The Anatomy and Physiology of the Male Reproductive System

CHAPTER 1

INTRODUCTION

Understanding the anatomy and physiology of the male reproductive system is key to clinical practice across a range of healthcare disciplines. This knowledge not only supports accurate assessment, diagnosis and treatment of male reproductive health conditions but also underpins respectful and informed communication with patients, particularly in sensitive or intimate care settings. A clear grasp of male reproductive structure and function allows clinicians to promote health, identify pathology and support individuals across the lifespan, from puberty through to older age.

The male reproductive system is a complex network of organs and structures designed primarily for the production, nourishment, transport and delivery of sperm, as well as the synthesis and regulation of male sex hormones, particularly testosterone. It works in close coordination with the urinary system and is heavily influenced by hormonal feedback mechanisms involving the hypothalamus, pituitary gland and gonads, a relationship that is collectively termed the hypothalamic–pituitary–gonadal axis (see Box 1.1).

BOX 1.1 THE HYPOTHALAMIC–PITUITARY–GONADAL AXIS IN MALE REPRODUCTIVE PHYSIOLOGY

The hypothalamic–pituitary–gonadal axis is a critical neuroendocrine system that governs male reproductive function through a tightly regulated cascade of hormonal signals. It plays a central role in the development, maintenance and regulation of spermatogenesis, testosterone production and male secondary sexual characteristics. Understanding this axis is essential for interpreting male reproductive physiology and recognising the pathophysiology of related disorders.

1. Hypothalamic regulation

   The hypothalamus, situated at the base of the brain, initiates the hormonal regulation of the male reproductive system by releasing gonadotropin-releasing hormone (GnRH) in rhythmic pulses. These pulses are delivered into the hypothalamo-hypophyseal portal system, a specialised network of blood vessels that connects the hypothalamus to the anterior pituitary gland. The pattern of GnRH release, specifically its frequency and intensity, is critical, as it determines how the

(*Continued*)

BOX 1.1 ***(CONTINUED)***

pituitary gland responds in terms of luteinising hormone (LH) and follicle-stimulating hormone (FSH) secretion. Disruptions in this pulsatile pattern can impair the normal secretion of LH and FSH, leading to downstream effects on testosterone production and spermatogenesis.

2. Pituitary response

   In response to GnRH, the anterior pituitary gland releases two key gonadotropins:
   - LH
   - FSH

   These hormones are secreted into the systemic circulation and act on the testes to regulate reproductive function.

3. Testicular effects

   Within the testes, LH and FSH act on distinct but interdependent cell types:
   - LH binds to receptors on Leydig cells, stimulating the synthesis and secretion of testosterone, the principal androgen. Testosterone is essential for the initiation and maintenance of spermatogenesis, sexual function, anabolic effects and the development of male secondary sexual characteristics.
   - FSH acts primarily on Sertoli cells within the seminiferous tubules. Sertoli cells provide structural and nutritional support for developing germ cells and are critical for the regulation of spermatogenesis. FSH also stimulates the production of androgen-binding protein, which increases local concentrations of testosterone within the tubules, further supporting sperm production.

4. Feedback regulation

   The hypothalamic–pituitary–gonadal axis is governed by negative feedback mechanisms:
   - Testosterone exerts negative feedback at both the hypothalamic and pituitary levels, reducing the secretion of GnRH, LH and FSH.
   - Additionally, inhibin B, a hormone produced by Sertoli cells in response to FSH, provides specific feedback to suppress FSH secretion.

This feedback loop maintains hormonal balance and ensures the stability of male reproductive function. Disruption at any level of this axis, hypothalamic, pituitary or testicular, can lead to reproductive and endocrine disorders.

Clinical relevance

- Hypogonadotropic hypogonadism (secondary hypogonadism) occurs when there is insufficient GnRH or gonadotropin secretion, as seen in conditions such as Kallmann syndrome or pituitary adenomas.
- Hypergonadotropic hypogonadism (primary hypogonadism) results from testicular failure, where the gonads do not respond adequately to LH and FSH, leading to elevated gonadotropin levels due to lack of negative feedback (e.g. in Klinefelter syndrome).
- Exogenous androgens (e.g. anabolic steroids) can suppress the hypothalamic–pituitary–gonadal axis through feedback inhibition, reducing endogenous testosterone and sperm production, sometimes resulting in infertility and testicular atrophy.
- Assessment of hormone levels, LH, FSH, testosterone and inhibin B, is a key component of the diagnostic evaluation in cases of male infertility, delayed puberty and suspected disorders of the endocrine system.

Key point

The hypothalamic–pituitary–gonadal axis is fundamental to male reproductive health. A sound understanding of its anatomical and physiological basis enables us to assess, diagnose and manage a wide range of male reproductive and endocrine conditions with greater accuracy and confidence.

This chapter provides a detailed overview of the male reproductive system, comprising the gross anatomy of the external and internal structures, including the penis, scrotum, testes, epididymides, vas deferens, seminal vesicles, prostate gland and bulbourethral glands. The chapter also explores the microscopic anatomy and physiology of key tissues and cells involved in spermatogenesis and hormone production, particularly within the seminiferous tubules and interstitial spaces of the testes.

The physiological processes discussed include spermatogenesis, the process by which spermatozoa are produced and matured; ejaculation, the coordinated neural and muscular process that expels semen; and hormonal regulation, which maintains reproductive function and male secondary sexual characteristics. Consideration is also given to developmental and age-related changes, highlighting the impact of puberty, ageing and common conditions such as benign prostatic hyperplasia or hypogonadism.

Importantly, this chapter integrates clinical relevance throughout, including anatomical landmarks for examination, implications for procedures such as testicular self-examination or digital rectal examination and the pathophysiology underlying common reproductive conditions. Emphasis is also placed on the need for sensitive, non-judgemental engagement with male patients when discussing reproductive health concerns, recognising the potential influence of cultural, psychological and social factors.

THE MALE REPRODUCTIVE SYSTEM

The male reproductive system, being partially located outside the body cavity, is generally more visually apparent than the female reproductive system. Externally visible structures such as the penis and scrotum contribute to this visibility; however, the system also comprises several important internal components. These include the testes (housed within the scrotum), epididymides, vas deferens, seminal vesicles and the prostate gland, all of which play essential roles in the production, maturation, storage and transport of sperm, as well as the secretion of seminal fluid.

