Chapter 1

Reproductive Organs of Male Domestic Animals

The male reproductive organs consist of two testes (or testicles) which are contained in the scrotum, ducts, accessory sex glands and the penis. The reproductive organs of the bulls are shown in Fig. 1.1 and the comparative anatomy of the male reproductive organs of different domestic animals is illustrated in Fig. 1.2.

The testis produces spermatozoa and the male sex hormone (testosterone). The scrotum helps in maintaining optimum temperature for the spermatozoa production. The other structures help for the passage of the spermatozoa to the site of deposition in the female's genitalia in a fairly good condition that may lead to fertilization of the ovum/ova.

SCROTUM AND TESTES

The scrotum is a cutaneous pouch (derived from the skin and fascia) in which testicles are located. The scrotum in all the domestic animals except in boar and cat is located in between thighs. In boar and cat the scrotum is located caudal to thighs. The testis is fixed to the scrotum by means of scrotal ligament attached to its caudal end near the tail of the epididymis. The hairs on the scrotum are very scantly present. Different layer of tissues that are present in between the scrotal skin and the testis proper are shown in Fig. 1.3.

1. **Tunica dartos layer** is present under the scrotal skin and is composed of smooth muscle fibers with fibrous and elastic connective tissue. Tunica dartos layer surrounds both the testes and forms a medial septum in between two testes.

2. **Loose connective tissue layer** is present under the tunica dartos layer.

3. **Vaginal process layer** is present under the loose connective tissue layer. Vaginal process is an extension of peritoneum passing through the abdominal wall at the inguinal canal. The vaginal process layer is composed of (a) superficial layer called tunica vaginalis communis, which corresponds to the parietal peritoneum of the abdominal cavity; and (b) deeper layer called tunica vaginalis propria, which corresponds the visceral layer of peritoneum of the abdominal cavity.

