

Chapter 2

Male Reproductive System

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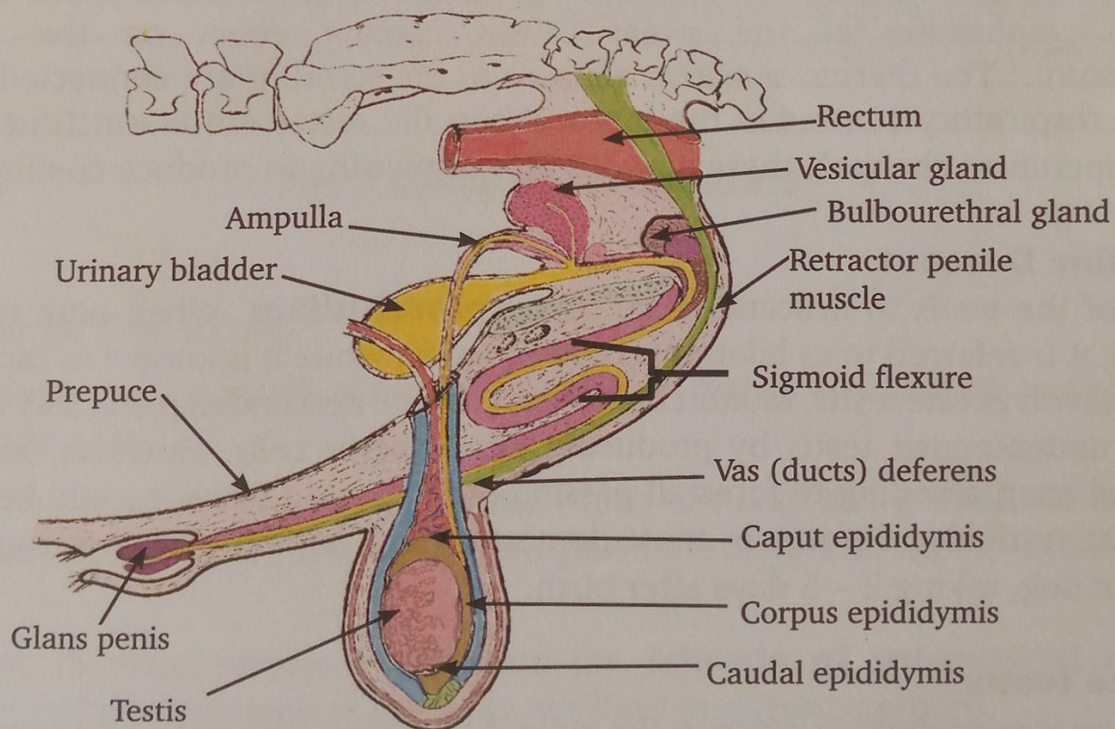
2.1 Male Reproductive Organs

The primary functions of reproductive organs in male animals can be delineated into three, namely:

- Production of spermatozoa – **spermatogenesis**.
- Production of hormones – **androgenesis** which affect male sexual behaviour and characteristics as well as spermatogenesis.
- Transportation, maturation, concentration and introduction of spermatozoa into female genitalia during mating.

In performing these roles, the male reproductive organs are classified as

- Primary sex organ – testis
- A paired excurrent duct system – Vas eferentia, epididymis and Vas deferens,
- Accessory sex glands
- The copulatory organ – penis.



From Senger 2009

Fig. 2.1: Male reproductive organs – bull

At the early stage of embryogenesis *in utero*, the testes are located internally just caudal to the kidney in a retroperitoneal position. The rapid growth of the ligamentous gubernaculum produces the force that mechanically pushes the testes through the inguinal canal while the regression thereof (of the same gubernaculum) sustains the retention of the testis in the scrotum. In avian and elephant, testes are retained within the body (*in vivo*).

(i) The scrotum

This is a lobulated sac enclosing the testis and made up of several layers, namely: the skin, tunica dartos, scrotal fascia and parietal tunica vaginalis.

The primary functions of the scrotum are:

- (a) **Protection of testes:** The scrotal skin is the first point of contact before the testis, therefore it protects the testis from noxious substances. The strategic location of the testes between the hind limbs is meant to prevent it from fractural damage.
- (b) **Thermoregulation:** In cold condition, the scrotum shrinks to get the testes close to the body, while under high temperature; it relaxes to free the testes far away from the body. Several sweat glands of the scrotum cause sweating so that evaporation of the sweat causes cooling effect on the testes and scrotum. The thermo-sensitive neurons in the scrotum are connected directly to the respiratory centres in the brain. When the testes are warm (due to a small temperature change), these neurons induce panting to produce cooling effect.