The testes are the male gonads and are central to reproductive function. Working in concert with the neuroendocrine system, they produce hormones, particularly testosterone, which are vital for the development of the male reproductive tract, sexual behaviour and secondary sexual characteristics. Additionally, the male reproductive system shares certain anatomical structures with the urinary system, most notably the urethra and penis, which serve dual functions in the excretion of urine and the ejaculation of semen. The functions associated with the male reproductive system include:

- The generation, maturation and conveyance of spermatozoa (male reproductive cells)
- The synthesis of seminal fluid, which combines with sperm to form semen
- The expulsion of sperm from the male reproductive tract via the penis during ejaculation
- The production and release of male sex hormones, primarily testosterone, which regulate reproductive and sexual function

The major structures of the male reproductive system include the testes and other external genitalia (penis and scrotum); a number of ducts responsible for the transportation of the sperm

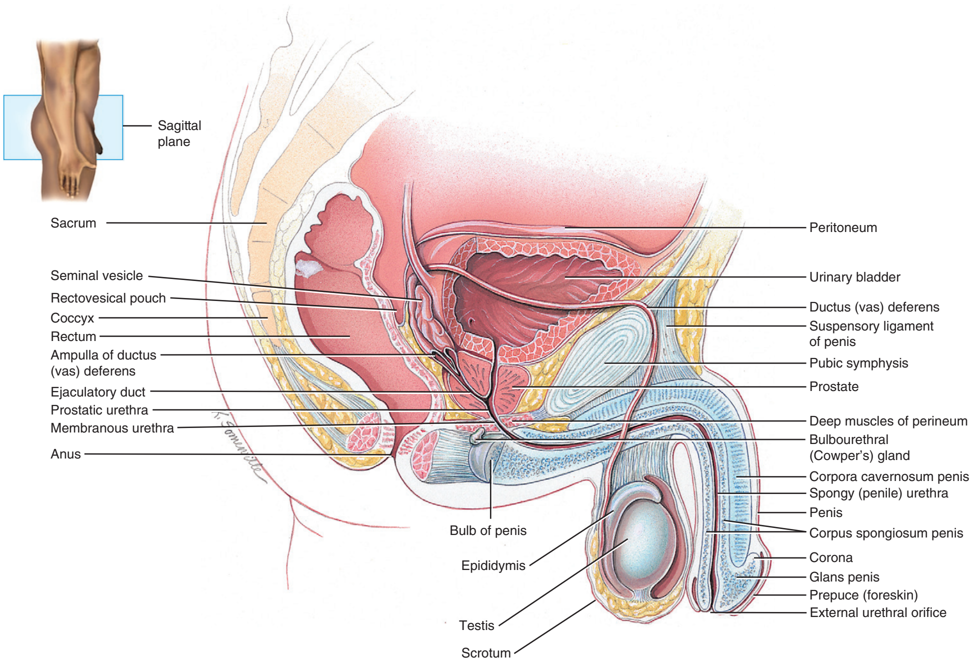


FIGURE 1.1 The male reproductive system. *Source*: Tortora and Derrickson (2009). With permission of John Wiley & Sons.

from the testes to the penis (epididymis and vas deferens) and outside the body (ejaculatory duct and urethra); and two seminal vesicles, bulbourethral glands and the prostate gland. The male reproductive system is shown in Figure 1.1.

THE SCROTUM

The scrotum is a loose, pouch-like structure composed of skin and connective tissue, suspended from the base of the penis. Externally, it typically appears as a single sac, divided into two lateral compartments by a visible midline ridge known as the raphe. Internally, the scrotum is partitioned into two separate chambers by a scrotal septum, with each compartment housing one testis (see Figure 1.2).

The positioning of the scrotum outside the pelvic cavity plays an important role in maintaining the testes at an optimal temperature for spermatogenesis, approximately 2–3 °C below the body's core temperature. This slightly cooler environment is essential because elevated temperatures can impair sperm production and reduce fertility. The scrotum's temperature regulation is facilitated by two specialised layers of muscle fibres: the cremaster muscle and the dartos muscle.

The cremaster muscle, which surrounds the spermatic cord, contracts in response to cold environmental conditions. This contraction elevates the testes closer to the body, allowing them to absorb heat and to maintain a warmer temperature. At the same time, the dartos muscle, a layer of smooth muscle within the scrotal skin, contracts to wrinkle and tighten the scrotal skin around the testes, thereby reducing surface area and minimising heat loss.

In contrast, when the external temperature rises and cooling is necessary, the cremaster muscle relaxes, which allows the testes to descend further from the body's heat source. The dartos muscle also relaxes, causing the scrotal skin to become smoother and more flaccid, increasing the surface area for heat dissipation and promoting effective cooling of the testes.

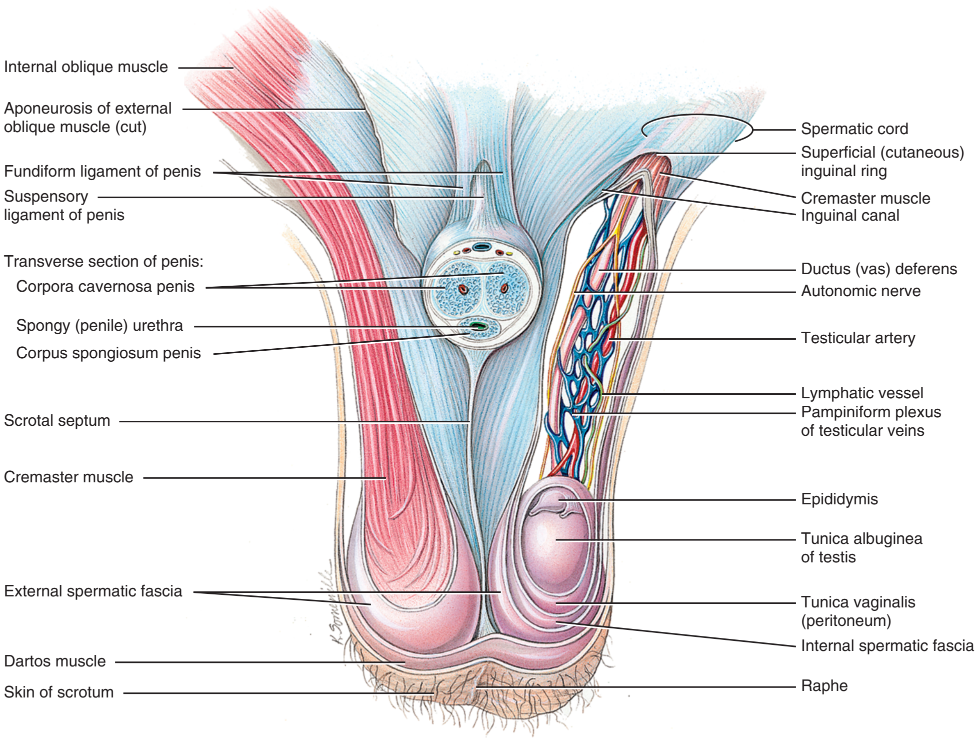


FIGURE 1.2 The scrotum and testes. *Source*: Tortora and Derrickson (2009). With permission of John Wiley & Sons.

Together, these muscular responses enable the scrotum to act as a dynamic thermoregulatory system, ensuring that the testes remain within the ideal temperature range to support optimal sperm development and reproductive function.