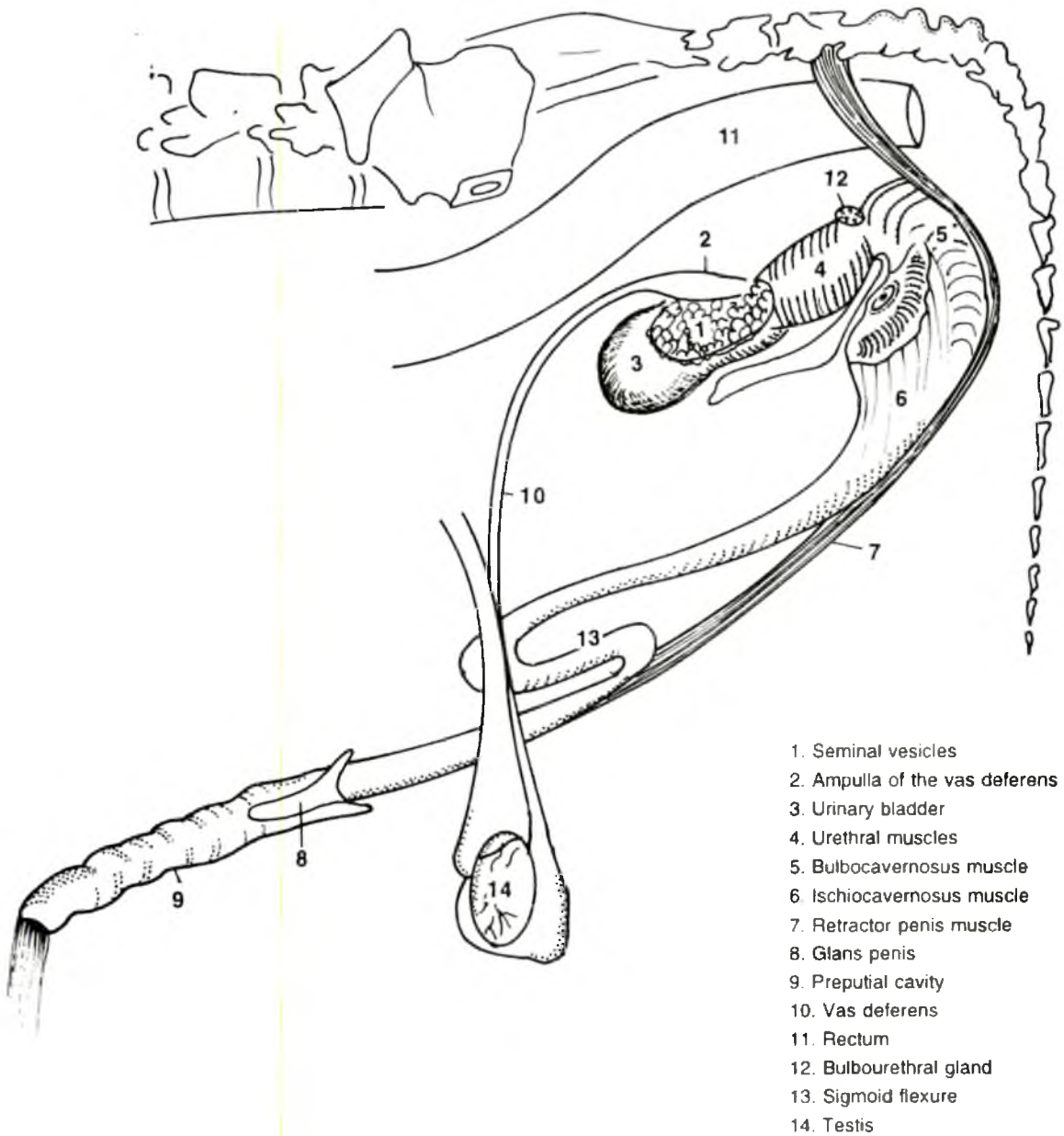

Fig. 1.1. Reproductive organs of the bull.

4. **Tunica albuginea layer** is the tough layer composed of fibromuscular tissue present beneath the visceral layer of the vaginal process.

Extensions of the tunica albuginea penetrate the testicular parenchyma to join at mediastinum. Fibrous septa divided the testicular parenchyma into lobules containing the highly coiled seminiferous tubules. About 75% of the testicular mass is composed of seminiferous tubules. The length of the seminiferous tubules estimated in different species is as follows :

