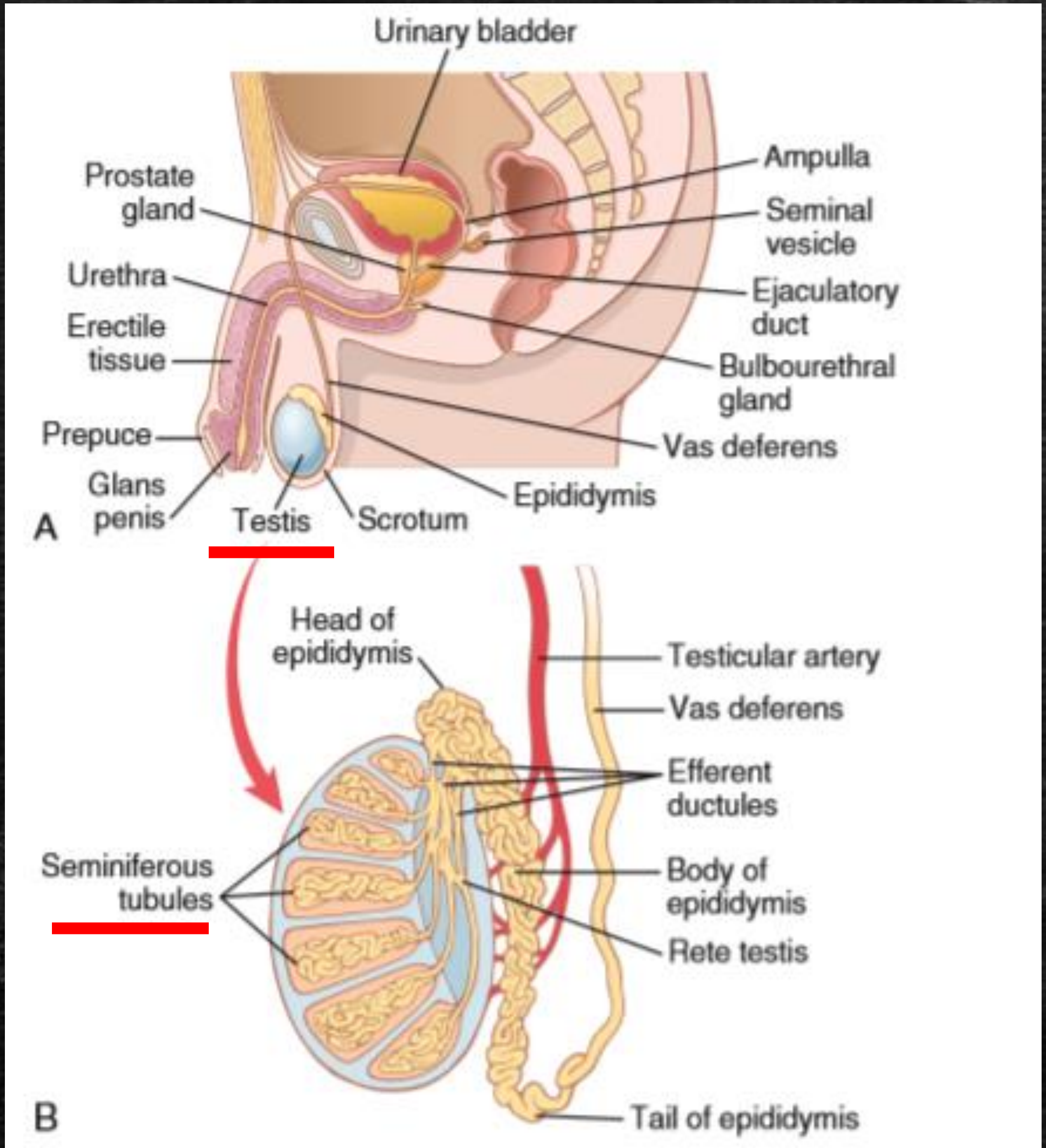
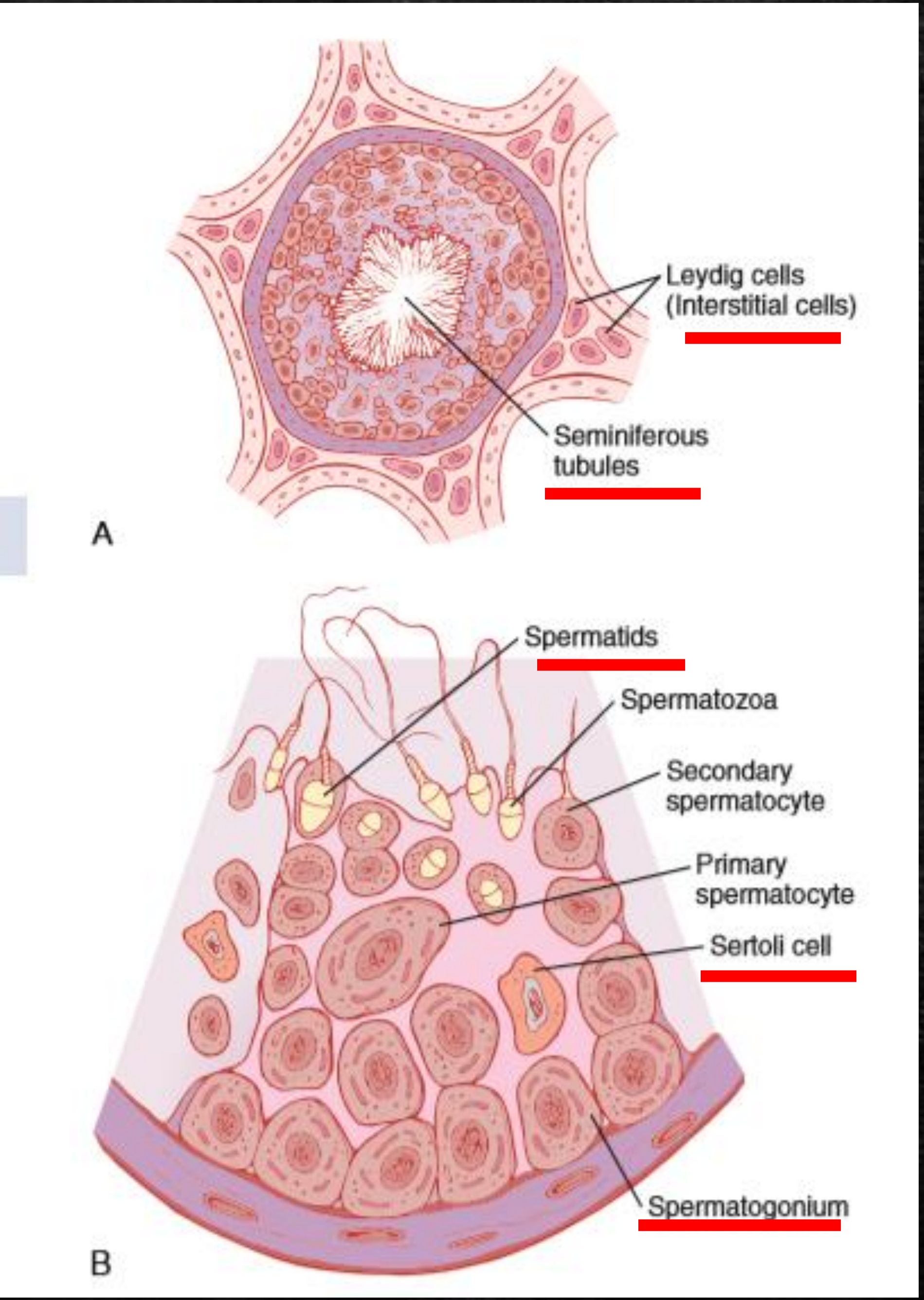
Reproductive Physiology