THE TESTES

During male fetal development, the testes initially form within the abdominal cavity. Prior to birth, they migrate through the inguinal canal and descend into the scrotal sac (Brewster 2024). Within the scrotum, the testes are suspended on either side of the penis, typically with one testis positioned slightly lower than the other. The primary functions of the testes are to:

- Produce spermatozoa (sperm cells)
- Synthesise and secrete male sex hormones, chiefly testosterone

Anatomically, the testes are small, oval-shaped organs measuring roughly 5 cm in length and 2.5 cm in width. They are enclosed by a protective layer of serous, fibrous connective tissue. This covering consists of three distinct layers:

1. Tunica vaginalis
2. Tunica albuginea
3. Tunica vasculosa

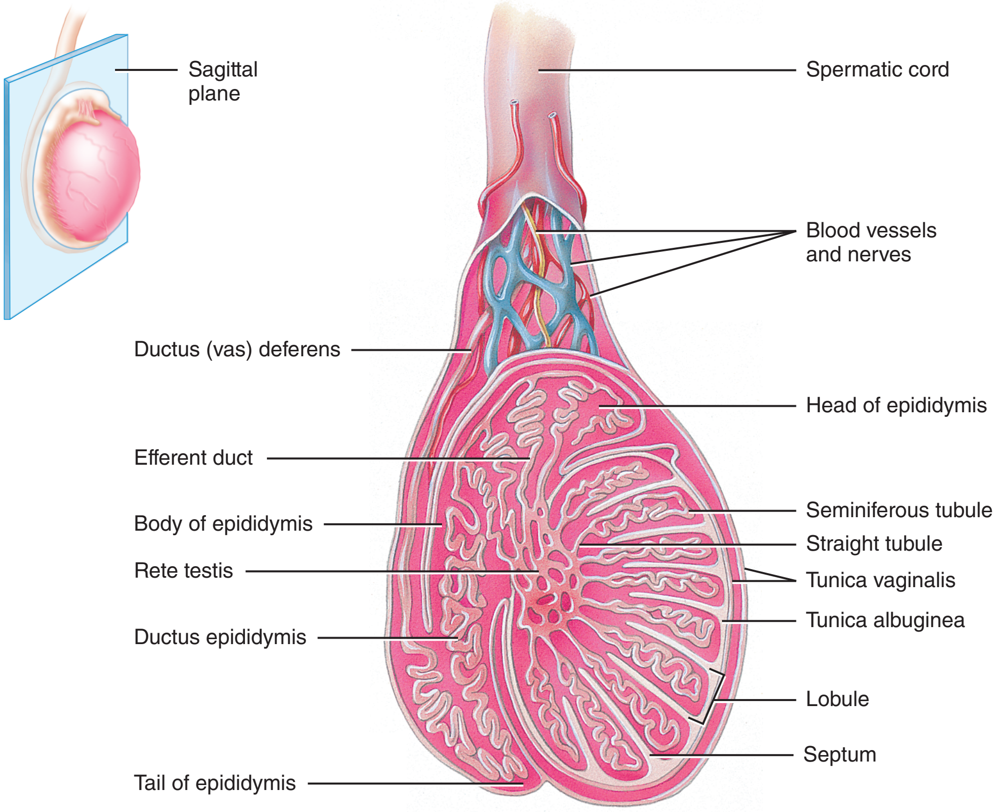


FIGURE 1.3. A testicle demonstrating seminiferous tubules. *Source*: Tortora and Derrickson (2009). With permission of John Wiley & Sons.

Internally, the testes are subdivided into approximately 250–300 lobules or compartments. Each lobule contains numerous tightly coiled hollow tubes called seminiferous tubules, which serve as the site of sperm production (see Figure 1.3). Between these tubules lie interstitial spaces that contain clusters of Leydig cells (also known as interstitial cells). The Leydig cells are responsible for synthesising and secreting testosterone and other androgens.

The seminiferous tubules themselves are composed of an outer layer of smooth muscle cells and an inner lining of Sertoli cells alongside developing sperm cells. As sperm mature, they move through the spaces between adjacent Sertoli cells until they are released into the lumen of the tubule. Sertoli cells play a crucial supportive role in spermatogenesis and are often referred to as ‘nurse cells’ or ‘mother cells’. Their key functions include promoting sperm proliferation and differentiation, providing nutrients to developing sperm, phagocytosing defective sperm and secreting fluid and proteins into the lumen to facilitate sperm transport.

SPERMATOGENESIS

Sperm production, known as spermatogenesis, takes place within the seminiferous tubules of the testes (see Figure 1.4). This process typically begins at puberty and continues throughout a man’s life, with the average daily production ranging between 50 and 200 million sperm.

Spermatogenesis is a highly intricate process that lasts approximately 74 days in humans. It initiates with the mitotic division of spermatogonia, which are undifferentiated stem cells

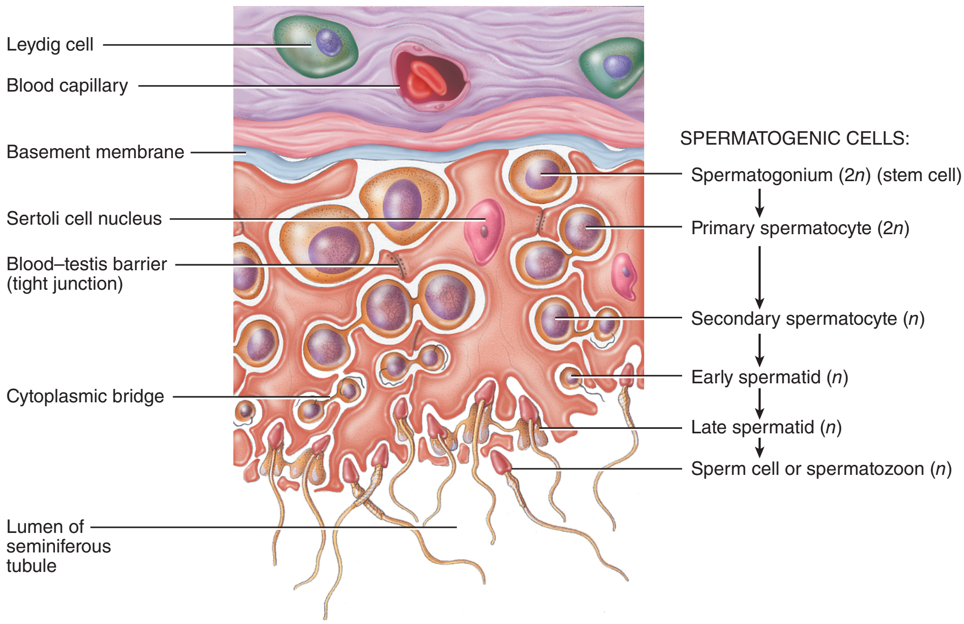


FIGURE 1.4 Stages of spermatogenesis. *Source*: Tortora and Derrickson (2009). With permission of John Wiley & Sons.

located near the basement membrane of the seminiferous tubules. Spermatogonia contain the diploid number of chromosomes ($2n = 46$) and undergo continuous mitotic divisions to produce primary spermatocytes, which also retain the diploid chromosome count. A subset of spermatogonia remains adjacent to the basement membrane, serving as a reservoir of stem cells for ongoing sperm production.

The primary spermatocytes then enter the first meiotic division, reducing their chromosome number by half to form haploid secondary spermatocytes, each with 23 chromosomes. These secondary spermatocytes undergo a second meiotic division to produce spermatids. Consequently, each primary spermatocyte (with 46 chromosomes) yields four spermatids, each containing 23 chromosomes.

The final phase of spermatogenesis involves the transformation of round spermatids into mature, elongated spermatozoa. These fully developed sperm cells are subsequently released into the lumen of the seminiferous tubules.

