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Male Reproductive System

Introduction

Reproductive system ensures the continuation of species. **Gonads** are the primary reproductive organs which produce the gametes (egg or ovum); a pair of testes (singular = testis) produces sperms in males and a pair of ovaries produces ovum in females.
In humans and most of the higher animals, reproduction occurs sexually, i.e. by mating. However, there are some species like insects which can produce offsprings without mating.

Reproductive organs include:
1. Primary sex organs
2. Accessory sex organs.

Primary Sex Organs

Testes are the primary sex organs or gonads in males.

Accessory sex organs in males are:

1. Seminal vesicles
2. Prostate gland 3. Urethra 4. Penis.

External and Internal Genitalia

Reproductive organs are generally classified into two groups, namely external genitalia (genital organs) and internal genitalia. External genital organs in males are scrotum, penis and urethra. Remaining sex organs constitute the internal genitalia.

Functional Anatomy Of Tests

Testes are the primary sex organs or gonads in males. There are two testes in almost all the species. In human beings, both the testes are ovoid or walnut-shaped bodies that are located and suspended in a sac-like structure called scrotum.

Each testis weighs about 15 to 19 g and measures about 5 × 3 cm. Testis is made up of about 900 coiled tubules known as seminiferous tubules, which produce sperms. Seminiferous tubules continue as the vas efferens, which form the epididymis. It is continued as vas deferens.

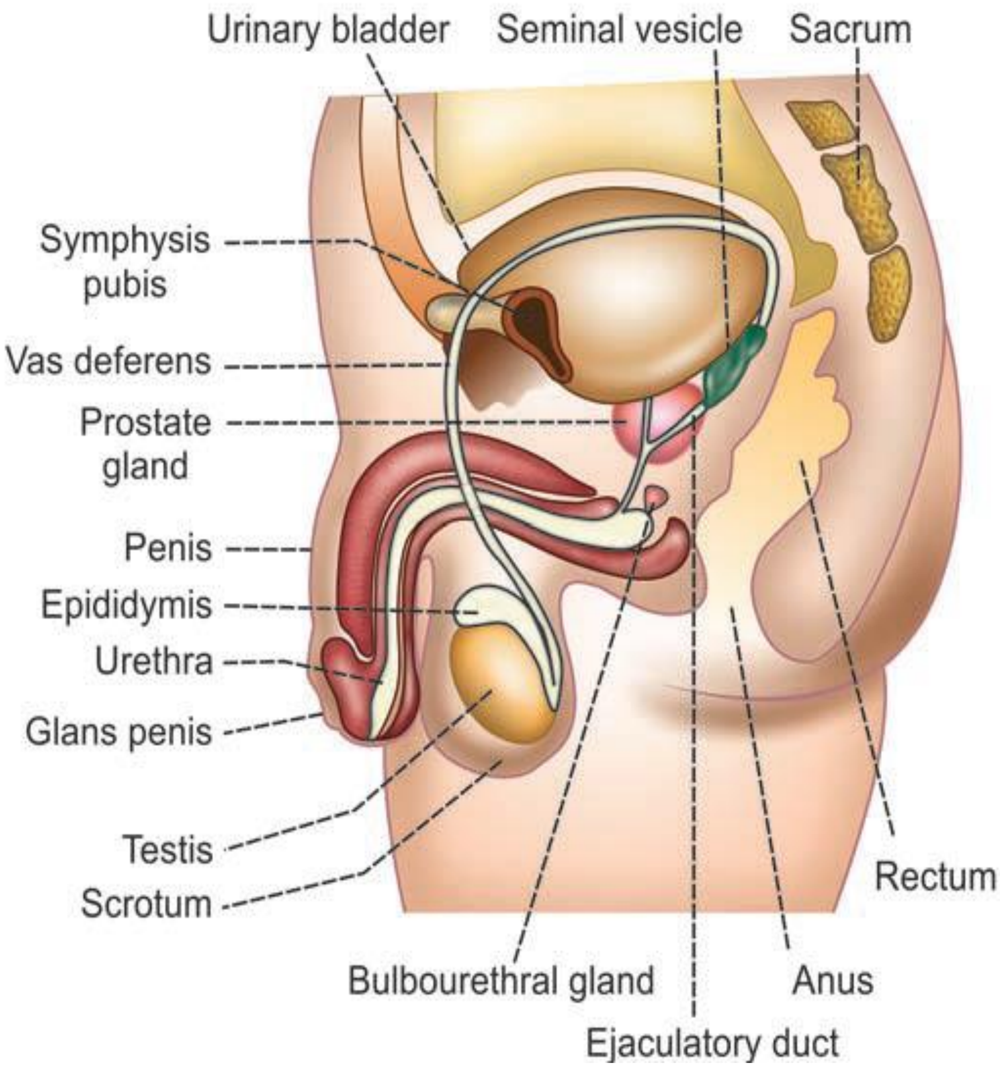

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FIGURE 74.1: Male reproductive system and other organs of pelvis

Vas deferens is also called ducts deferens, spermatic deferens or sperm duct. From epididymis in scrotum, the vas deferens extends on its one side upwards into abdominal cavity via inguinal canal. Terminal portion of vas deferens is called ampulla (Fig.