Testicular Descent

Failure of the testis to descend is called **cryptorchidism**. When both testes fail to descend, it is referred to as bilateral cryptorchidism while it is known as monorchidism when it involves one testis. Monorchid is fertile as the descended testis may compensate for the undescended testis by producing more sperm cells. However, monorchid is restricted from breeding to forestall passing over the trait since it could be hereditary. Note that testicular descent in most domestic/farm animal occurs during gestation, except in dog, taking 2 – 5 days after birth.

(ii) The testis

The primary reproductive organ in the male is the testis. The testis performs dual roles: exocrine function of producing the spermatozoa and endocrine function of producing the androgens-testosterone.

Histologically, the testis is made up of two regions: the peripheral parenchymal and middle mediastinum layer. The testicular capsules are the layers enclosing the testis. Tunica albuginea is the outer layer, while tunica vaginalis is the continuation

of the peritoneum from the body cavity. On a cross-sectional view of the testis, the **mediastinum** lies in the middle. It encloses the **rete testis** (the cavernous openings through which spermatozoa pass). The organ is covered by the testicular capsule.

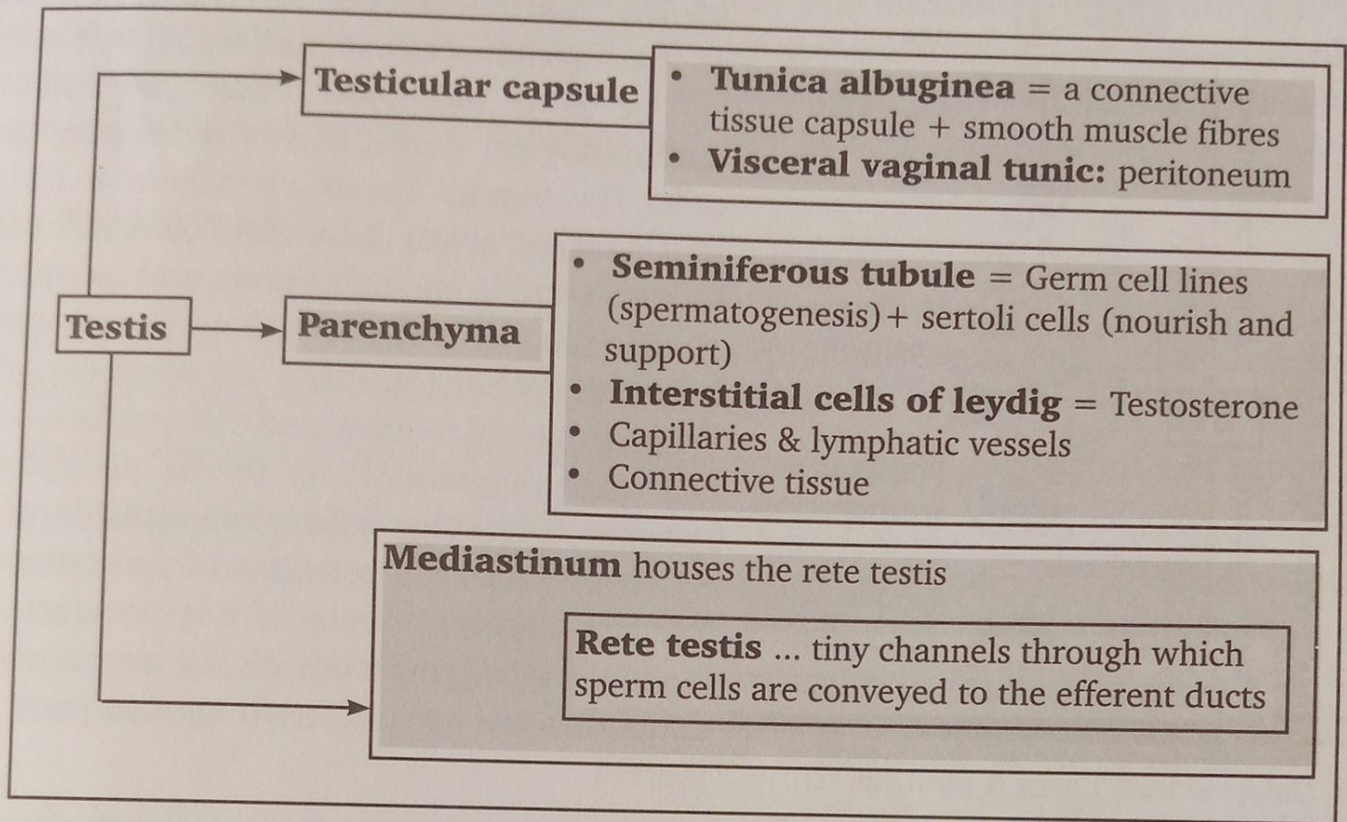
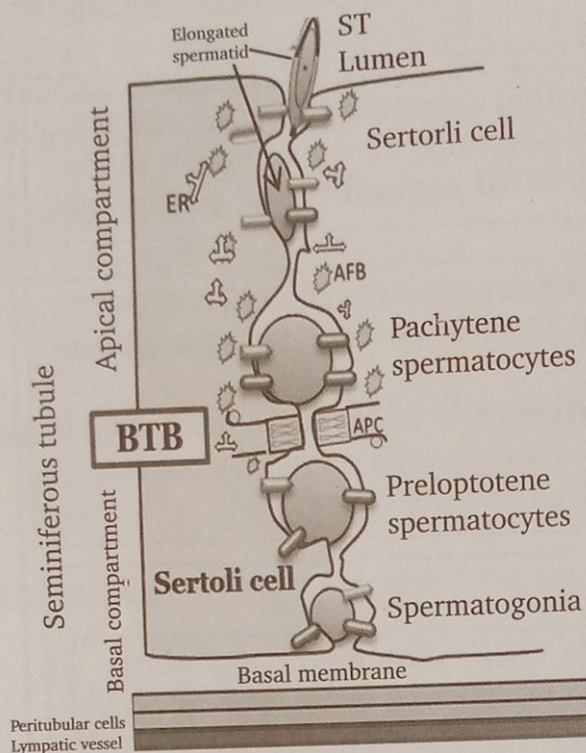