Each sperm cell carries 23 chromosomes – half the normal number found in human somatic cells. Upon fertilisation, the sperm fuses with an ovum, which also contains 23 chromosomes, restoring the diploid number (46 chromosomes) essential for the development of a new individual.

SPERM

Approximately 200 million sperm are produced daily (Tortora and Derrickson 2023). Each sperm cell is uniquely adapted with specialised structures that enable it to reach and fertilise the ovum. The elongated tail (flagellum) facilitates motility, allowing the sperm to swim through the female reproductive tract. The midpiece is packed with mitochondria, which generate the energy required for movement. The head contains the paternal genetic material and is covered by the acrosomal cap, a specialised structure that houses enzymes essential for penetrating the ovum's protective cellular and non-cellular layers (see Figure 1.5).

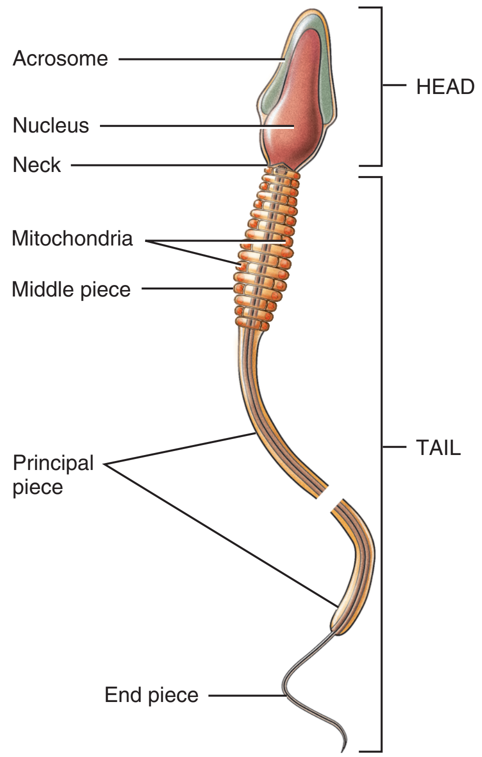


FIGURE 1.5 Sperm. *Source*: Tortora and Derrickson (2009). With permission of John Wiley & Sons.

Following their release into the lumen of the seminiferous tubules, spermatozoa migrate towards the rete testis, a network of interconnected channels that drain into the epididymis, a single, elongated tube where sperm undergo further maturation and storage.

EPIDIDYMIS

The epididymis is a long, tightly coiled duct loosely attached to the testis. Its lining consists of pseudostratified columnar epithelium, surrounded by a layer of smooth muscle. If fully extended, the epididymis would measure approximately 5 m in length. As sperm pass through this highly convoluted duct, they acquire the ability to move independently and actively, which is a process known as motility.

The transit of sperm through the epididymis typically takes between one and two weeks. This period is essential for the sperm to gain motility and the capacity to fertilise an ovum. The epididymis also serves as a storage site for mature sperm. During sexual arousal, rhythmic contractions of the surrounding smooth muscle propel sperm through the epididymis into the vas deferens via peristaltic movement. Sperm can be stored in the epididymis for several weeks; those not ejaculated are eventually broken down and reabsorbed by the body.

The epididymis connects directly to the vas deferens, a larger, more muscular duct that continues the sperm's journey towards ejaculation.

THE VAS DEFERENS, SPERMATIC CORD AND EJACULATORY DUCT

The vas deferens (plural: vasa deferentia), also known as the ductus deferens, is less convoluted than the epididymis and it also has a larger diameter. It measures approximately 45 cm in length (Tortora and Derrickson 2023). The inner lining consists of ciliated epithelium, while the tube itself is surrounded by a thick layer of smooth muscle. The vas deferens functions to transport sperm from the scrotum, passing through the inguinal canal, which is a narrow slit-like opening in the abdominal wall, into the abdominal cavity.

Located between the scrotal sac and the inguinal canal is the spermatic cord, a supportive structure that contains the vas deferens as it ascends through the scrotum, along with accompanying blood vessels, lymphatics and nerves.

There are two vasa deferentia, one arising from each testis that travel upwards and converge near the base of the urinary bladder. Each vas deferens joins with a seminal vesicle to form the paired ejaculatory ducts. These ducts open into the urethra, through which sperm is expelled during ejaculation, either as a result of sexual intercourse or masturbation. Once ejaculated, sperm typically survive no longer than 48 hours within the female reproductive tract.

THE SEMINAL VESICLES AND PROSTATE GLAND

The seminal vesicles and prostate gland are key accessory glands of the male reproductive system that contribute the majority of the fluid found in semen. These secretions play a vital role in creating a supportive environment for sperm survival and function, particularly by neutralising the acidic conditions of the vaginal tract.

Each seminal vesicle is approximately 5 cm in length and is located at the base of the urinary bladder. There are two vesicles, one associated with each vas deferens. The seminal vesicles secrete a viscous, alkaline fluid that is rich in fructose, which serves as an energy source for sperm and contains clotting proteins that facilitate the coagulation of semen following ejaculation. These secretions enter the ejaculatory ducts and contribute to roughly two-thirds of the total semen volume.

THE PROSTATE GLAND: STRUCTURE, FUNCTION AND SURROUNDING ANATOMY

The prostate gland, an exocrine gland of the male reproductive system, is the largest accessory gland within this system. Although not all of its functions are fully understood, the prostate plays a crucial role in male fertility and urinary control.

A fibrous capsule, known as the prostatic capsule, encases the prostate. Posteriorly, the prostate and the adjacent seminal vesicles are separated from the rectum by a thin layer of connective tissue. The gland itself comprises several distinct types of cells:

- Glandular epithelial cells, responsible for producing the fluid portion of semen.
- Smooth muscle cells, which regulate the flow of urine and ejaculation.
- Fibroblasts and connective tissue cells, which provide structural support.

Anatomically, the prostate is a firm, partly glandular and partly muscular organ located just below the internal urethral orifice. It surrounds the initial portion of the urethra. Situated within the pelvic cavity, it lies inferior to the symphysis pubis, superior to the urogenital diaphragm and anterior to the rectum. Shaped like a walnut and measuring approximately 4 cm in width, it is conical with clearly defined zones and surfaces (Cancer Research UK 2024).

VASCULAR AND LYMPHATIC SUPPLY

- Arterial blood is supplied via branches of the internal iliac artery.
- Venous drainage occurs through the periprostatic venous plexus, which drains into the internal iliac vein via the inferior vesical vein.
- Lymphatic drainage is directed to the internal iliac lymph nodes, particularly the anterior obturator nodes.
- Nerve supply is autonomic, derived from the inferior hypogastric plexus running alongside the internal iliac artery.

ZONES OF THE PROSTATE

The prostate is divided into three histologically and functionally distinct zones (see Figure 1.6):

- Peripheral zone: This zone lies closest to the rectum and constitutes around 70% of the prostate's volume. It is the most common site for prostate cancer.
- Transition zone: Surrounding the urethra, this zone accounts for about 20% of the gland in men under 40 years but enlarges with age, often becoming the dominant zone. Benign prostatic hyperplasia typically originates here.
- Central zone: Located at the base of the prostate, surrounding the ejaculatory ducts and lying posterior to the transition zone, this zone contributes ducts to the prostatic urethra and produces prostatic secretions.