74.1). Ampulla of vas deferens joins ducts of seminal vesicle of same side, to form ejaculatory duct.

Thus, there are two ejaculatory ducts each of which receives sperm from vas deferens and secretions of seminal vesicle on its own side. Both the ejaculatory ducts empty into a single urethra. Actually, ejaculatory ducts open into prostatic part of urethra.

Coverings Of Testis

Each testis is enclosed by three coverings.

1. Tunica Vasculosa

2. Tunica Albuginea

3. Tunica Vaginalis

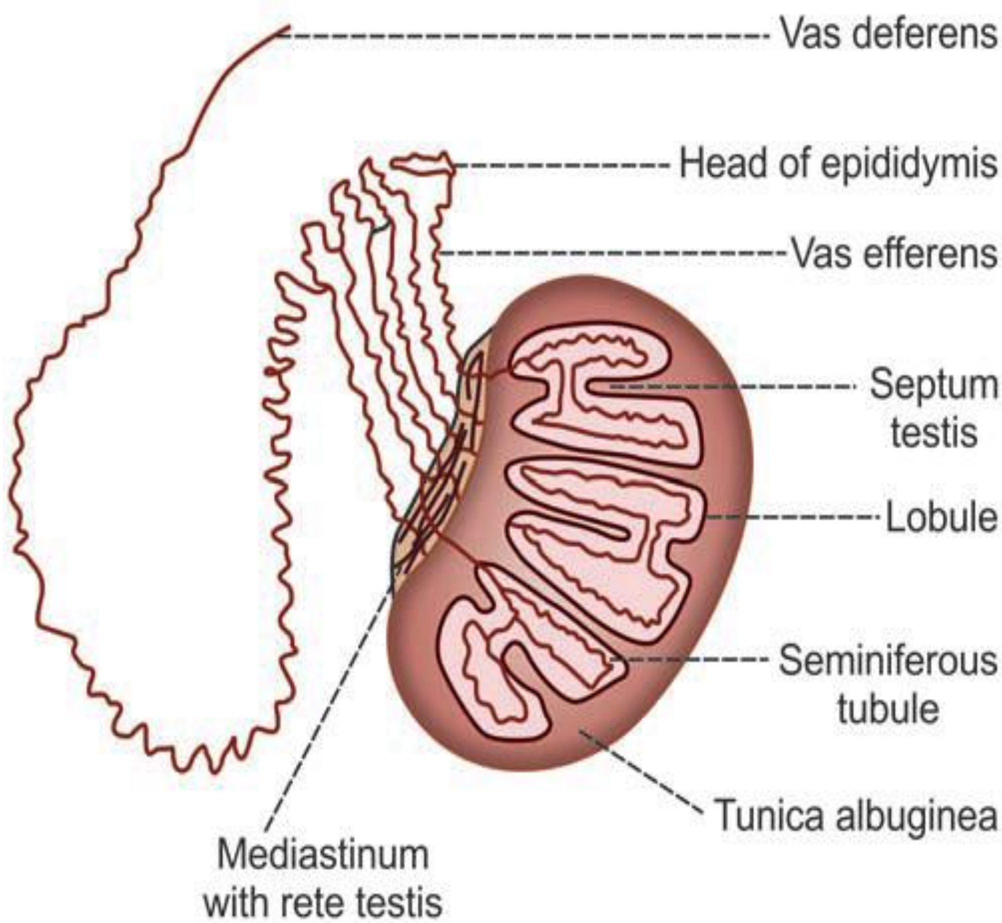

FIGURE 74.2: Structure of testis

Seminiferous Tubules

Seminiferous tubules are thread-like convoluted tubular structures which produce the spermatozoa or sperms. There are about 400 to 600 seminiferous tubules in each testis. Each tubule is 30 to 70 cm long with a diameter of 150 to 300 µ. Wall of the seminiferous tubule is formed by three layers:

1. Outer capsule or tunica propria, formed by fibroelastic connective tissue
2. Thin homogeneous basement membrane
3. Complex stratified epithelium, which consists of two types of cells:
i. Spermatogenic cells or germ cells
ii. Sertoli cells or supporting cells.