Fig. 2.2: Regions of the testis

Cell types in the testis

- (i) The convoluted seminiferous tubule (ST) is highly coiled and is the site of spermatogenesis.
- (ii) ST is lined by seminiferous epithelium which contains the **germinal cells** and large **Sertoli cells**, which provide nutrition and support for the developing sperm cells.
- (iii) Between the seminiferous tubules are the **islands of interstitial cells** or **Leydig cells** which secrete the male sex hormone (testosterone).
- (iv) The seminiferous tubules connect into area of cavernous-like tissue with wide anastomosing channels known as the **rete testis**.
- (v) Leading from the rete testis are 6 to 12 **efferent ducts** (ductus eferentia) which pierce the tunica albuginea at a small area (about a centimetre in diameter) at the dorsal (anterior) part of the testis and enter the **head of the epididymis**.

The seminiferous tubule is a highly convoluted tubule and may be up to 3 miles (5km) in bull.



(Adapted from Cheng & Mruk, 2012)

Blood Testis Barrier (BTB): Also known as the Sertoli cell seminiferous epithelium barrier is a mechanism that prevents the immunological destruction of developing germ cells. The seminiferous epithelium is divided into basal and apical (adluminal) compartments. Meiosis I and II, spermiogenesis, and spermiation all take place in a specialized microenvironment behind the BTB in the apical compartment, while spermatogonial renewal and differentiation and cell cycle progression up to the preleptotene spermatocyte stage take place outside of the BTB in the basal compartment of the epithelium. The seminiferous tubule is not penetrated by blood vessels, lymph vessels, or nerves so that antibodies are not produced against germ cells therein.

Legends: AFB; actin filament bundle, APC; adhesion protein complex, ER; endoplasmic reticulum, JCP; junctional complexes protein

Fig. 2.3: Seminiferous epithelium

- i. Peritubular cells surrounding the seminiferous epithelium serve as the first barrier by screening large molecular weight materials especially immunoglobulin.
- ii. Junctional complexes in between sertoli cells ensure that immune cells (lymphocytes, macrophages and immunoglobulins) do not have access to the germ cells as they are excluded from the adluminal compartment.

Spermatic Cord (SC) components: SC extends from abdominal inguinal canal to its attachment with the testis, covered by a serosal layer (tunica vaginalis) which is derived from the peritoneum. It suspends the testis within the scrotum and as passage for testicular vascular, lymphatic and nerves, vas deferens and cremaster muscle. Cremaster muscle is a major supporting entity of the cord and aids in controlling testicular temperature by holding the testes close to or further away from the body. Testicular arteries are highly coiled and surrounded with veins network giving rise to pampiniform plexus.

Pampiniform plexus: This is made up of network and anastomoses of veins (at 34°C) surrounding testicular arteries (38.7°C) in order to cause counter current heat exchange between the warmer arteries (coming from the body) and the cooler venous blood returning from the testis going into the body. The testicular temperature of 34°C is most conducive for spermatogenesis and steroidogenesis though does not necessarily need to be constant. However, heat is capable of damaging DNA of spermatozoa with severe implication of low survival of eggs fertilized by such spermatozoa.

(iii) Epididymis

- (a) This is composed of a single convoluted tubule.
- (b) It has smooth muscles that facilitate spermatozoa movement into the vas deferens through a peristaltic wave within the epididymis
- (c) Morphologically, it can be delineated into three parts: Caput, corpus and caudal
- (d) **Epididymal transit** from the caput through the corpus to the caudal may take about 14 days in bull during which sperm cells undergo maturation. Such maturation involves membrane changes, stability of nucleus and flagellum, translocation of cytoplasmic droplets and acquisition of motility and fertility potentials.