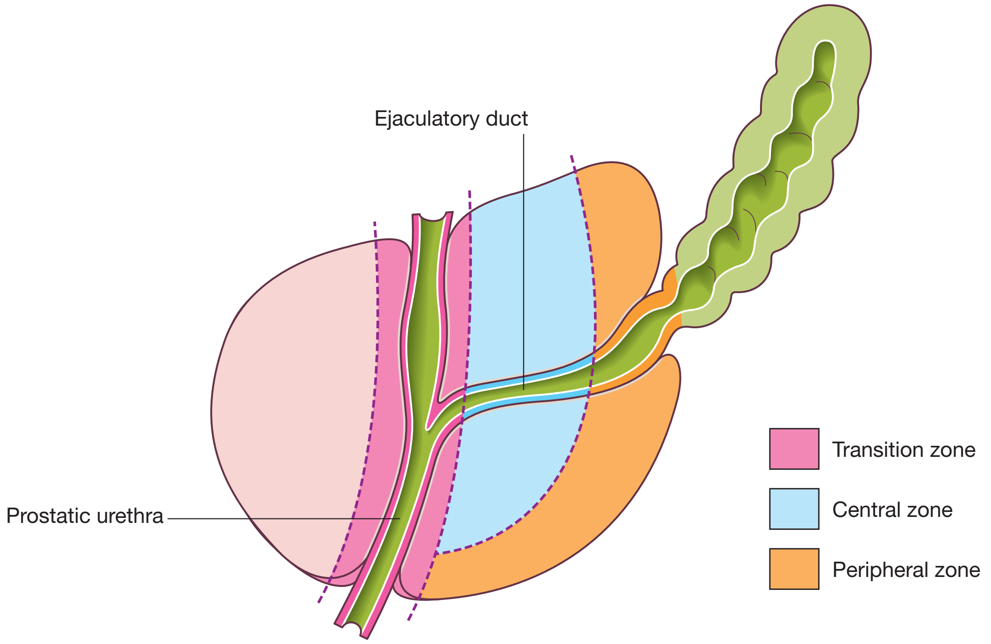


FIGURE 1.6 The prostate gland and the three zones

SURFACES OF THE PROSTATE GLAND

The prostate gland presents with several anatomical surfaces:

- Base: Directed superiorly and in contact with the bladder. The urethra enters the prostate closer to the anterior aspect of the base.
- Apex: Tapered and directed inferiorly; it sits against the urogenital diaphragm, through which the urethra exits.
- Anterior surface: Narrow and positioned behind the pubic symphysis, connected by the puboprostatic ligament.
- Inferolateral surfaces: Curving inwards, they lie adjacent to the levator ani muscles, separated by the prostatic venous plexus.
- Posterior surface: Broad and flattened, it faces the rectum and is separated into right and left lobes by a shallow longitudinal groove. The ejaculatory ducts enter the prostate near this groove.

FUNCTION OF THE PROSTATE GLAND

The prostate gland plays a central role in the production of seminal fluid. Under the influence of testosterone, glandular epithelial cells secrete a thin, milky, alkaline fluid that makes up approximately one-third of the total semen volume. This fluid contains proteins, enzymes and minerals that support sperm motility, viability and the facilitation of fertilisation. During sexual arousal, secretion increases and mixes with sperm for ejaculation.

In addition to its secretory role, the prostate contributes to urinary continence. Smooth muscle fibres surrounding the urethra contract involuntarily to control urinary flow.

Several critical anatomical structures surround the prostate gland:

- Seminal vesicles: Paired glands located posterolateral to the prostate that contribute the majority of the seminal fluid.
- Vas deferens: Tubes transporting sperm from the testes to the ejaculatory ducts.
- Neurovascular bundles: These bundles, essential for erectile and bladder function, run along the lateral edges of the prostate.
- Pelvic floor muscles: These help regulate urination and support pelvic structures.

PROSTATE-SPECIFIC ANTIGEN

Prostate-specific antigen (PSA) is a protein enzyme secreted by epithelial cells of the prostate (GPNotebook 2024). PSA plays a critical role in liquefying semen after ejaculation, aiding the movement of sperm through the female reproductive tract. It acts by breaking down seminal vesicle proteins that initially coagulate the semen, allowing sperm to eventually access the uterine cavity.

Because PSA is produced exclusively by prostatic epithelial cells, its levels in blood are commonly used as a biomarker in the screening and monitoring of prostate conditions, including benign enlargement and prostate cancer. Elevated levels of PSA in the blood can be an indicator of prostate cancer (Cancer Research UK 2025). However, raised PSA levels may also occur for several other non-cancerous reasons, such as:

- Ejaculation within the past 48 hours
- Intense physical activity or vigorous exercise within the past 48 hours
- A recent urinary tract infection (within the last six weeks)
- A recent prostate biopsy (within the past six weeks)
- A digital rectal examination performed shortly before the PSA test

Because these factors can temporarily elevate PSA levels, there are varying guidelines regarding how long to wait after such activities before having a PSA test. Additionally, PSA levels tend to rise naturally with age. A diagnosis of prostate cancer is not based on PSA level alone; further diagnostic evaluation is usually required.

The person's age and the size of their prostate, if known, are taken into consideration when trying to interpret what a PSA score means. There is no universally agreed 'normal' PSA level. Instead, a significant rise from an individual's baseline or a high PSA velocity (rate of change over time) may prompt further investigation. Prostate Matters (2024) suggests the following:

- For men in their 40s and 50s: A PSA score greater than 2.5 ng/mL is considered abnormal. The median PSA for this age range is 0.6–0.7 ng/mL.
- For men in their 60s: A PSA score greater than 4.0 ng/mL is considered abnormal. The normal range is between 1.0 and 1.5 ng/mL.

STRUCTURE AND FUNCTION OF THE PENIS

The penis is the primary male copulatory organ and forms part of both the urinary and reproductive systems. Functionally, it serves two key purposes: the elimination of urine via the urethra and the ejaculation of semen during sexual intercourse. It is a highly vascular and sensitive organ, richly supplied with blood vessels and nerve endings that support its complex physiological functions.

ANATOMICAL OVERVIEW

The penis consists of three main regions:

- Root (crura): The fixed base of the penis, which is anchored to the pubic arch and formed by the proximal portions of the corpora cavernosa.
- Body (shaft): The cylindrical and mobile portion that extends from the root to the glans.
- Glans penis: The distal, enlarged tip of the penis. It contains the external urethral orifice and is often covered by the prepuce (foreskin) in uncircumcised people.