Reproductive and Hormonal Functions of the Male

Chapter 81



Urinary bladder
Prostate gland
Urethra
Erectile tissue
Prepuce
Glans penis
A
Testis
Scrotum
Epididymis
Vas deferens
Bulbourethral gland
Ejaculatory duct
Seminal vesicle
Ampulla
Head of epididymis
Testicular artery
Vas deferens
Efferent ductules
Seminiferous tubules
Body of epididymis
Rete testis
B
Tail of epididymis

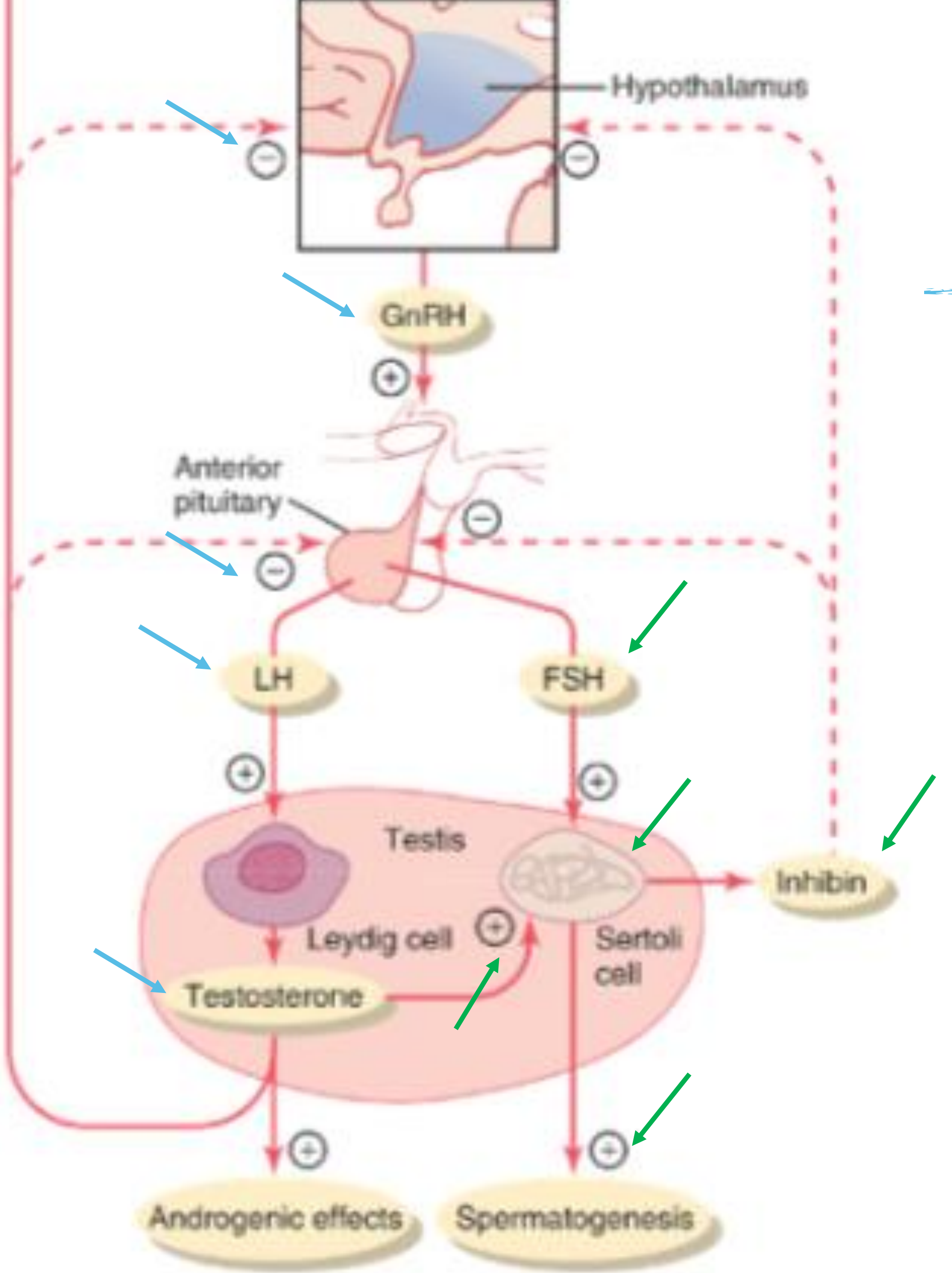


Leydig cells (Interstitial cells)
Seminiferous tubules
A
Spermatids
Spermatozoa
Secondary spermatocyte
Primary spermatocyte
Sertoli cell
Spermatogonium
B

Testosterone and Other Male Sex Hormones

Chapter 81

Control of Male Sexual Functions by Hormones from the Hypothalamus and Anterior Pituitary Gland



- **GnRH is secreted intermittently a few minutes at a time once every 1 to 3 hours. The intensity of this hormone's stimulus is determined in two ways: (1) by the frequency of these cycles of secretion and (2) by the quantity of GnRH released with each cycle.

- **The secretion of LH by the anterior pituitary gland is also cyclical, with LH following fairly faithfully the pulsatile release of GnRH.

- ** Conversely, FSH secretion increases and decreases only slightly with each fluctuation of GnRH secretion; instead, it changes more slowly over a period of many hours in response to longer-term changes in GnRH.

- ** Because of the much closer relation between GnRH secretion and LH secretion, GnRH is also widely known as *LH-releasing hormone*.

- **Most of this inhibition probably results from a direct effect of testosterone on the hypothalamus to decrease the secretion of GnRH. This in turn causes a corresponding decrease in secretion of both LH and FSH by the anterior pituitary, and the decrease in LH reduces the secretion of testosterone by the testes.