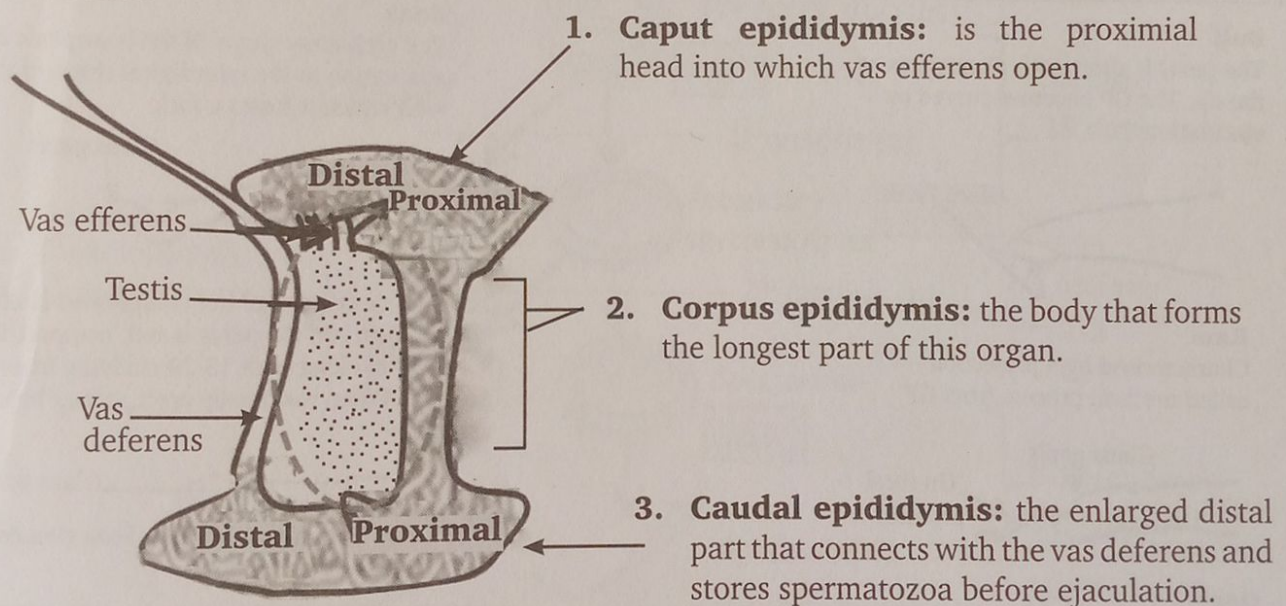


Fig. 2.4: Epididymis

(iv) Vas deferens

- (a) This may be regarded as the continuation of the epididymis connecting the caudal epididymis to the pelvic urethra.
- (b) It has a thick muscular tube situated medio-caudally within the spermatic cord with tiny lumen.

- (c) It contains both longitudinal and circular muscles that contract involuntary during ejaculation to expel the sperm cells into the pelvic urethra.
- (d) Vas deferens also acts as reservoir for spermatozoa (extra-gonadal sperm reserve)
- (e) The secretions of accessory sex glands mix with spermatozoa in the pelvic urethra.

(v) Penis

Penis is a copulatory organ that comprises three distinct parts, namely:

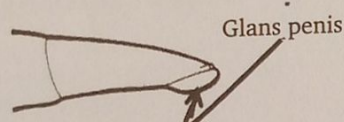
- (a) The **base/root** that attaches to the ischial arch,
- (b) **The shaft**, the main portion of the penis and
- (c) Specialised distal free end called the **glans penis** (GP).

Erection may be described as a neurovascular and haemodynamic events leading to increased arterial flow to the cavernous spaces.

The GP is populated with sensory nerves which are stimulated to cause ejaculation during coitus as GP bruises the vagina mucosa.

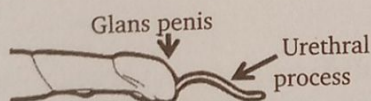
Bull

The penis is short with glans penis at the tip. The GP becomes curved on ejaculation.



Ram

Characterised by a projection called urethral process from GP



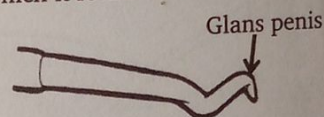
Dog

Characterised by presence of os penis (bone). The bulbus glandis swelling after intromission within bitch genitalia leads to coitus lock.

The penis is so flexible to the extent of allowing a 180°C turn during "copulatory tie".