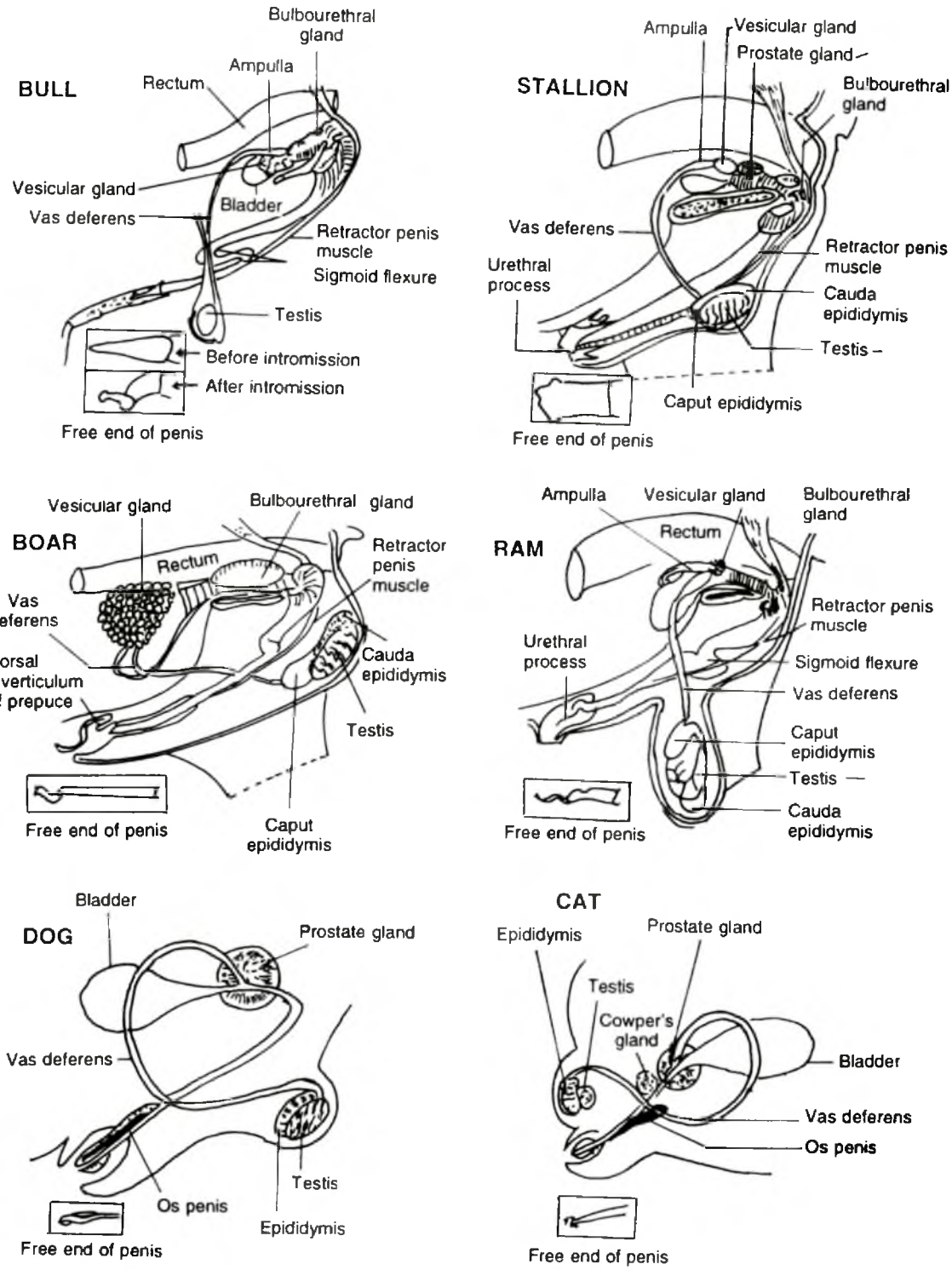

Fig. 1.2. Diagrams showing comparative anatomy of male reproductive organs of bull, stallion, boar, ram, dog and cat.

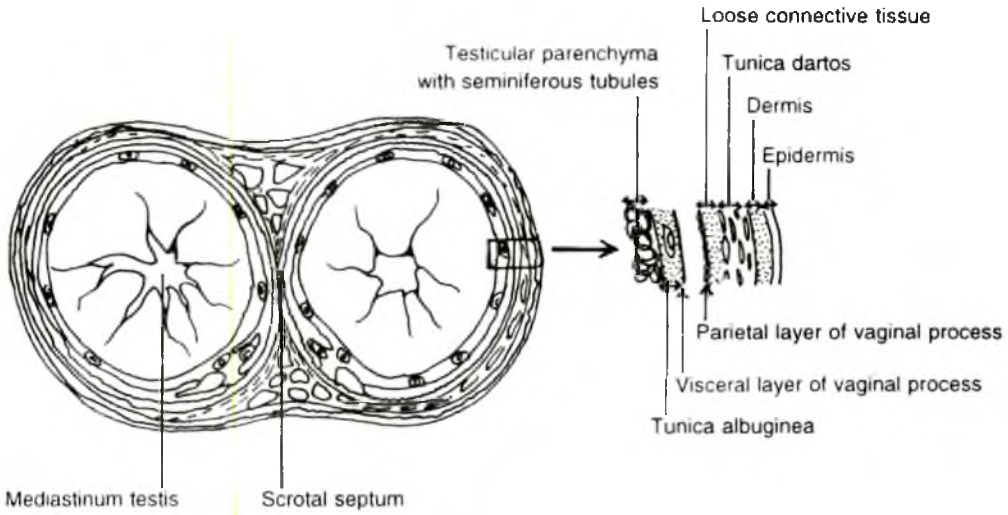

Fig. 1.3. Schematic horizontal section through scrotum to show different layers.