Spermatogenic Cells

Spermatogenic cells or germ cells present in seminiferous tubules are precursor cells of spermatozoa. These cells lie in between Sertoli cells and are arranged in an orderly manner in 4 to 8 layers. In children, the testis is not fully developed. Therefore, the spermatogenic cells are in primitive stage called spermatogonia. With the onset of puberty, spermatogonia develop into sperms through different stages.

Stages of spermatogenic cells

Different stages of spermatogenic cells seen from periphery to the lumen of seminiferous tubules are:

1. Spermatogonium
2. Primary spermatocyte
3. Secondary spermatocyte
4. Spermatid.

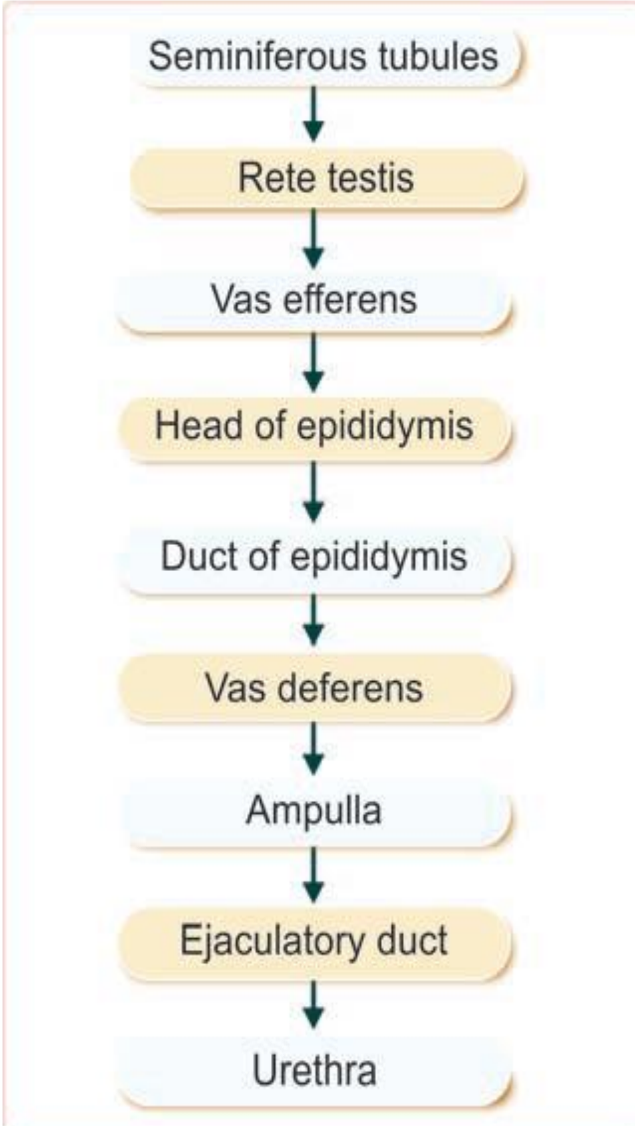

FIGURE 74.3: Pathway for the passage of sperms

Sertoli Cells

Sertoli cells are the supporting cells for spermatogenic cells in seminiferous tubules. These cells are also called sustentacular cells or nurse cells. Sertoli cells are the large and tall irregular columnar cells, extending from basement membrane to lumen of the seminiferous tubule. Germ cells present in seminiferous tubule are attached to Sertoli cells by means of cytoplasmic connection. This attachment between germ cells and Sertoli cells exists till the matured spermatozoa are released into the lumen of seminiferous tubules.

Functions of Sertoli cells

Sertoli cells provide support, protection and nourishment for the spermatogenic cells present in seminiferous tubules.
Sertoli cells:

1. Support and nourish the spermatogenic cells till the spermatozoa are released from them
2. Secrete the enzyme aromatase, which converts androgens into estrogen
3. Secrete androgen-binding protein (ABP), which is essential for testosterone activity, especially during spermatogenesis
4. Secrete estrogen-binding protein (EBP)
5. Secrete inhibin, which inhibits FSH release from anterior pituitary
6. Secrete activin, which has opposite action of inhibin (increases FSH release)
7. Secrete müllerian regression factor (MRF) in fetal testes. MRF is also called müllerian inhibiting substance (MIS). MRF is responsible for the regression of müllerian duct during sex differentiation in fetus.