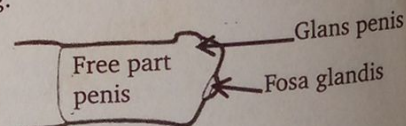
Boar

The corkscrew shape of the boar penis is an adaptation to the interdigital shape of the cervix with which it forms a lock.



Horse

The body is cylindrical but compressed laterally. When quiescent, the penis is soft, compressible, and about 50 cm long with 15-20 cm lying free in the prepuce. When maximally erect, it may be about 120 cm long.



Bull, boar and ram have fibro-elastic penis with limited extension. The **S-shape sigmoid flexure** conceals the full length of the penis. Relaxation of the retractor penile muscle during copulation causes disappearance of the sigmoid flexure and elongates the penis, causing its protrusion out of the prepuce for intromission. At rest, the retractor penile muscle contracts.

Fig. 2.5: Different shapes of the mammalian penis

2.2 Spermatogenesis

Spermacytogenesis = spermatogonium to spermatids (mitosis + meiosis)

Spermiogenesis = Spermatids to spermatozoa (differentiation)

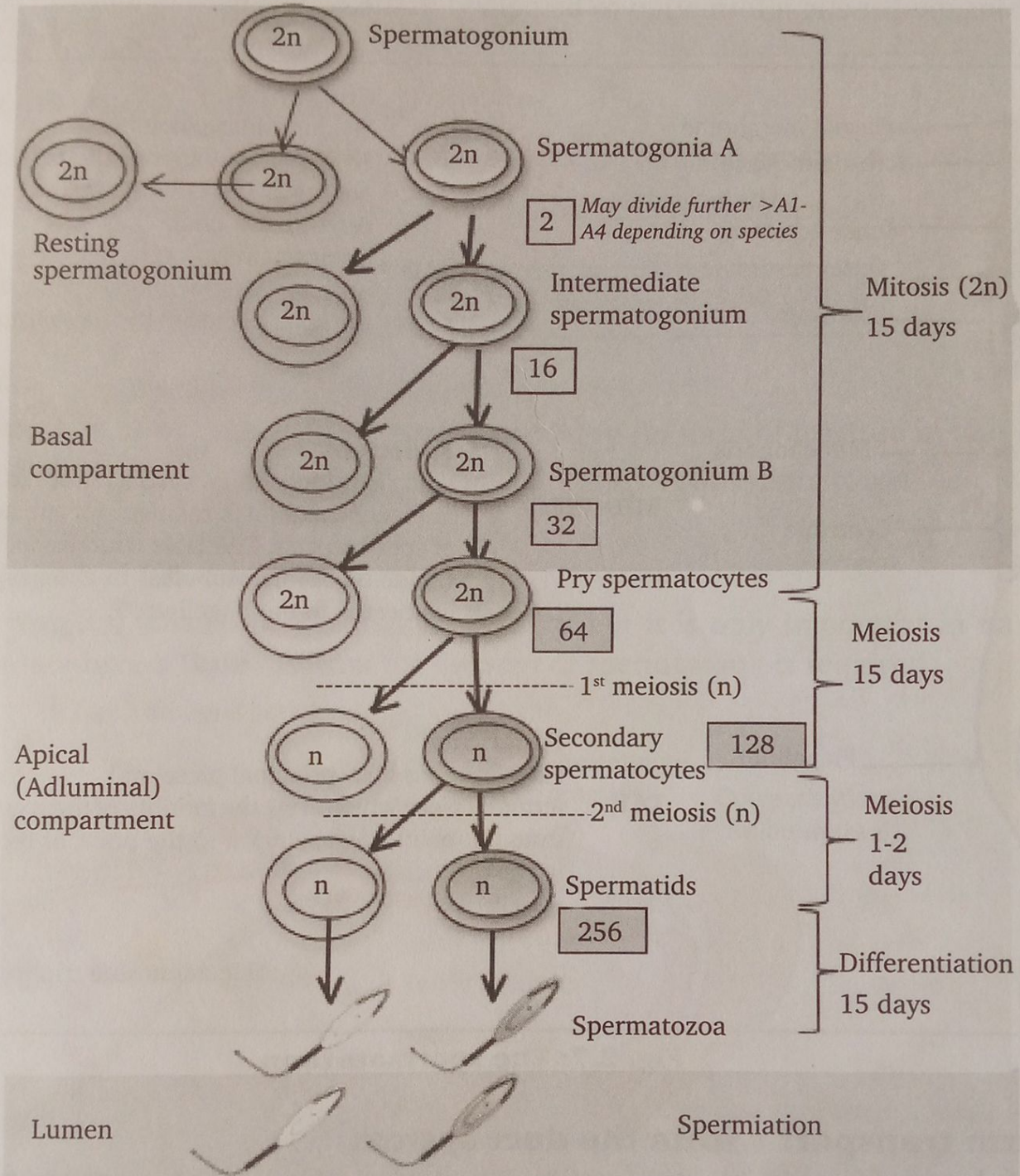


Fig. 2.6: Spermatogenesis

2.3 Structure of Spermatozoon

Morphologically, a matured spermatozoon has mainly the head, mid-piece and the tail. The head is the major part containing the nucleus and acrosomes which take actual parts in fertilization process, though others play significant roles as well. The nucleus contains the genetic information to be passed to the offspring.