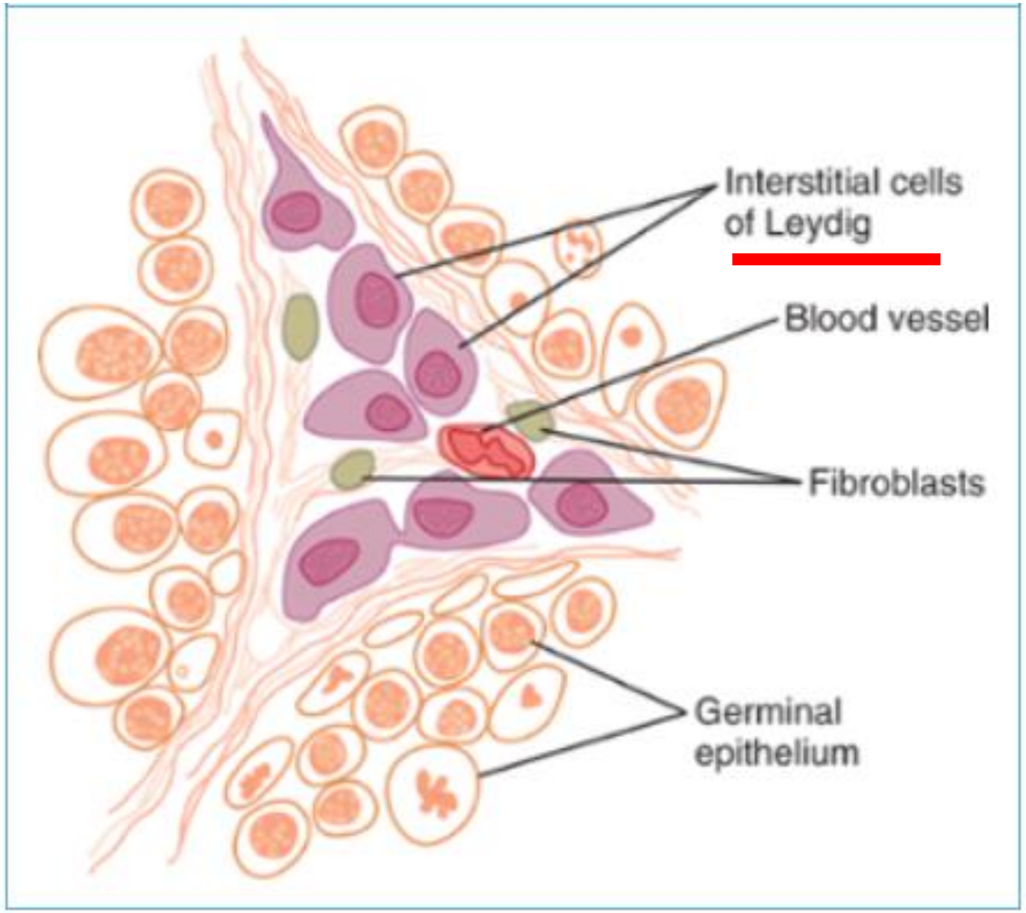
- **FSH binds with specific FSH receptors attached to the Sertoli cells in the seminiferous tubules. This causes the Sertoli cells to grow and secrete various spermatogenic substances. Simultaneously, testosterone (and dihydrotestosterone) diffusing into the seminiferous tubules from the Leydig cells in the interstitial spaces also has a strong tropic effect on spermatogenesis. Thus, to initiate spermatogenesis, both FSH and testosterone are necessary.

- **When the seminiferous tubules fail to produce sperm, secretion of FSH by the anterior pituitary gland increases markedly. Conversely, when spermatogenesis proceeds too rapidly, pituitary secretion of FSH diminishes. The cause of this negative feedback effect on the anterior pituitary is believed to be secretion by the Sertoli cells of still another hormone called *inhibin*

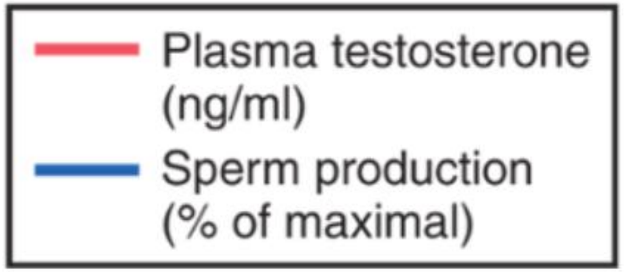
Testosterone

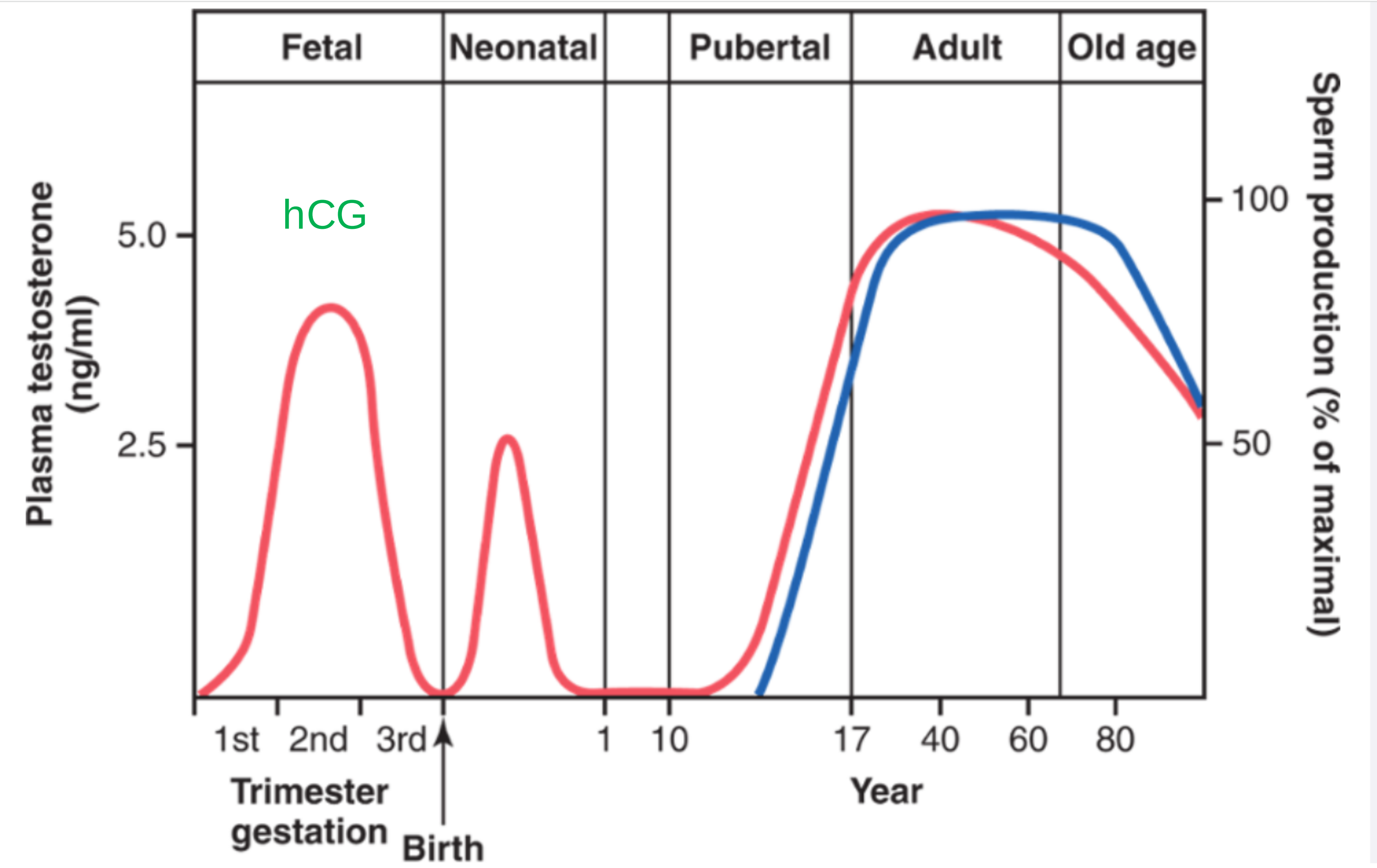
- Leydig cells are almost nonexistent in the testes during childhood.
- They are numerous in the newborn male infant for the first few months of life and in the adult male after puberty.

** Furthermore, when tumors develop from the interstitial cells of Leydig, great quantities of testosterone are secreted. When the germinal epithelium of the testes is destroyed by x-ray treatment or excessive heat, the Leydig cells, which are less easily destroyed, often continue to produce testosterone.