Blood-testes Barrier

Blood-testes barrier is a mechanical barrier that separates blood from seminiferous tubules of the testes. It is formed by tight junctions between the adjacent Sertoli cells, near the basal membrane of seminiferous tubule.

Functions of blood-testes barrier

1. Protection of seminiferous tubules Blood-testes barrier protects the seminiferous tubules and spermatogenic cells by preventing the entry of toxic substances from blood and fluid of the surrounding tissues into the lumen of seminiferous tubules. However, blood-testes barrier permits substances essential for spermatogenic cells.

Substances prevented by blood-testes barrier:

i. Large molecules including proteins, polysaccharides

and cytotoxic substances
ii. Medium-sized molecules like galactose.
Substances permitted by blood-testes barrier:
i. Nutritive substances essential for spermatogenic cells
ii. Hormones necessary for spermatogenesis
iii. Water.
2. Prevention of autoimmune disorders Blood-testes barrier also prevents the development of autoimmune disorders by inhibiting the movement of antigenic products of spermatogenesis, from testis into blood.

Damage of blood-testes barrier
Blood-testes barrier is commonly damaged by trauma or viral infection like mumps. Whenever, the blood testes barrier is damaged the sperms enter the blood. The immune system of the body is activated, resulting in the production of autoantibodies against sperms. The antibodies destroy the germ cells, leading to consequent sterility.

„ *Functions Of Tests*

Testes performs two functions:
1. Gametogenic function: Spermatogenesis
2. Endocrine function: Secretion of hormones.

„ *Gametogenic Functions Of Tests – Spermatogenesis*

Spermatogenesis is the process by which the male gametes called spermatozoa (sperms) are formed from the primitive spermatogenic cells (spermatogonia) in the testis (Fig. 74.4). It takes 74 days for the formation of sperm from a primitive germ cell.

Throughout the process of spermatogenesis, the spermatogenic cells have cytoplasmic attachment with Sertoli cells.Sertoli cells supply all the necessary materials for spermatogenesis through the cytoplasmic attachment.

„ Stages Of Spermatogenesis

Spermatogenesis occurs in four stages:
1. Stage of proliferation
2. Stage of growth