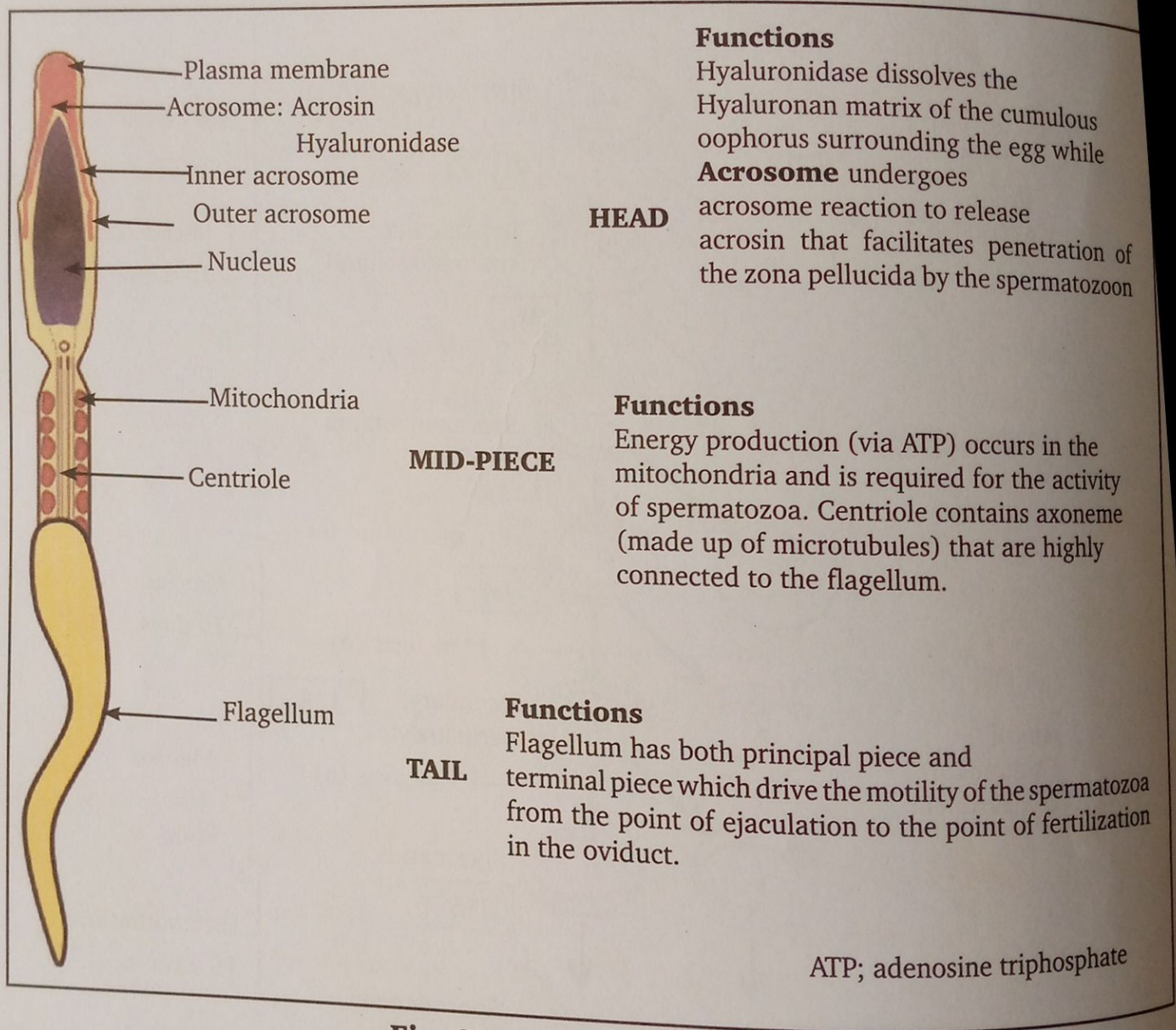


Fig. 2.7: The spermatozoon

Sperm transport within the duct system

The release of sperm into the seminiferous tubule lumen is known as spermiation (similar to ovulation in females), collected by the rete testis and transported to the caput epididymis.

..Seminiferous tubule → rete testis → efferent duct → caput epididymis → corpus epididymis → caudal epididymis → Vas deferens → Ampulla → pelvic Urethra → penile urethra → female reproductive tract.

