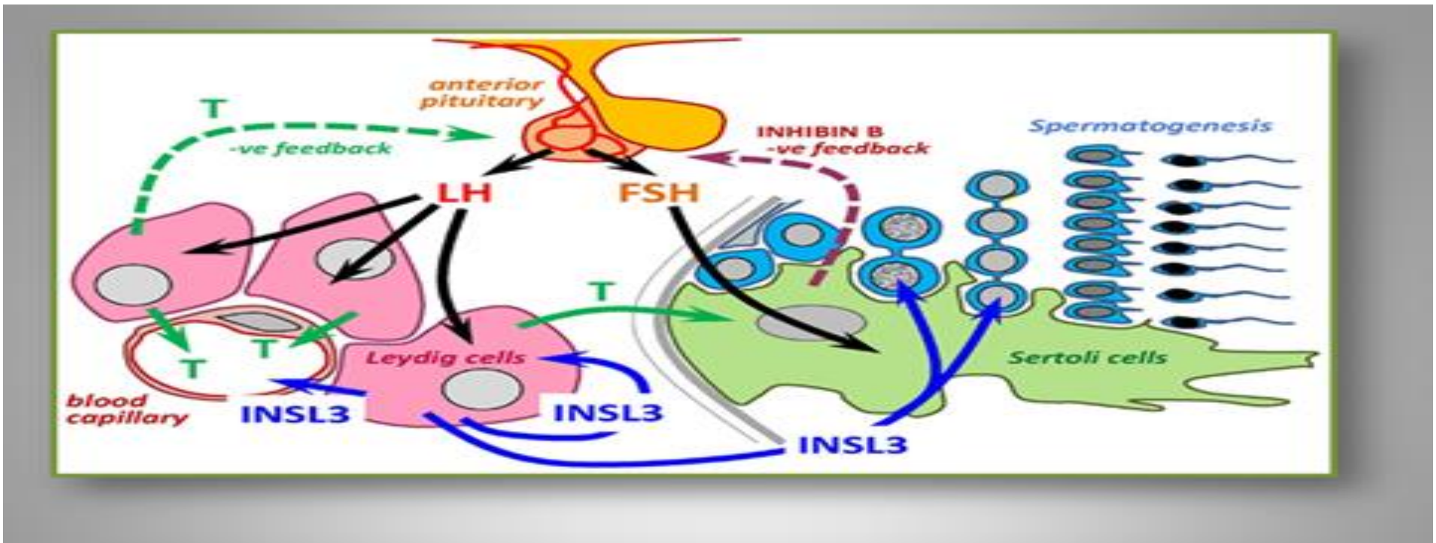


THE TESTES PRODUCE THREE MAIN HORMONES.

Hormone	Produced by	Regulation	Action
Testosterone	Leydig Cells	GnRH from the Hypothalamus causes LH secretion from the Pituitary Gland which stimulates the Leydig Cells.	This hormone controls and maintains the growth and functions of the reproductive organs. It enhances libido and is essential for spermatogenesis.
Inhibin	Sertoli Cells	GnRH from the Hypothalamus causes FSH secretion from the Pituitary Gland which stimulates the Sertoli Cells.	Prevents secretion of further FSH from the Pituitary Gland.
Oestradiol	Sertoli Cells	GnRH from the Hypothalamus causes FSH secretion from the Pituitary Gland which stimulates the Sertoli Cells	Converted from testosterone, this hormone's function is complex. It may prevent apoptosis of male germ cells.



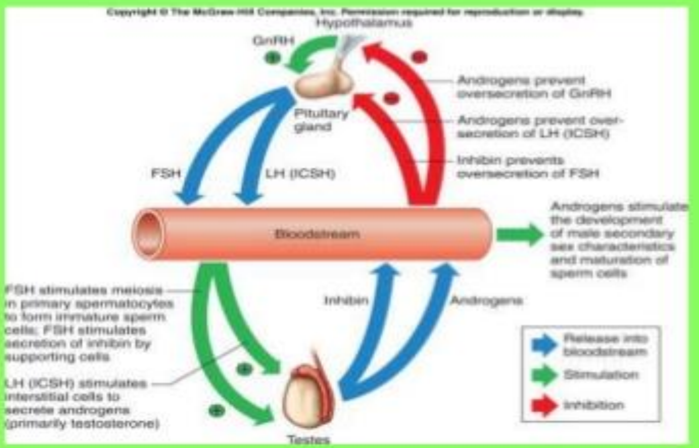
Feedback regulation of the hypothalamic-pituitary-testicular axis in males. Stimulatory effects are shown by ⊕ and negative feedbacks inhibitory effects are shown by ⊖. GnRH, gonadotropin-releasing hormone; LH, luteinizing hormone; FSH, follicle-stimulating hormone.



The hypothalamic–pituitary–gonadal (HPG) axis

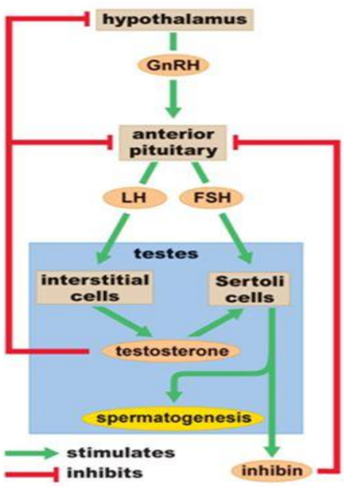
Regulation of Testosterone

- Hypothalamus regulates through negative feedback
- Increasing Concentration
  - Inhibits hypothalamus
  - stimulation of anterior pituitary gland decreases
  - As secretion of LH falls, testosterone release from cells decreases
- Decreasing Concentration
  - Hypothalamus stimulates anterior pituitary gland to release LH
  - Secretion causes interstitial cells to release testosterone



Testicular function is regulated by negative feedback

- Testosterone inhibits the release of GnRH, LH, and FSH
- The Sertoli cells are stimulated by FSH and testosterone to secrete inhibin, which inhibits FSH production by the anterior pituitary
- This complex feedback process maintains constant levels of testosterone and sperm production



Human Chorionic Gonadotropin Secreted by the Placenta During Pregnancy Stimulates Testosterone Secretion by the Fetal Testes

During pregnancy the hormone *human chorionic gonadotropin* (hCG) is secreted by the placenta and circulates both in the mother and in the fetus. This hormone has almost the same effects on the sexual organs as LH. During pregnancy, if the fetus is a male, hCG from the placenta causes the testes of the fetus to secrete testosterone. This testosterone is critical for promoting formation of the male sexual organs, as pointed out earlier.

Puberty and Regulation of Its Onset

Initiation of the onset of puberty has long been a mystery, but it has now been determined that *during childhood the hypothalamus does not secrete significant amounts of GnRH.* One of the reasons for this is that, during childhood, the slightest secretion of any sex steroid hormones exerts a strong inhibitory effect on hypothalamic secretion of GnRH. Yet, for reasons still not understood, at the time of puberty, the secretion of hypothalamic GnRH breaks through the childhood inhibition and adult sexual life begins.