Testosterone





- **In general, testosterone is responsible for the distinguishing characteristics of the masculine body.
- ** During fetal life, the testes are stimulated by chorionic gonadotropin from the placenta to produce moderate quantities of testosterone throughout the entire period of fetal development and for 10 or more weeks after birth.
- ** No testosterone is produced during childhood.
- ** About the ages of 10 to 13 years, testosterone production increases rapidly under the stimulus of anterior pituitary gonadotropic hormones at the onset of puberty and lasts throughout most of the remainder of life.
- ** Dwindling rapidly beyond age 50 to become 20 to 50 percent of the peak value by age 80.

Functions of Testosterone During Fetal Development

- The male chromosome has the SRY (sex-determining region Y) gene.
- The SRY protein initiates a cascade of gene activations that cause the genital ridge cells to differentiate into cells that secrete testosterone and eventually become the testes.
- Responsible for the development of the male body characteristics, including the formation of a penis and a scrotum.
- The testes usually descend into the scrotum during the last 2 to 3 months of gestation when the testes begin secreting reasonable quantities of testosterone.

Effect of Testosterone on Development of Adult Primary and Secondary Sexual Characteristics

1- After puberty, the increasing amounts of testosterone cause enlargement of the penis, scrotum & testis & secondary sexual characteristics.

2- Effect on the distribution of body hair:

Testosterone causes growth of hair over the pubis and on the face

3- Baldness:

Testosterone decreases the growth of hair on the top of the head (two factors

1) genetic background; 2) large quantities of androgenic hormones.

4- Effect on voice:

causes hypertrophy of the laryngeal mucosa, enlargement of the larynx (typical adult masculine voice)

- ** A man who does not have functional testes does not become bald. However, many virile men never become bald because baldness is a result of two factors: first, a genetic background for the development of baldness and, second, superimposed on this genetic background, large quantities of androgenic hormones. A woman who has the appropriate genetic background and who develops a long-sustained androgenic tumor becomes bald in the same manner as does a man.

Effect of Testosterone on Development of Adult Primary and Secondary Sexual Characteristics

5- Testosterone increases thickness of the skin and can contribute to development of acne.

6- Testosterone increases protein formation and muscle development

7- Testosterone increases bone matrix and causes Ca^{2+} retention:
Bones grown thicker & deposit additional Ca^{2+}. Thus it increases the total quantity of bone matrix & causes Ca^{2+} retention (anabolic effect).

8- Testosterone increases basal metabolism:
increases the basal metabolic rate by about 15% (indirectly as a result of the anabolic effect).

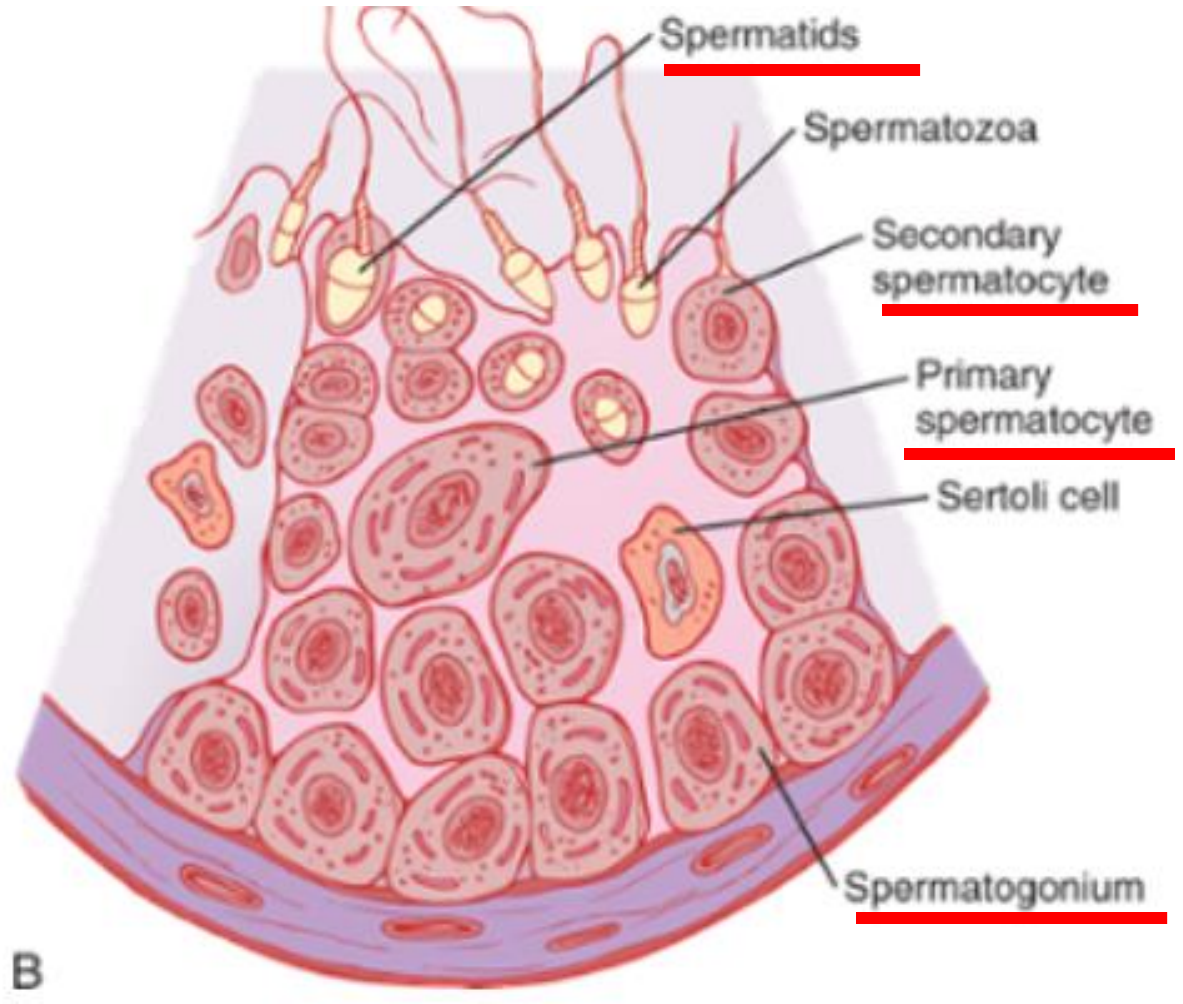
9- Effect on red blood cells:
increases red blood cells 15-20% (due to increased metabolic rate).