Bull	5000 m
Ram	4000 m
Boar	6000 m
Dog	150 m
Cat	25 m

The seminiferous tubules are lined by germinal epithelium and produce spermatozoa. The seminiferous tubules join the rete testes through straight tubules (the tubuli recti). From rete testes the sperm cells are passed to efferent tubules (6 to 24 in number) and than to head of the epididymis (Fig. 1.4).

In stallion there is no mediastinum testes and the collecting tubules join the efferent tubules. Thus in bull the passage of the spermatozoa from seminiferous tubules is as follows :

Seminiferous tubules → Tubuli recti → Rete testes → Efferent tubules

↓

Urethra ← Ampulla ← Vas deferens ← Epididymis

The testis in the scrotal pouch is held by its tunics and the spermatic cord. The spermatic cord is composed of the following :

1. Internal spermatic artery.

Vaginal process is an extension of the peritoneum passing through abdominal wall at the inguinal canal.

Inguinal canal is the slit like space between the internal abdominal oblique muscle forming the internal inguinal ring (deep opening of the inguinal canal) and the external inguinal ring (superficial opening of the inguinal canal) formed by the tendon of the external oblique muscle.

Rut is the certain definite period of sexual excitement in some wild animals (e.g. deer, camel and elephant). In these animals spermatogenesis occurs only during this period.

2. Internal spermatic vein.
3. Vas deferens
4. Autonomic nerves from renal and caudal mesenteric plexus
5. Lymphatic vessels
6. Internal cremaster muscle
7. Tunica vaginalis propria.

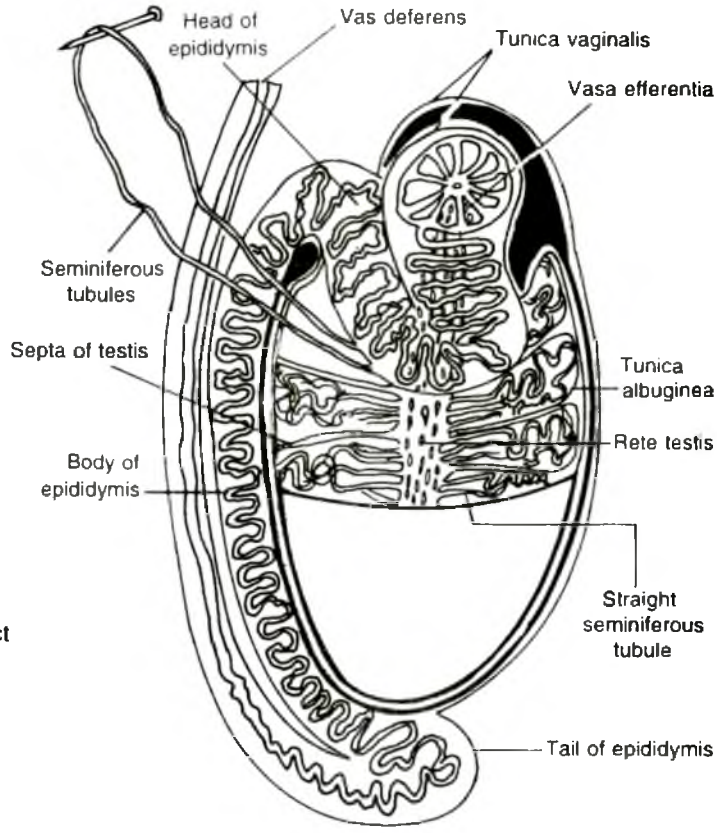

Fig. 1.4. Schematic diagram to show duct system of the testis and epididymis.

The **mesorchium** is delicate and double layer of peritoneum connecting visceral and parietal layer of vaginal process (as mesentery connects visceral and parietal layer of abdominal peritoneum) and continues up to dorsolateral abdominal wall.

In bull, ram and buck the testicles are placed in the scrotum vertically. In the stallion the testicles are placed nearly horizontally in the scrotum but when these are retracted, they become nearly vertical. In boar the long axis of the testis is oblique (neither vertical nor horizontal). Testicular details in different species are given in Table 1.1.