3. Stage of maturation
4. Stage of transformation.

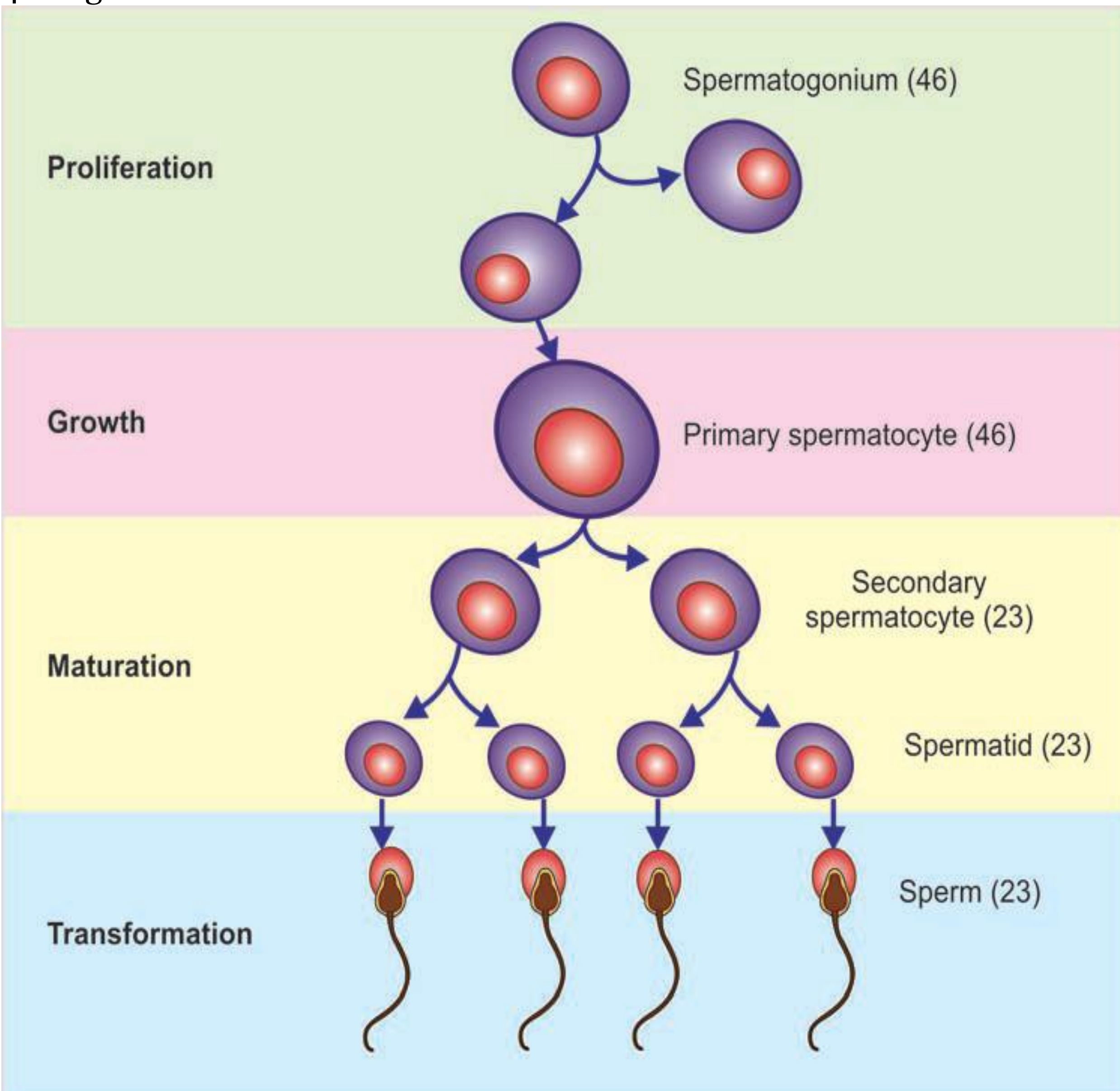

FIGURE 74.4: Spermatogenesis. Number in parenthesis indicate chromosomal number

Factors Affecting Spermatogenesis

Spermatogenesis is influenced by:
1. Sertoli cells
2. Hormones
3. Other factors.

1. *Role of Sertoli Cell in Spermatogenesis*

Sertoli cells influence spermatogenesis by:

i. Supporting and nourishing the germ cells
ii. Providing hormonal substances necessary for spermatogenesis
iii. Secreting androgen-binding protein (ABP),which is essential for testosterone activity, particularly on spermatogenesis
iv. Releasing sperms into the lumen of seminiferous tubules (spermination).

2. Role of Hormones in Spermatogenesis

Spermatogenesis is influenced by many hormones, which act either directly or indirectly: Table 74.1 gives the hormones essential for each stage of spermatogenesis.

Hormones necessary for spermatogenesis are:
i. Follicle-stimulating hormone (FSH)
ii. Testosterone
iii. Estrogen
iv. Luteinizing hormone (LH)
v. Growth hormone (GH)
vi. Inhibin
vii. Activin.

i. Follicule-stimulating hormone

Follicule-stimulating hormone is responsible for the **initiation of spermatogenesis**. It binds with Sertolicells and spermatogonia and induces the proliferation of spermatogonia. It also stimulates the formation of estrogen and androgen-binding protein from Sertoli cells (Fig. 74.5).

ii. Testosterone

Testosterone is responsible for the sequence of remaining stages in spermatogenesis. It is also responsible for the maintenance of spermatogenesis. Testosterone activity is largely influenced by androgen-binding protein.

iii. Estrogen

Estrogen is formed from testosterone in Sertoli cells. It is necessary for spermeogenesis.

iv. Luteinizing Hormone

In males, this hormone is called interstitial cellstimulating hormone. It is essential for the secretion of testosterone from Leydig cells.