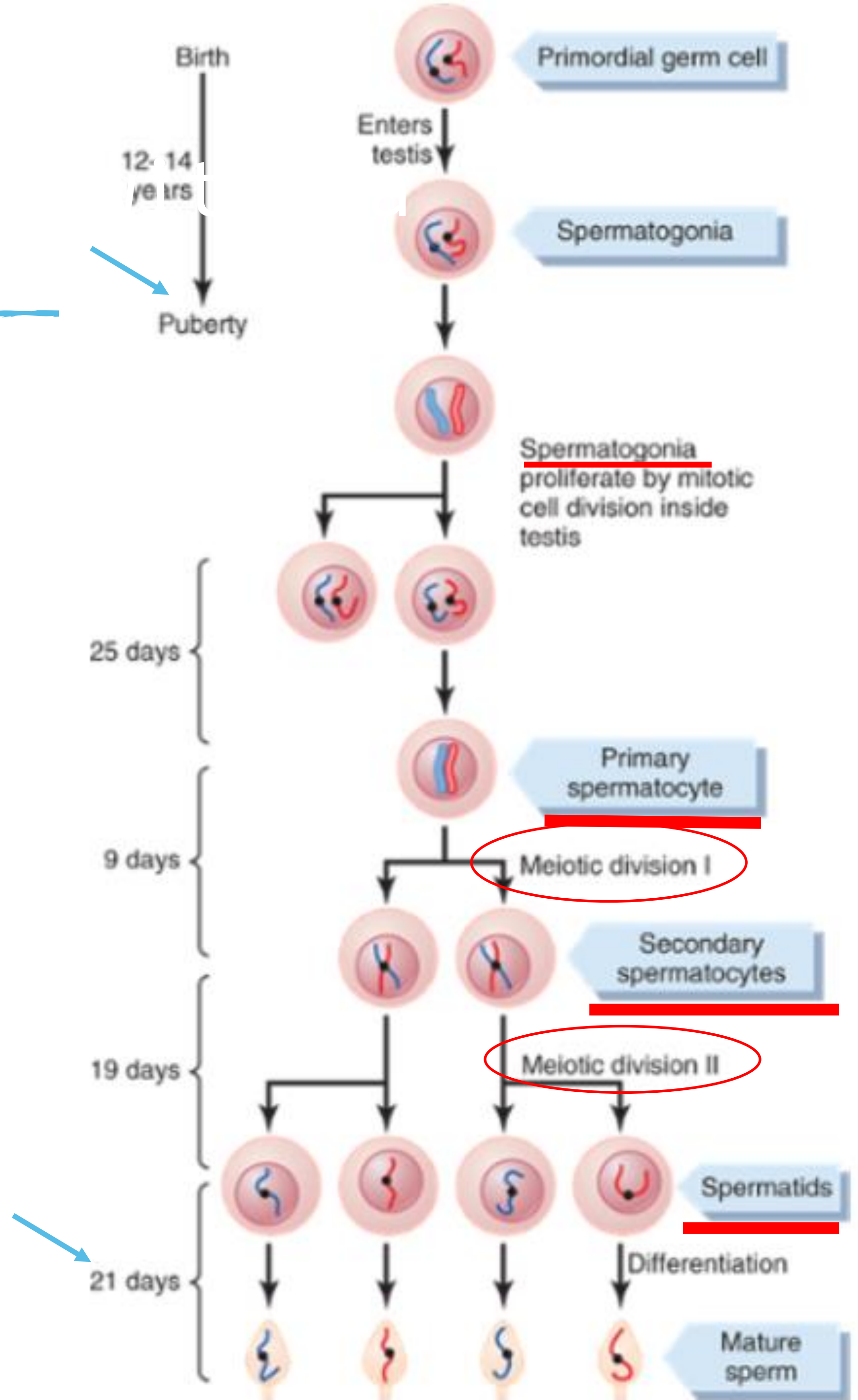
10- Effect on electrolyte and water balance.
increase the reabsorption of Na^+ in the distal tubules of the kidneys.

Spermatogenesis

Chapter 81

Spermatogenesis





- **Spermatogonia that cross the barrier into the Sertoli cell layer become progressively modified and enlarged to form large primary spermatocytes.

- **The rate of spermatogenesis is constant and cannot be accelerated by hormones such as gonadotropins or androgens.

** In the female, the mitotic proliferation of germ cells takes place entirely before birth. In the male, spermatogonia proliferate only after puberty and then throughout life

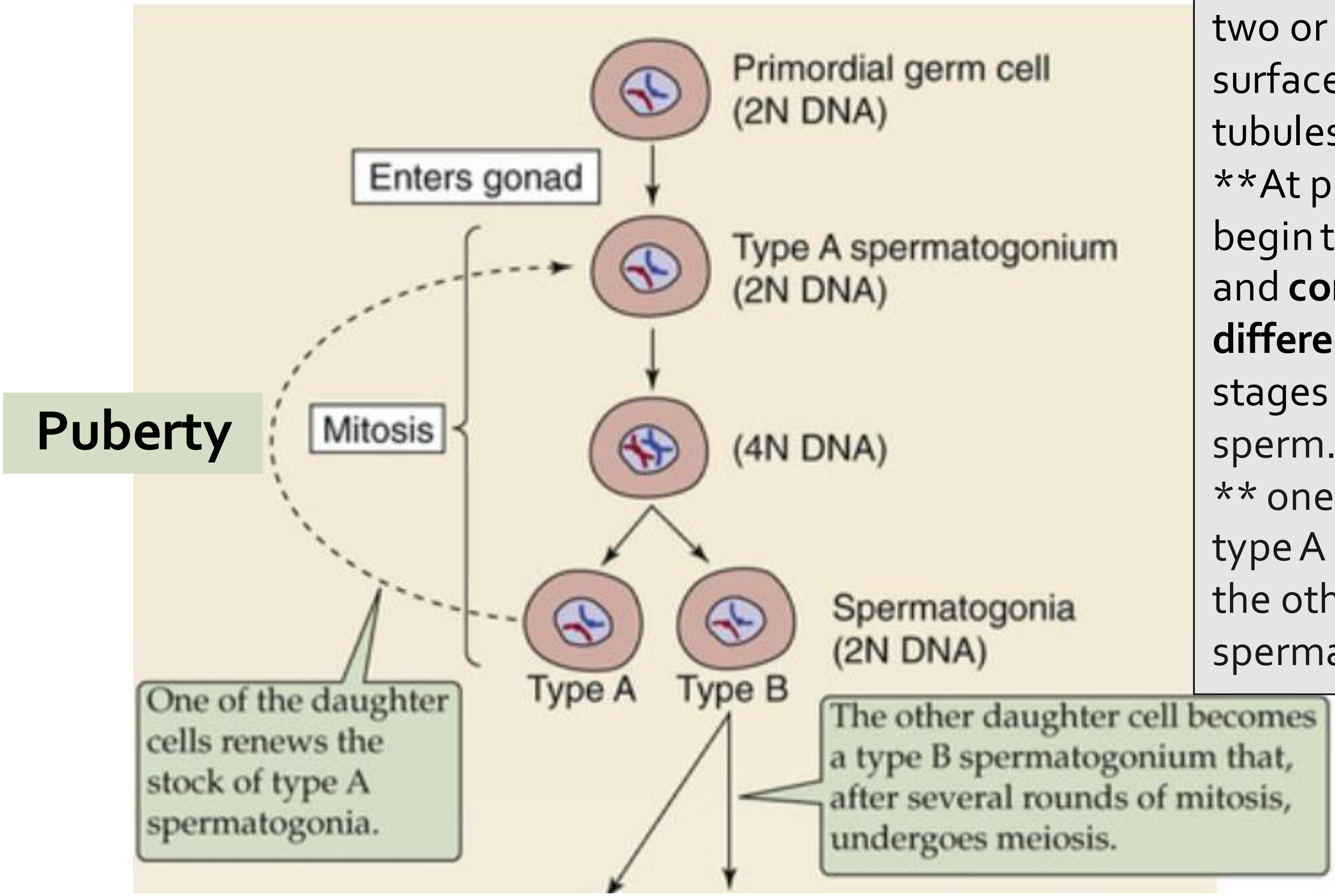
- ** The entire period of spermatogenesis, from spermatogonia to spermatozoa, takes about 74 days.