Table 1.1. Shape, colour of parenchyma and measurement of testis

	Horse	Bull	Ram	Boar	Dog	Cat
Shape	Oval	Elongated oval	Elongated oval	Elliptical	Round to oval	Round to oval
Parenchyma	Reddish gray	Yellow	Creamy white	Grayish to dark red	Reddish	Reddish
Measurement (cm)	11 × 6 × 4	14 × 7 × 7	10 × 6 × 6	13 × 7 × 7	1 × 1.2 to 4 × 2.5	1.2 × 0.7 to 2 × 1.5
Weight (gm)	200-300	250-300	200-300	150-200	7-15	—
Plane	Horizontal	Vertical	Vertical	Oblique	Oblique	Oblique

Thermoregulation of testes

For optimum production of the spermatozoa, the temperature of the testis be maintained at a temperature lower by 2 to 5°C than that of the body of the animal. This lowering of the temperature of testis is maintained by the following mechanisms.

1. The scrotal skin lacks subcutaneous fat.
2. The scrotal skin is richly supplied by sweat glands.
3. During cold weather, the cremaster and dartos muscles contract and thus testicles are held close to the body during cold. During hot weather, the cremaster and dartos muscles relax to lower the testis in a thin walled pendulous scrotum.
4. The internal spermatic artery enters the testis from the spermatic cord. The testicular artery is highly convoluted and cone shaped on the dorsal pole of the testis. These arterial coils are enmeshed with the pampiniform plexus of the testicular vein (Fig. 1.5). This arrangement further assists in the heat regulatory mechanisms of the testis. The arterial blood reaching the testis is cooled down by the venous blood leaving the testis.