INTERNAL COMPOSITION

Internally, the penis is composed of three columns of erectile tissue (see Figure 1.7), each surrounded by a tough fibrous sheath known as the tunica albuginea:

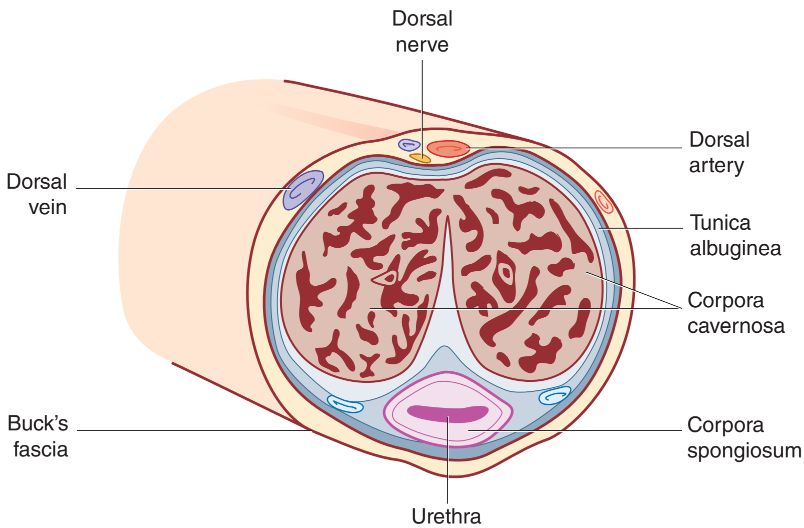


FIGURE 1.7 The anatomy of the penis

1. Two corpora cavernosa: Positioned dorsally, these paired structures are primarily responsible for penile rigidity during erection. They contain extensive vascular spaces (sinusoids) that fill with blood during arousal.
2. Corpus spongiosum: Located ventrally, it surrounds the spongy urethra, which carries both urine and semen. The corpus spongiosum expands distally to form the glans penis and remains more pliable during erection to ensure patency of the urethral passage.

VASCULAR AND NEURAL CONTROL OF ERECTION

In the flaccid state, the penile arteries are constricted and minimal blood flows into the erectile tissues. During sexual arousal, parasympathetic stimulation, mediated by the pelvic splanchnic nerves (S2–S4), triggers the release of nitric oxide (NO), which causes vasodilation of arterioles supplying the erectile tissue. As blood fills the vascular sinuses of the corpora cavernosa and corpus spongiosum, the penis becomes engorged, firm and erect. Figure 1.8 considers the arterial blood supply to the penis.

Erection can be initiated by a range of stimuli, psychogenic (visual, auditory or imaginative) or reflexogenic (physical stimulation of the genital region). The ischiocavernosus and bulbospongiosus muscles, under somatic control via the pudendal nerve, compress venous outflow and help sustain the erection.

EJACULATION AND DETUMESCENCE

Ejaculation is primarily a sympathetic reflex (T11–L2), involving contraction of the smooth muscle in the vas deferens, seminal vesicles and prostate gland, propelling semen into the urethra (emission). This is followed by rhythmic contractions of the pelvic floor muscles (e.g. bulbospongiosus), expelling semen from the urethral meatus.

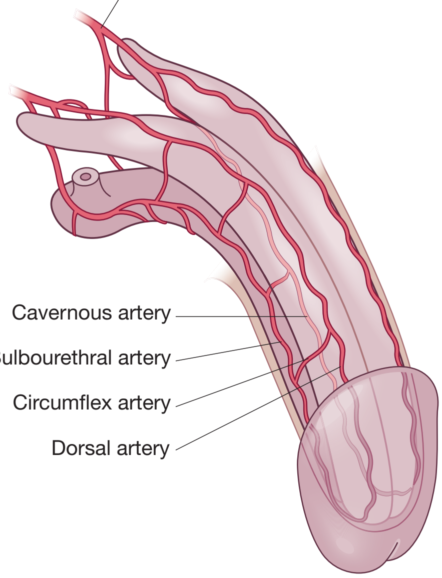


FIGURE 1.8 The arterial blood supply to the penis

After ejaculation, sympathetic vasoconstriction of penile arterioles reduces blood inflow and venous outflow resumes, leading to the loss of erection, a process known as detumescence.

CLINICAL CONSIDERATIONS

- Circumcision: In uncircumcised males, the glans is protected by the prepuce. Circumcision, the surgical removal of the foreskin, may be performed for cultural, religious or medical reasons.
- Erectile dysfunction: A common clinical issue affecting the ability to achieve or maintain an erection. Causes may be vascular, neurological, hormonal or psychological.
- Peyronie's disease: A fibrotic condition resulting in abnormal curvature of the erect penis due to plaque formation within the tunica albuginea.
- Urethral strictures or congenital abnormalities (e.g. hypospadias) may affect urination or ejaculation.

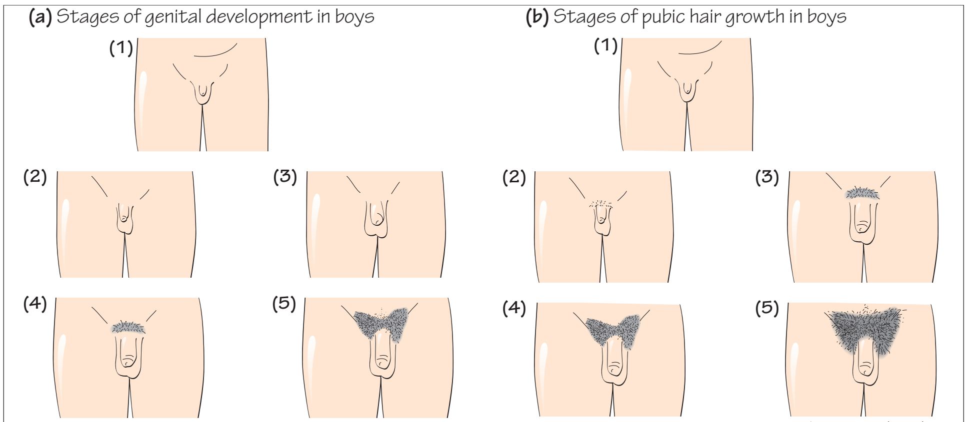
HORMONAL REGULATION OF MALE REPRODUCTIVE FUNCTION

The regulation of testicular function, including the production of sperm (spermatogenesis) and the secretion of male sex hormones, is governed by a tightly coordinated endocrine feedback system known as the hypothalamic–pituitary–gonadal axis.

ANDROGENS AND THEIR ROLE

Androgens are the primary male sex hormones, with testosterone being the most significant and biologically active form. The vast majority of testosterone is synthesised by the Leydig cells located within the interstitial tissue of the testes. A much smaller quantity is produced by the zona reticularis of the adrenal cortex. Testosterone plays a central role in:

- The development, growth and maintenance of the male reproductive organs, including the penis, testes and prostate (see Figure 1.9).
- The manifestation of male secondary sexual characteristics during puberty, such as deepening of the voice, growth of facial and body hair, increased muscle mass and changes in body composition (see Figure 1.10).
- Supporting spermatogenesis within the seminiferous tubules.
- Enhancing libido (sexual drive) and aggression.
- Promoting anabolic effects such as protein synthesis, muscle growth and bone density.