Spermatogenesis

- Spermatogenesis occurs in the seminiferous tubules **during active sexual life** as the result of stimulation by **anterior pituitary gonadotropic hormones.**

- Spermatogenesis continues throughout most of the remainder of life but **decreases markedly in old age.**

Spermatogenesis



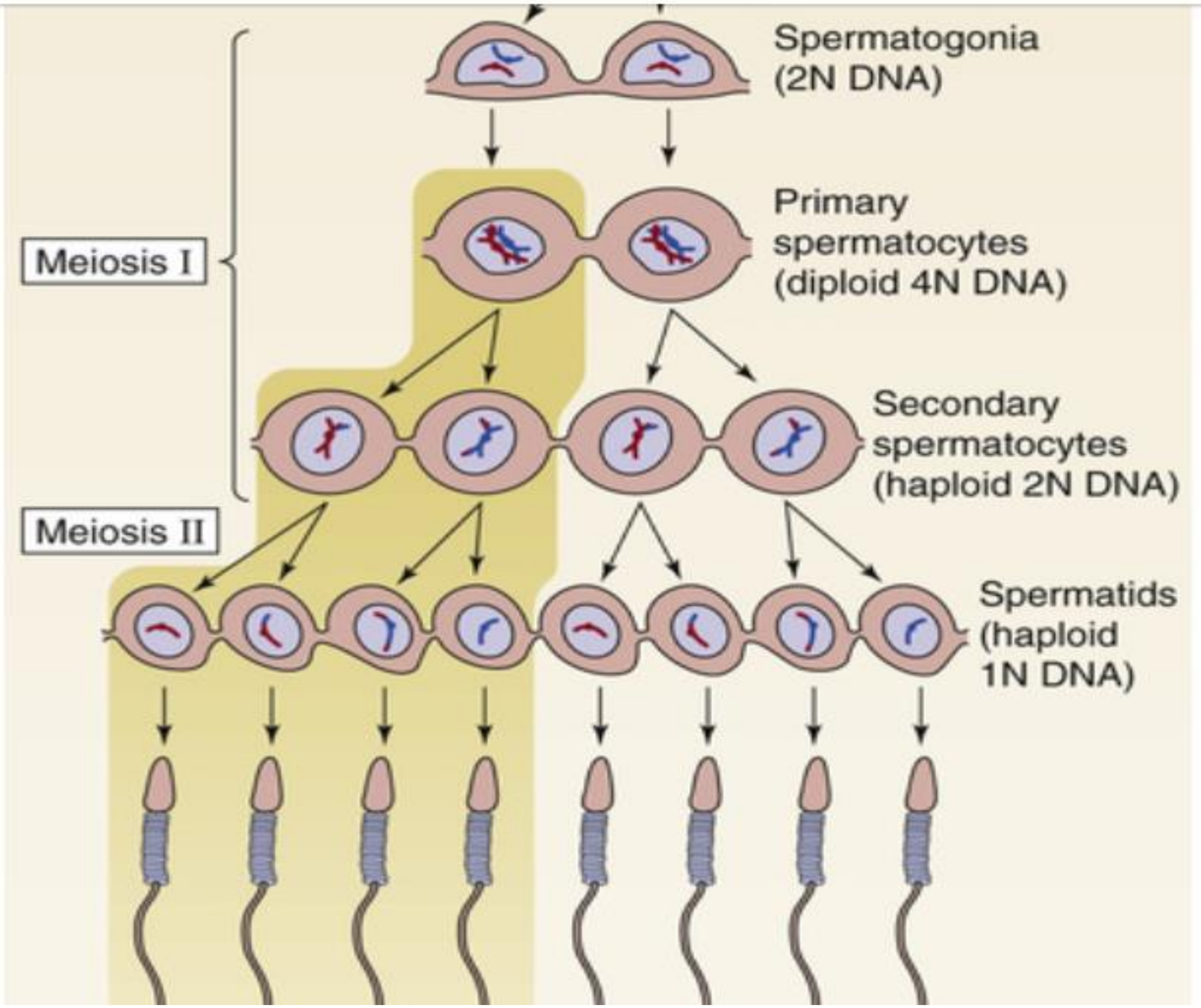
**During formation of the embryo, the primordial germ cells migrate into the testes and become immature germ cells called spermatogonia, which lie in two or three layers of the inner surfaces of the seminiferous tubules.

At puberty the spermatogonia begin to undergo **mitotic division and **continually proliferate** and **differentiate** through definite stages of development to form sperm.

** one daughter cell renewing the type A stem-cell population and the other generating type B spermatogonia.

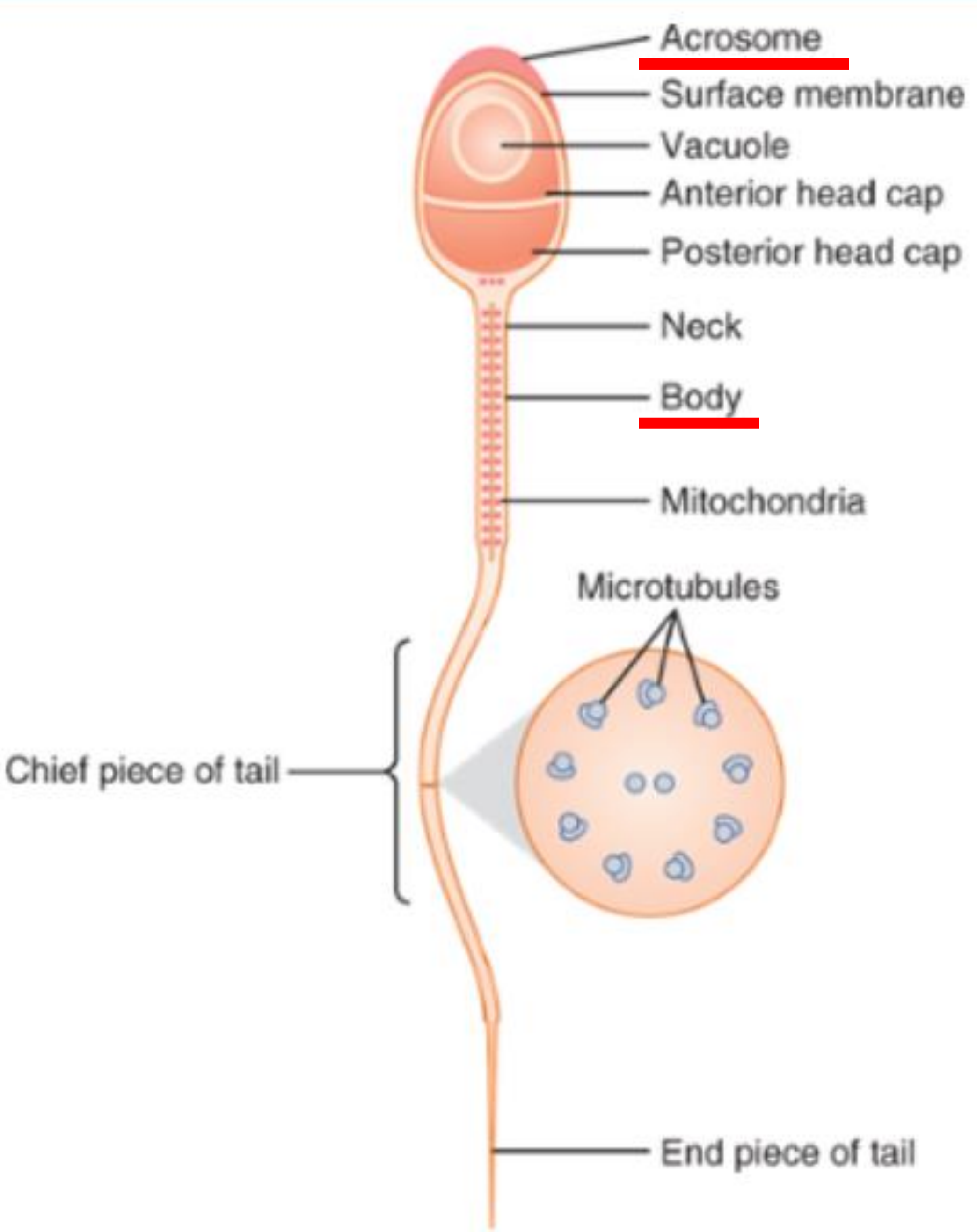
**After many mitotic divisions, type B spermatogonia (2N DNA) enter the first meiotic division, at which time they are referred to as primary spermatocytes.