↑
Seminal plasma (from accessory sex glands)

2.4 Accessory Sex Glands (ASG)

- These are glands closely associated with the pelvic urethra and produce seminal plasma.
- When seminal plasma is mixed with spermatozoa, they form semen.

Semen = Spermatozoa (20%) + Seminal plasma (80%)

The functions of the seminal plasma include:

- nourishment of the sperm by providing energy (in form of fructose in bull);
- facilitating sperm motility and enhancing transport of spermatozoa;
- maintenance of osmotic pressure; and
- chelation of Ca_2+ and buffering.

Note that seminal plasma is essential for fertility, but it is only important in natural insemination where a fluid medium for delivery of spermatozoa is required.

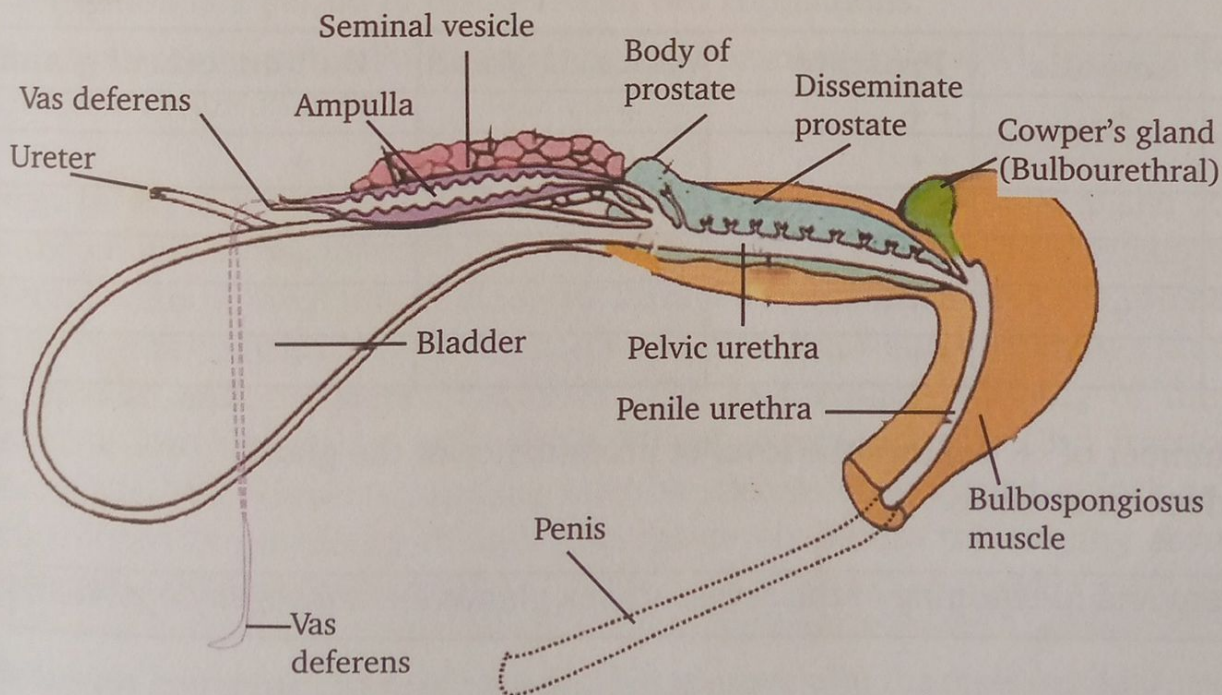


Fig. 2.8: Accessory sex glands in bull

- (a) **Ampullae:** These are dilations of the urethra end of the ductus deferens just before they open into the pelvic urethra. They act as storage organ for semen in between ejaculation. And their contribution to seminal plasma is pronounced in horse. Note that ampulla is also found in female genitalia and it applies to part of the oviduct (pg 26)
- (b) **Vesicular glands:** These are paired organs located on each side of the neck of the bladder. They are paired lobulated (ram and bull) or sac-like structure (boar). VGs are most prominent in the ruminant, boar and stallion. Their watery secretions are opened into the urethra.
- (c) **Prostate:** This is intimately relates to the urethra. It is the major ASG in dog. Morphologically, it can be delineated in to two parts, the body (corpus prostate) that surrounds the neck of the bladder and the neck (disseminate prostate) that spreads around the pelvic urethra. The body has several openings into the urethra.
- (d) **Bulbourethral (Cowper's) gland:** This is a small round structure lying between the anus and the urethra. Their secretions are discharged before ejaculation and are believed to cleanse the urethra of urine. In boar, the secretion is large and viscid because of high concentration of sialomucin in them, when mixed with vesicular gland secretion produces a gelatinous phase of boar seminal plasma.