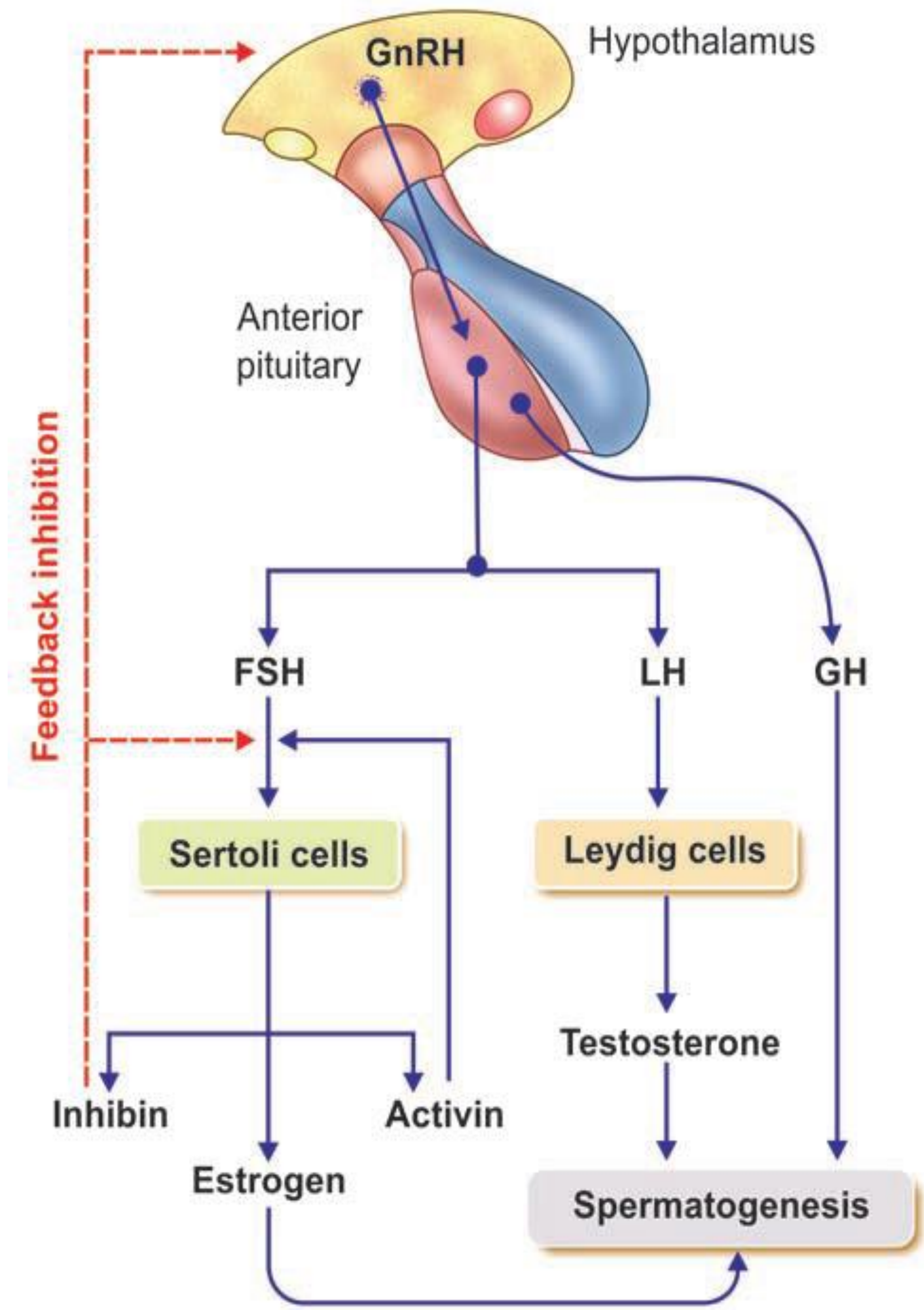

FIGURE 74.5: Role of hormones in spermatogenesis. Blue arrow = Stimulation, Red dotted arrow = inhibition, GnRH = Gonadotropin-releasing hormone, FSH = Follicle-stimulating hormone, LH = Lutinizing hormone, GH = Growth hormone.

v. Growth Hormone

Growth hormone is essential for the general metabolic processes in testis. It is also necessary for the proliferation of spermatogonia. In pituitary dwarfs, the spermatogenesis is severely affected.

vi. Inhibin

Inhibin is a peptide hormone and serves as a transforming growth factor. It is secreted by Sertoli cells. In females, it is secreted by granulosa cells of ovarian follicles. Its secretion is stimulated by FSH.

Inhibin plays an important role in the regulation of spermatogenesis by inhibiting FSH secretion through feedback mechanism. FSH secreted from anterior pituitary induces spermatogenesis by stimulating Sertoli cells.

It also stimulates the secretion of inhibin from Sertoli cells. So, when the rate of spermatogenesis increases, there is a simultaneous increase in inhibin secretion also. Inhibin in turn, acts on anterior pituitary and inhibits the secretion of FSH, leading to decrease in the pace of spermatogenesis.

TABLE 74.1: Hormones necessary for spermatogenesis

Stage of m spermatogenesis	Hormone necessary
Stage of proliferation	Follicle-stimulating hormone Growth hormone
Stage of growth	Testosterone Growth hormone
Stage of maturation	Testosterone Growth hormone
Stage of transformation	Testosterone Estrogen

It is believed that inhibin also inhibits FSH secretion indirectly by inhibiting GnRH secretion from hypothalamus.

vii. Activin

Activin is also a peptide hormone secreted in gonads along with inhibin. The exact location of its secretion in testis is not known. It is suggested that activin is secreted by Sertoli cells and Leydig cells.

Activin has opposite actions of inhibin. It increases the secretion of FSH and accelerates spermatogenesis.