(a) Stages of genital development in boys

Stage	Description	Age at onset (years) Mean	Range
1	Preadolescent: Testes, scrotum and penis about the same size and proportion as in early childhood.		
2	Scrotum and testes have enlarged, texture of scrotal skin has changed. Testicular length > 2.0 cm < 3.2 cm.	11.6	9.5–13.8
3	Penis has grown primarily in length. Testes and scrotum growing. Testicular length > 3.3 cm < 4.0 cm.	12.9	10.8–14.9
4	Penis further enlarged in length and breadth. Glans develops. Further enlargement of testes and scrotum. Scrotal pigmentation darkening.	13.8	11.7–15.8
5	Genitalia adult size and shape. Testicular length > 5 cm	14.9	12.7–17.1

(b) Stages of pubic hair growth in boys

Stage	Description	Age at onset (years) Mean	Range
1	Preadolescent: No pubic hair (no thicker than over abdominal wall).		
2	Sparse growth of downy, long, slightly pigmented hair chiefly at base of penis.	13.4	11.2–15.6
3	Hair considerably darker, coarser and mostly curled. Hair spread sparsely on pubic junction.	13.9	11.9–16.0
4	Hair now adult in appearance but area covered still smaller than adult. No spread to medial surface of thighs.	14.4	12.2–16.5
5	Adult hair in appearance and quantity. Triangle is inverse of classical female pattern. Spread to medial surface of thighs but not above triangle base. In about 80% of men pubic hair eventually spreads further up beyond triangle base. This widespread pubic hair growth is not complete until the mid-twenties and may be called 'stage 6'.	15.2	13.0–17.3

FIGURE 1.9 Tanner stages (boys)

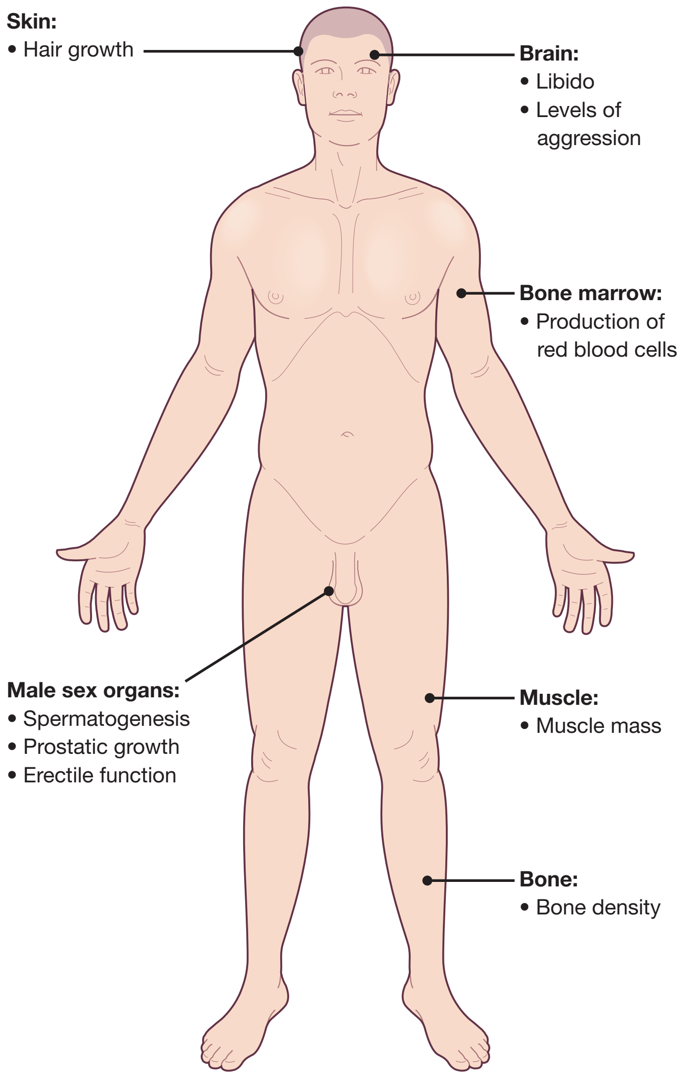


FIGURE 1.10 Primary and secondary sex characteristics

HORMONAL CHANGES ACROSS THE LIFESPAN

During fetal development, there are small amounts of testosterone secreted by the fetal testes under the influence of human chorionic gonadotropin, aiding in the differentiation of the male reproductive tract. After birth, testosterone levels fall and remain low throughout childhood.

At puberty, the hypothalamus becomes more active and begins secreting GnRH in a pulsatile manner. This hormone stimulates the anterior pituitary gland to release two key gonadotropins:

- LH: Stimulates the Leydig cells in the testes to synthesise and secrete testosterone.
- FSH: Acts primarily on the Sertoli cells within the seminiferous tubules to promote spermatogenesis and the production of androgen-binding protein, which helps maintain high local concentrations of testosterone within the testes.

NEGATIVE FEEDBACK REGULATION

As blood levels of testosterone rise, a negative feedback mechanism is initiated:

- High testosterone levels inhibit the release of GnRH from the hypothalamus.
- This, in turn, reduces the secretion of LH and FSH from the anterior pituitary.
- The decline in LH reduces testosterone production by Leydig cells, thereby maintaining hormonal balance.

This feedback loop ensures that testosterone levels remain within a physiologically appropriate range and that sperm production is optimally regulated (see Figure 1.11).

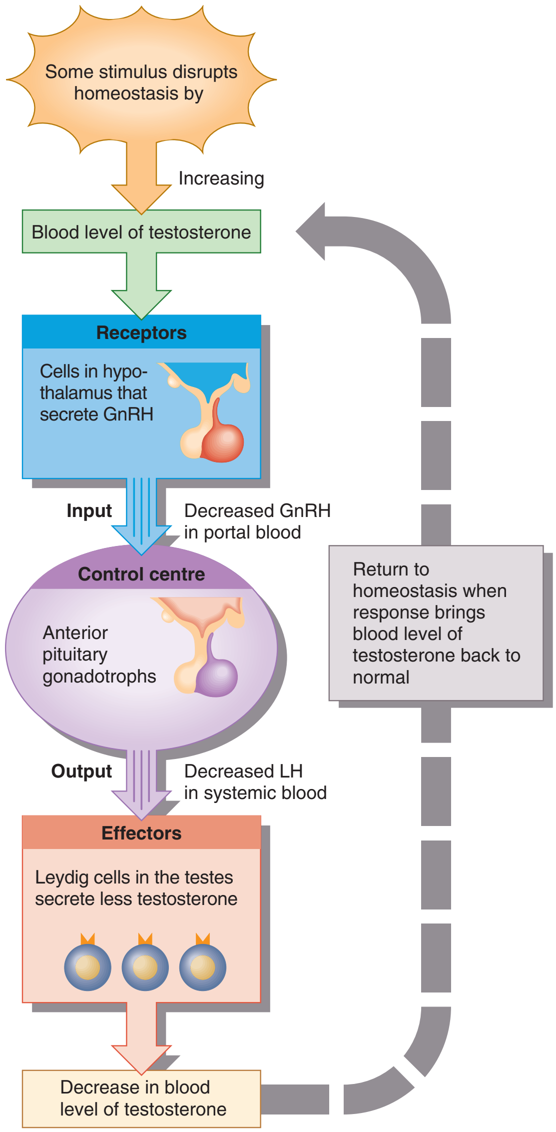


FIGURE 1.11 Negative feedback system associated with the control of testosterone in the blood.
Source: Tortora and Derrickson (2009). With permission of John Wiley & Sons.