Table 2.1: Accessory glands in domestic mammals (Source: Noakes *et al*, 2009)

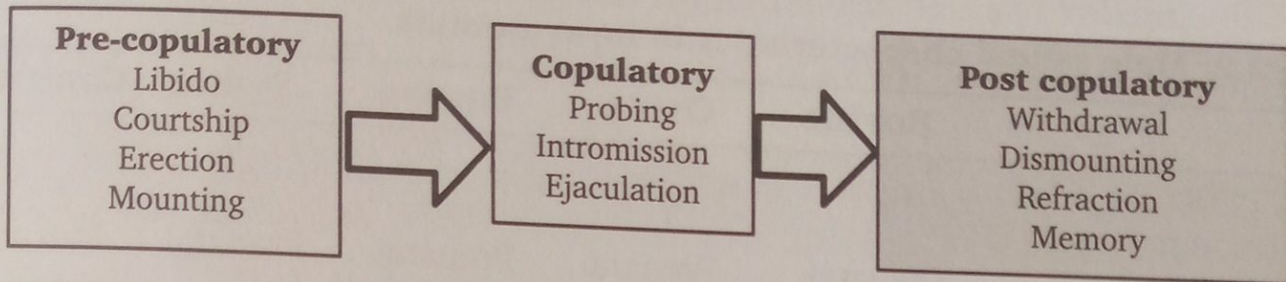
	Ampulla	Prostate	Vesicular gland	Bulbourethral gland
Bovine	+	++	+++	+
Ovine	+	++	+++	+
Equine	++	++	++	+
Swine	-	+	++	+++
Canine	+	+++	-	-
Cat	-	++	-	++

Note: The number of + denotes the level of prominence of the gland While the - denotes absence.

Development and functioning of the accessory sex glands are androgen dependent

2.5 Male Sexual Behaviour

Male sexual behaviour can be classified into three main stages with each step occurring in succession as follows.



- Libido is a sexual desire or urge that enables a bull to detect a cow on oestrus.
- Courtship is familiarisation between the male and female prior to mounting which leads to turgidity of the penis (erection), followed by mounting.
- The animal having sustained mounting makes an attempt of getting the penis inserted into the vagina with several prior unsuccessful attempts called probing.
- Intromission is the successful insertion of the male organ into the female genitalia
- The peak of mating behaviour is ejaculation during which semen is mobilised from the epididymis and deposited into female tract through the penile urethra.
- Soon after ejaculation, there is detumescence (flaccidity) of the penis which is followed by withdrawal of the penis while the male comes down from the mount (dismounting).
- Refraction is a period of rest between two copulations.
- Memory is important. Positive mating experience stimulates while negative experience inhibits future mating.

Dog: In dogs, dismounting occurs before withdrawal because of the “coitus lock”. As the couple faces opposite direction, the penis is turned 180°C which occludes the efferent veins of the penis. This, in addition to the constriction of the sphincter muscles of the vagina contribute to the lock. It takes between 5 and 45 minutes for the “couple” to separate and complete copulation. The lock ensures flushing of the sperm-rich ejaculate into the uterus with about 30 ml seminal plasma (3rd fraction) released during the lock. However, mating may be successful without the lock as the sperm-rich fraction is ejaculated though into the cervix before the turning around and the formation of the coitus lock.

Flehmen reaction: In ruminant and horse especially, the male exhibits a phenomenon called Flehmen reaction/response after sniffing the vulva/female urine just prior to copulation. It is believed to form part of sexual preparation but may occur without

actual mating. Flehmen reaction is characterised by elevation of the head, closing of the nostrils and curling of the upper lips to expose the teeth.

Table 2.2: Male sexual characteristics in farm animals

	Bovine	Ovine	Equine	Swine	Canine
Age at puberty (months)	11	7	14	7	9
Time of testicular descent	Prenatal	Prenatal	Prenatal	Prenatal	Pre/post natal
Duration of copulation	1-3 s	1-2s	20-60	3-20 min	5-45 min
Volume of ejaculate (ml)	3-5	0.8-1	75-120	200-250	1-6*
Point of ejaculation	Fornix vagina	Ext cervical os	Ext cervical os	Cervix & uterus	Ant. vagina
Average number of copulation to satiation	20	10	3	3	-
Maximum number of copulation to exhaustion	60-80	30-40	20	8	-
Duration of spermatogenesis (days)	61	47	55	39	62
Sperm concentration (1×10^9 /ml)	10	14	3	25	1-5
Duration of epididymal transit (days)	9-14	12	9	14	12
Duration of spermatogenesis (day)	61	47	55	39	62
Length of the penis (cm)	95	5-7.5	50	45-50	-

*Sperm-rich fraction

Sources: Noakes *et al.*, (2009), Senger (2005), Hafez & Hafez, (2009).

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