** Each primary spermatocyte producing four spermatozoa, two with an X chromosome and two with a Y chromosome.



Formation of Sperm (Spermiogenesis)

- **Spermatids -- have the usual characteristics of epithelioid cells.**
- **Head -- Acrosome**
- **Tail – microtubules, cell membrane, mitochondria (body).**



- **This term refers to the maturation of spermatids (haploid 1N DNA) to mature spermatozoa. Spermiogenesis involves no cell division.
- ** The head comprises the condensed nucleus of the cell, with only a thin cytoplasmic and cell membrane layer around its surface.
- ** On the outside of the anterior two-thirds of the head is a thick cap called the acrosome that is formed mainly from the Golgi apparatus.
- ** The acrosome contains several enzymes **similar to those found in lysosomes** of the typical cell, including **hyaluronidase** (which can digest proteoglycan filaments of tissues) and powerful **proteolytic** enzymes (which can digest proteins). These enzymes play important roles in allowing the sperm to enter the ovum and fertilize it.

Hormonal Factors That Stimulate Spermatogenesis

- **1. Testosterone → essential for growth and division of the testicular germinal cells, which is the first stage in forming sperm.**

- **2. Luteinizing hormone→ stimulates the Leydig cells to secrete testosterone.**

- **3. Follicle-stimulating hormone → without this stimulation, conversion of the spermatids to sperm (the process of spermiogenesis) will not occur.**

Hormonal Factors That Stimulate Spermatogenesis

- **4. Estrogens, formed from testosterone by the Sertoli cells.**

- **5. Growth hormone (as well as most of the other body hormones) is necessary for controlling background metabolic functions of the testes. Growth hormone specifically promotes early division of the spermatogonia.**

**** In pituitary dwarfs, spermatogenesis is severely deficient or absent, thus causing infertility.**

Effect of Temperature on Spermatogenesis

- **Increasing the temperature of the testes can prevent spermatogenesis by causing degeneration of most cells of the seminiferous tubules besides the spermatogonia.**

- **It has often been stated that the reason the testes are located in the dangling scrotum is to maintain the temperature of these glands below the internal temperature of the body, although usually only about 2°C below the internal temperature.**

Effect of Temperature on Spermatogenesis

- **On cold days, scrotal reflexes cause the musculature of the scrotum to contract, pulling the testes close to the body to maintain this 2° differential.**

- **Thus, the scrotum acts as a cooling mechanism for the testes (but a controlled cooling), without which spermatogenesis might be deficient during hot weather.**

- **Although sperm can live for many weeks in the male genital ducts, once they are ejaculated in the semen, their maximal life span is only 24 to 48 hours at body temperature.**

- **** At lowered temperatures, however, semen can be stored for several weeks, and when frozen at temperatures below –100°C, sperm have been preserved for years.**

Maturation of sperm in the epididymis

- After their formation in the seminiferous tubules, sperms require several days to pass through the epididymis (non-motile).
- After 18 to 24 hrs → they develop the **capability of motility** in epididymis.
- some inhibitory proteins in the epididymal fluid prevent final motility until ejaculation.

Semen

Ejaculated semen during sexual act and is composed of :

- Fluid & sperm from the vas deferens (~10%)
- Fluid from the seminal vesicles (~60%)

✓ a mucoid material containing an abundance of fructose, citric acid, and other nutrient substances, as well as large quantities of prostaglandins and fibrinogen

- Fluid from the prostate gland (~30%)

✓ thin, milky fluid that contains calcium, citrate ion, phosphate ion, a clotting enzyme, and a profibrinolysin.

✓ slightly alkaline.

- Small amounts of mucous from the bulbourethral glands

- **Prostaglandins are believed to aid fertilization in two ways: (1) by reacting with the female cervical mucus to make it more receptive to sperm movement and (2) by possibly causing backward, reverse peristaltic contractions in the uterus and fallopian tubes to move the ejaculated sperm toward the ovaries (a few sperm reach the upper ends of the fallopian tubes within 5 minutes).
- **A slightly alkaline characteristic of the prostatic fluid may be quite important for successful fertilization of the ovum because the fluid of the vas deferens is relatively acidic owing to the presence of citric acid and metabolic end products of the sperm and, consequently, helps to inhibit sperm fertility. Also, the vaginal secretions of the female are acidic (pH of 3.5 to 4.0). Sperm do not become optimally motile until the pH of the surrounding fluids rises to about 6.0 to 6.5. Consequently, it is probable that the slightly alkaline prostatic fluid helps to neutralize the acidity of the other seminal fluids during ejaculation and thus enhances the motility and fertility of the sperm.
- **The average pH of the combined semen is about 7.5, the alkaline prostatic fluid having more than neutralized the mild acidity of the other portions of the semen.

Differences between oogenesis and spermatogenesis

- (1) In the **female**, the **mitotic** proliferation of germ cells takes place **entirely before birth**. In the male, spermatogonia proliferate **only after puberty and then throughout life**.
- (2) The meiotic divisions of a primary oocyte in the female produce only **one mature ovum** with a **large amount of cytoplasm** and two to three polar bodies. In the male, the meiotic divisions of a primary spermatocyte produce **four mature spermatozo**a with a **minimal amount of cytoplasm**.

Differences between oogenesis and spermatogenesis

- (3) In the female, the second meiotic division is completed only on fertilization, and **thus no further development of the cell takes place after the completion of meiosis**.
- In the male, the products of meiosis (the spermatids) **undergo substantial further differentiatio**n to produce mature spermatozoa.

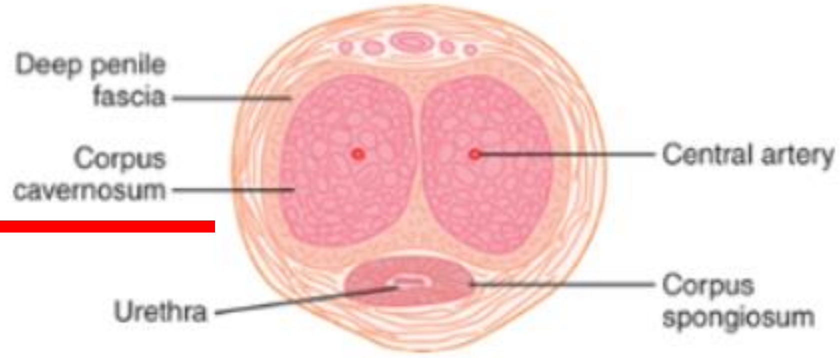
Male sexual act

Chapter 81

Male Sexual Act

The male sexual act results from inherent reflex mechanisms integrated in the sacral and lumbar spinal cord, and these mechanisms can be initiated by either psychic stimulation from the brain or actual sexual stimulation from the sex organs, but usually it is a combination of both.