3. Role of Other Factors in Spermatogenesis

i. Increase in body temperature

Increase in body temperature prevents sperma togenesis. Normally, the temperature in scrotum is about 2°C less than the body temperature. This low temperature is essential for spermatogenesis. When the temperature increases, the spermatogenesis stops. It is very common in cryptorchidism (undescended testes).

In cryptorchidism, the testes are in the abdomen, where the temperature is always higher than that of scrotum. High temperature in the abdomen causes degeneration of seminiferous tubules and stoppage of spermatogenesis.

ii. Diseases

Infectious diseases such as mumps cause degeneration of seminiferous tubules and stoppage of spermatogenesis.

„ Endocrine Functions Of Tests

„ Hormones Secreted By Tests

Testes secrete male sex hormones, which are collectively called the androgens.

Androgens secreted by testes are:

1. Testosterone
2. Dihydrotestosterone
3. Androstenedione.

Among these three androgens, testosterone is secreted in large quantities. However, dihydrotestosterone is more active.

Female sex hormones, namely estrogen and progesterone are also found in testes.

Two more hormones activin and inhibin are also secreted in testes. However, these two hormones do not have androgenic actions.

Source of Secretion of Androgens

Androgens are secreted in large quantities by testes and in small quantity by adrenal cortex.

Testes

In testes, androgens are secreted by the interstitial cells of Leydig, which form 20% of mass of adult testis. Leydig cells are numerous in newborn male baby and in adult male. But in childhood, these cells are scanty or nonexisting. So, the secretion of androgens occurs in newborn babies and after puberty.

Adrenal cortex

Androgens secreted by zona reticularis of adrenal cortex are testosterone, androstenedione and dehydroepiandrosterone. Adrenal androgens do not have any significant physiological actions because of their small quantity. In abnormal conditions, the hypersecretion of adrenal androgens results in sexual disorders .

Chemistry

Testosterone is a C19 steroid.

Synthesis

Androgens are steroid hormones synthesized from cholesterol. Androgens are also synthesized directly from acetate. Synthesis of male sex hormones is given in Fig. 70.2, Chapter 70.

Plasma Level and Transport

Plasma level of testosterone in an adult male varies between 300 and 700 ng/dL. In adult female, the testosterone level is 30 to 60 mg/dL.

Two thirds of testosterone is transported in plasma by gonadal steroid-binding globulin. It is β-globulin in nature and it is also called sex steroid-binding globulin. The remaining one third of testosterone is transported by albumin.

Metabolism

In many target tissues, testosterone is converted into dehydrotestosterone, which is the most active androgen. In some of the tissues such as adipose tissue, hypothalamus and liver, testosterone is converted into estradiol. Major portion of testosterone is degraded in liver. It is converted into inactive forms of androsterone and dehydroepiandrosterone. These two substances are later conjugated and excreted through urine.

Functions Of Testosterone

In general, testosterone is responsible for the distinguishing characters of masculine body. It also plays an important role in fetal life.

Functions of Testosterone in Fetal Life

Testosterone performs three functions in fetus:

1. Sex differentiation in fetus
2. Development of accessory sex organs
3. Descent of the testes.

1. Sex differentiation in fetus

Sex chromosomes are responsible for the determination of sex of the fetus (Chapter 84), whereas testosterone is responsible for the sex differentiation of fetus. Fetus has two genital ducts:

i. **Müllerian duct**, which gives rise to female accessory sex organs such as vagina, uterus and fallopian tube

ii. **Wolffian duct**, which gives rise to male accessory sex organs such as epididymis, vas deferens and seminal vesicles. If testosterone is secreted from the genital ridge of the fetus at about 7th week of intrauterine life, the müllerian duct system disappears and male sex organs develop from Wolffian duct.

In addition to testosterone, **müllerian regression factor** (MRF) secreted by Sertoli cells is also responsible for regression of müllerian duct.

In the absence of testosterone, Wolffian duct regresses and female sex organs develop from müllerian duct.

2. Development of accessory sex organs and external genitalia

Testosterone is also essential for the growth of the external genitalia, viz. penis and scrotum and other accessory sex organs, namely genital ducts, seminal vesicles and prostate.

3. Descent of testes

Descent of testes is the process by which testes enter scrotum from abdominal cavity. Initially, testes are developed in the abdominal cavity and are later pushed down into the scrotum through inguinal canal, just before birth. The process by which testes enter the scrotum is called the descent of testes. Testosterone is necessary for descent of testes.