CLINICAL CONSIDERATIONS

- Hypogonadism: A deficiency in testosterone production or action can lead to underdeveloped secondary sexual characteristics, infertility, low libido and reduced muscle mass.
- Hypergonadism or exogenous testosterone use (e.g. anabolic steroid abuse) can suppress endogenous testosterone production and impair spermatogenesis via negative feedback inhibition.
- Age-related testosterone decline (sometimes referred to as andropause) may lead to symptoms such as fatigue, decreased libido and loss of bone density.

CONCLUSION

A comprehensive understanding of male reproductive anatomy and physiology is fundamental to recognising how reproductive health is maintained and how dysfunctions may arise. The male reproductive system is a highly coordinated network of structures, including the testes, epididymides, vas deferens, seminal vesicles, prostate gland and penis, working together to produce, nourish and deliver sperm, while also secreting essential hormones that influence secondary sex characteristics, sexual function and fertility.

Hormonal regulation, primarily through the hypothalamic–pituitary–gonadal axis, plays a critical role in supporting spermatogenesis and maintaining circulating levels of testosterone. Testosterone, in turn, exerts wide-ranging effects beyond reproduction, including influencing mood, muscle mass, bone density and libido.

Clinically, knowledge of male reproductive physiology underpins key diagnostic and therapeutic approaches in men's health, including the evaluation of infertility, sexual dysfunction, prostate conditions and hormonal imbalances. Markers such as PSA further link anatomical and physiological knowledge with practical screening and management strategies in urological and oncological care.

As healthcare professionals, a solid grasp of male reproductive anatomy and physiology supports effective communication, accurate assessment and the delivery of evidence-based care. It also lays the foundation for promoting reproductive health, preventing disease and supporting individuals across the lifespan in maintaining sexual and reproductive well-being.

GLOSSARY OF TERMS

Acrosome: A cap-like structure covering the head of a sperm that contains enzymes essential for penetrating the ovum during fertilisation.

Androgens: A group of male sex hormones, the most important of which is testosterone; responsible for the development and maintenance of male characteristics and reproductive functions.

Corpus cavernosum: One of two columns of erectile tissue in the penis that fill with blood during arousal, contributing to penile erection.

Corpus spongiosum: A column of erectile tissue surrounding the urethra in the penis that helps maintain an open urethral passage during erection.

Cremaster muscle: A muscle surrounding the spermatic cord and testes that contracts to elevate the testes in response to cold or arousal, aiding in temperature regulation.

Dartos muscle: A layer of smooth muscle in the scrotal wall that contracts to wrinkle the scrotum, helping to conserve heat for optimal testicular function.

Ejaculatory duct: A short duct formed by the union of the vas deferens and the seminal vesicle duct that conveys sperm and seminal fluid into the urethra.

Epididymis: A long, coiled duct situated along the back of the testis where sperm mature and are stored prior to ejaculation.

Glans penis: The sensitive, enlarged tip of the penis, often covered by the foreskin in uncircumcised people.

Gonadotrophin-releasing hormone (GnRH): A hormone secreted by the hypothalamus that stimulates the anterior pituitary to release LH and FSH.

Leydig cells: Cells located in the interstitial space of the testes that produce testosterone in response to LH stimulation.

Luteinising hormone (LH): A hormone produced by the anterior pituitary that stimulates Leydig cells in the testes to produce testosterone.

Penis: The male external genital organ that serves as a conduit for both urine excretion and semen ejaculation.

Peripheral zone (of the prostate): The largest anatomical zone of the prostate gland, located closest to the rectum and most commonly affected by prostate cancer.

Prostate gland: A walnut-sized exocrine gland located below the bladder that secretes fluid contributing to semen volume and supports sperm motility.

Prostate-specific antigen (PSA): A protein produced by prostatic epithelial cells that helps to liquefy semen; elevated blood levels can indicate prostate disorders.

Scrotum: The pouch of skin and muscle that contains the testes and helps regulate their temperature for effective spermatogenesis.

Seminal vesicles: Paired glands that secrete a significant proportion of the fluid in semen, including fructose and clotting proteins.

Sertoli cells: Supportive cells within the seminiferous tubules that provide nourishment and structural support to developing sperm cells.

Sperm (spermatozoa): The male reproductive cells produced in the testes that carry genetic material to the ovum during fertilisation.

Spermatic cord: A bundle of structures including the vas deferens, blood vessels, lymphatics and nerves that support the testes and travel through the inguinal canal.

Spermatogenesis: The process of sperm cell development within the seminiferous tubules of the testes.

Testes (testicles): The male gonads responsible for the production of sperm and secretion of testosterone.

Testosterone: The primary male sex hormone, essential for male reproductive development, secondary sex characteristics and spermatogenesis.

Tunica albuginea: A fibrous capsule that surrounds each testis and also encloses the erectile tissues in the penis.

Urethra: A shared terminal duct of the urinary and reproductive systems in males that passes urine and semen through the penis to the outside.

Vas deferens (ductus deferens): A muscular tube that transports mature sperm from the epididymis to the ejaculatory duct during ejaculation.

MULTIPLE CHOICE QUESTIONS

1. Which of the following structures is responsible for sperm storage and maturation?
a) Vas deferens
b) Prostate gland
c) Epididymis
d) Seminal vesicle

2. The testes are located in the scrotum primarily to:
a) Protect them from physical trauma
b) Maintain a temperature lower than core body temperature
c) Facilitate hormone synthesis
d) Ensure proper lymphatic drainage

3. The muscular tube that transports sperm from the epididymis to the ejaculatory duct is the:
a) Vas deferens
b) Urethra
c) Seminal vesicle
d) Spermatic cord

4. Which zone of the prostate is most commonly affected by prostate cancer?
a) Central zone
b) Transition zone
c) Anterior zone
d) Peripheral zone

5. Which hormone stimulates Leydig cells to produce testosterone?
a) LH
b) FSH
c) GnRH
d) Prolactin

6. Spermatogenesis takes place in which structure of the testes?
a) Epididymis
b) Seminiferous tubules
c) Rete testis
d) Tunica vaginalis

7. What is the function of the prostate-specific antigen (PSA)?
   a) Liquefies semen after ejaculation
   b) Supports testicular descent
   c) Increases sperm motility
   d) Enhances testosterone production

8. The function of Sertoli cells includes:
   a) Secretion of testosterone
   b) Structural support and nourishment of developing sperm
   c) Production of PSA
   d) Formation of the vas deferens

9. Testosterone exerts negative feedback on which of the following?
   a) Adrenal medulla
   b) Pineal gland
   c) Posterior pituitary and adrenal cortex
   d) Hypothalamus and anterior pituitary

10. Which of the following best describes the glans penis?
   a) It contains erectile tissue that surrounds the urethra
   b) It is the origin of the vas deferens
   c) It is the enlarged, sensitive distal tip of the penis
   d) It is the root portion anchored to the pelvis

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