Penile Erection—Role of the Parasympathetic Nerves

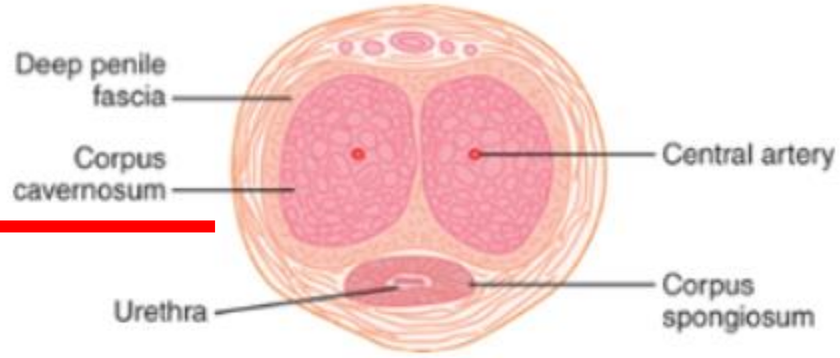


- **Parasympathetic** impulses that pass from the **sacral portion**, through the pelvic nerves to the penis.
- These parasympathetic nerve fibers release acetylcholine and nitric oxide and/or *vasoactive intestinal peptide*. (endothelium)
- Nitric oxide activates the enzyme guanylyl cyclase, causing increased formation of cyclic guanosine monophosphate (cGMP). (smooth muscle) (Sildenafil)

** The cyclic GMP especially relaxes the arteries of the penis and the trabecular meshwork of smooth muscle fibers in the *erectile tissue* of the *corpora cavernosa* and *corpus spongiosum* in the shaft of the penis

As the vascular smooth muscles relax, blood flow into the penis increases, causing release of nitric oxide from the vascular endothelial cells and further vasodilation.

Penile Erection—Role of the Parasympathetic Nerves



- The cyclic GMP especially relaxes the arteries of the penis.
- Increase blood flow into the penis.
- The erectile tissue of the penis consists of large cavernous sinusoids, which are normally relatively empty of blood but become dilated tremendously when arterial blood flows rapidly into them under pressure while the venous outflow is partially occluded.
- High pressure within the sinusoids causes ballooning of the erectile tissue to such an extent that the penis becomes hard and elongated.
- This is the phenomenon of *erection.*

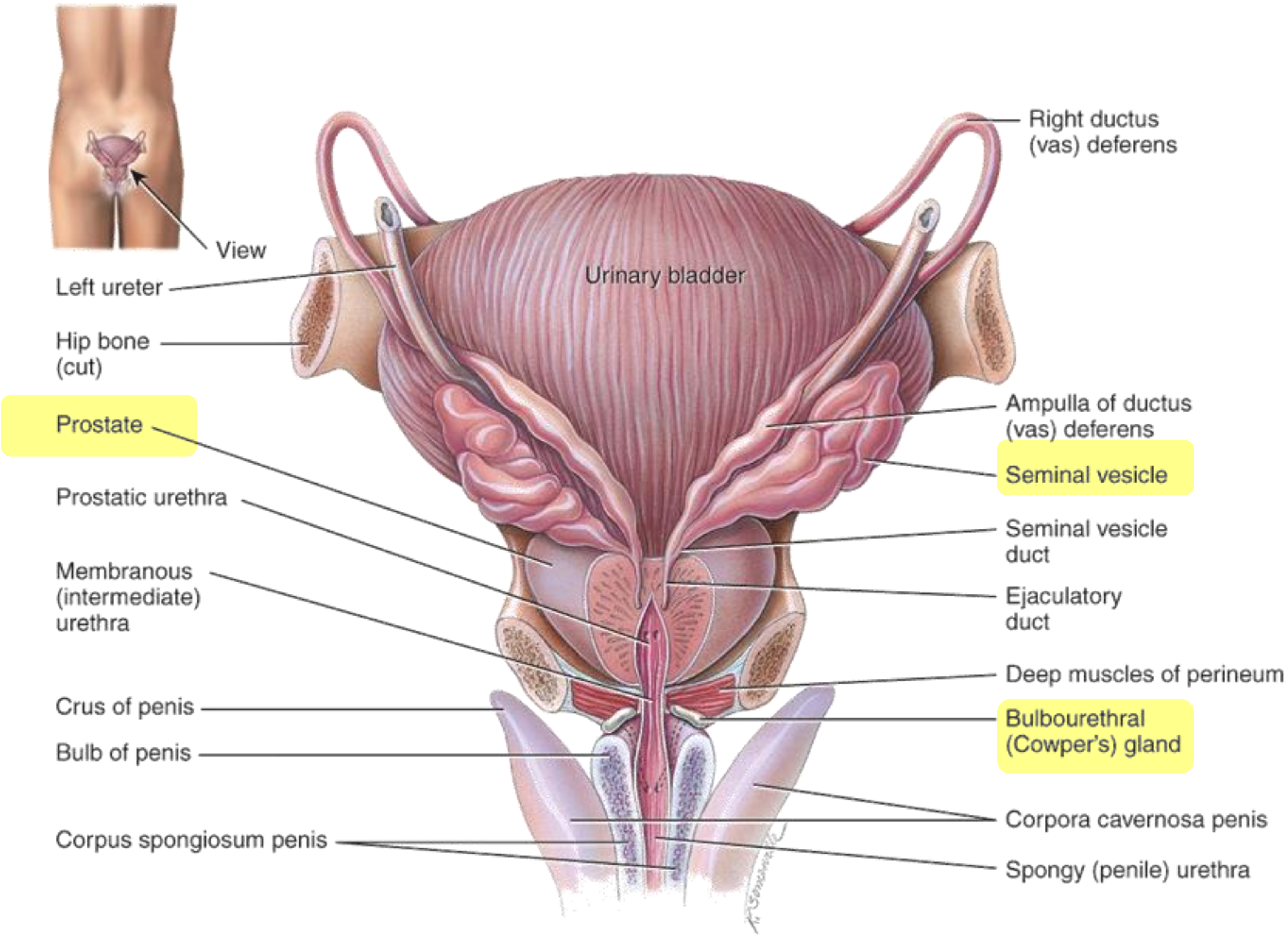
Emission and Ejaculation Are Functions of the Sympathetic Nerves.

- When the sexual stimulus becomes extremely intense, the reflex centers of the spinal cord begin to emit **sympathetic** impulses that leave the cord at **T-12 to L-2.**

- Emission begins with **contraction** of the vas deferens and the ampulla to cause expulsion of sperm into the internal urethra.

→ contractions of the muscular coat of the prostate gland → contraction of the seminal vesicles → expel prostatic and seminal fluid also into the urethra, forcing the sperm forward.

- All these fluids mix in the **internal urethra** with mucus already secreted by the bulbourethral glands to form the semen. The process to this point is emission.



(a) Posterior view of male accessory organs of reproduction

Emission and Ejaculation Are Functions of the Sympathetic Nerves.

- The filling of the internal urethra with semen elicits sensory signals.
- These sensory signals further excite rhythmical contraction of the internal genital organs muscles that compress the bases of the penile erectile tissue.
- These effects together cause **rhythmical, wavelike increases in pressure** in both the erectile tissue of the penis and the genital ducts and urethra, which "ejaculate" **the semen from the urethra to the exterior**. This final process is called ejaculation.

- This entire period of emission and ejaculation is called the male orgasm. At its termination, the male sexual excitement disappears almost entirely within 1 to 2 minutes and erection ceases, **a process called resolution**.