Functions of Testosterone in Adult Life

Testosterone has two important functions in adult:

1. Effect on sex organs
2. Effect on secondary sexual characters.

1. Effect on sex organs

Testosterone increases the size of penis, scrotum and the testes after puberty. All these organs are enlarged at least 8 folds between the onset of puberty and the age of 20 years, under the influence of testosterone.

Testosterone is also necessary for spermatogenesis.

2. Effect on secondary sexual characters

Secondary sexual characters are the physical and behavioral characteristics that distinguish the male from female. These characters appear at the time of puberty in humans. Testosterone is responsible for the development of secondary sexual characters in males.

Secondary sexual characters in males:

i. Effect on muscular growth One of the most important male sexual characters is the development of musculature after puberty. Muscle mass increases by about 50%, due to the anabolic effect of testosterone on proteins. Testosterone accelerates the transport of amino acids into the muscle cells, synthesis of proteins and storage of proteins. Testosterone also decreases the breakdown of proteins.

ii. Effect on bone growth

After puberty, testosterone increases the thickness of bones by increasing the bone matrix and deposition of calcium. It is because of the protein anabolic activity of testosterone. Deposition of calcium is secondary to the increase in bone matrix. In addition to increase in the size and strength of bones, testosterone also causes early fusion of epiphyses of long bones with shaft. So, if testes are removed before puberty, the fusion of epiphyses is delayed and the height of the person increases.

iii. Effect on shoulder and pelvic bones

Testosterone causes broadening of shoulders and it has a specific effect on pelvis, which results in:

a. Lengthening of pelvis
b. Funnel-like shape of pelvis.
c. Narrowing of pelvic outlet.
Thus, pelvis in males is different from that of females, which is broad and round or oval in shape.

iv. Effect on skin

Testosterone increases the thickness of skin and ruggedness of subcutaneous tissue. These changes in skin are due to the deposition of proteins in skin. It also increases the quantity of melanin pigment, which is responsible for the deepening of the skin color. Testosterone enhances the secretory activity of sebaceous glands. So, at the time of puberty, when the body is exposed to sudden increase in testosterone secretion, the excess secretion of sebum leads to development of acne on the face. After few years, the skin gets adapted to testosterone secretion and the acne disappears.

v. Effect on hair distribution

Testosterone causes male type of hair distribution on the body, i.e. hair growth over the pubis, along linea alba up to umbilicus, on face, chest and other parts of the body such as back and limbs. In males, the pubic hair has the base of the triangle downwards where as in females it is upwards.

Testosterone decreases the hair growth on the head and may cause baldness, if there is genetic background.

vi. Effect on voice

At the time of adolescence, the boys have a cracking voice. It is because of the testosterone effect, which causes:

a. Hypertrophy of laryngeal muscles
b. Enlargement of larynx and lengthening
c. Thickening of vocal cords.

Later, the cracking voice changes gradually into a typical adult male voice with a bossing sound.

vii. Effect on basal metabolic rate

At the time of puberty and earlier part of adult life, the testosterone increases the basal metabolic rate to about 5% to 10% by its anabolic effects on protein metabolism.

viii. Effect on electrolyte and water balance

Testosterone increases the sodium reabsorption from renal tubules, along with water reabsorption. It leads to increase in ECF volume.

ix. Effect on blood

Testosterone has got erythropoietic action. So, after puberty, testosterone causes mild increase in RBC count. It also increases the blood volume by increasing the water retention and ECF volume.

Production OF Female

Sex Hormones In Males

In addition to androgens, female sex hormones are also produced in testes.

Estrogen

Small amount of estrogen is produced in males. Estrogen level in plasma of normal adult male is 12 to 34 pg/mL. Estrogens have three sources of production in males.

1. Adrenal Cortex

Adrenal cortex secretes small quantity of estrogen.

2. Testes

Up to 20% of estrogen in males is produced in testes. Estrogen is formed from androgens in Sertoli cells of testes, by the influence of the enzyme aromatase.

3. Other Organs

About 80% of estrogen is formed from androgens in other organs, particularly liver.

Progesterone

Progesterone is also produced from androgens in males though the quantity is very less. Plasma progesterone level in normal adult male is 0.3 ng/mL.

„ Male Andropause Or Climacteric

Male andropause or climacteric is the condition in men, characterized by emotional and physical changes in the body, due to low androgen level with aging. It is also called viropause.

After the age of 50, testosterone secretion starts declining. It is accompanied by decrease in number and secretory activity of Leydig cells. Low level of testosterone increases the secretion of FSH and LH, which leads to some changes in the body. It does not affect most of the men. But some men develop symptoms similar to those of female menopausal syndrome (Chapter 82). Common symptoms are hot flashes, illusions of suffocation and mood changes.