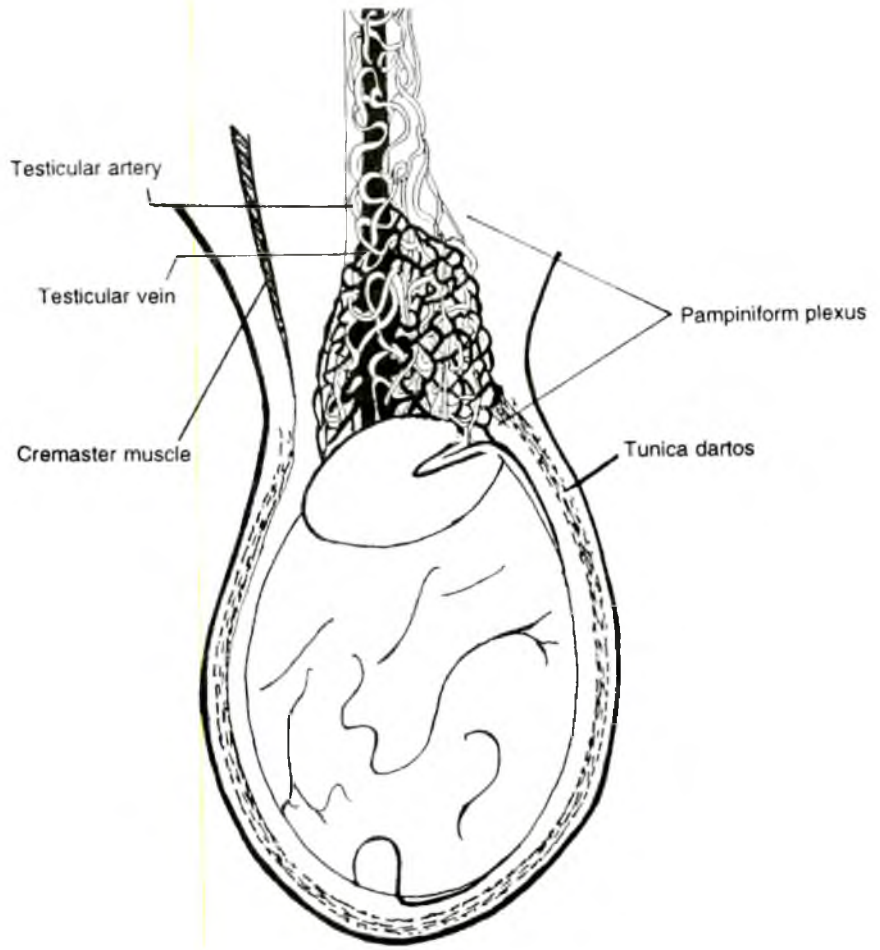

Fig. 1.5. Diagrammatic view to show pampiniform plexus and other structures that help in thermoregulation of testes in bull.

Functions of the testes

The following functions are performed by the testes :

1. Production of testosterone from the interstitial cells (Leydig's cells) lying between the seminiferous tubules (Endocrine function).
2. The spermatogonia situated peripherally in the seminiferous tubules undergo cell division and produce spermatozoa (Exocrine function). In bulls about 12-17 million spermatozoa are produced per gram of testicular tissue daily.

The above two important functional roles of the testes are controlled by the gonadotropic hormones of the pituitary. LH (ICSH) controls the endocrine activity of the Leydig's cells to produce testosterone. Testosterone produced by interstitial cells support the action of the FSH on spermatogenesis, develops and maintains the accessory sex glands, develops secondary sexual characteristics, develops sexual behaviour and is responsible for the functional maintenance of the male reproductive system. FSH controls spermatogenesis in the seminiferous tubules.

3. The blood testis barrier (at the level of the basement membrane of the seminiferous tubules and also by some special features of sustentacular cells) protect the germinal epithelium from the immunological damages.

EPIDIDYMIS

The epididymis is a coiled tube closely attached to the testis by fibrous tissue. The epididymis is more firm is consistency than the testis. The epididymis consists of head (caput), body (corpus) and tail (cauda). The length of the epididymal tube in different animals is :

Bull	30 m
Ram	50 m
Boar	50 m
Horse	20 m

The caput epididymis is broad, somewhat flat, U-shaped and covers nearly one third of the proximal end of the testis. The corpus epididymis is comparatively narrow part, running toward distal end of the testis along its posterior border. The cauda epididymis is enlarged end of the epididymis at the distal pole of the testis and is continuous with the vas deferens.

Histologically two prominent layers (1) circular muscle fibers layer and (2) pseudostratified columnar cells layer are seen in the epididymal wall. Based on histology, the epididymis can be divided in three segments (these segments do not coincide with the gross anatomical segments i.e. head, body and tail of the epididymis). The proximal segment has ciliated cells (having kinocilia) beating out-words. The lumen of the initial segment is almost obliterated (almost no lumen is present). The medusa formations seen in the semen ejaculates are actually the detached ciliated cells from this initial segment of the epididymis. In the middle segment of the epididymis, the lumen is wide and the cilia are not so straight. In the terminal segment of the epididymis the cilia are short, the lumen is very wide and is packed with spermatozoa.

Functions of the epididymis

Various functions of the epididymis are as follows :

1. Absorption

2. Secretion
3. Maturation
4. Transportation and
5. Storage

Absorption : The fluid released by testes is several times more than the volume of the semen ejaculate. It is estimated that ram's testes produce about 60 ml fluid daily while only about 1 ml semen ejaculate is obtained. The epithelial cells of the epididymis, especially of the tail region are involved in the active absorption of fluid. Thus in the cauda epididymis the spermatozoa suspension is highly concentrated.

Secretion : The secretions of the epididymal cells maintain viability of the spermatozoa during storage.

Maturation : During the storage period in the epididymis, the spermatozoa undergo maturation changes. There is migration of the cytoplasmic droplet from the neck of the spermatozoa (proximal protoplasmic droplet) to the distal end of the middle piece (distal protoplasmic droplet) in bull. This change is associated with cytochemical changes in the spermatozoa leading to its increased capacity for motility and fertilizing ability.

Transportation : The transportation of the spermatozoa from rete testis to the efferent tubules is mainly due to the presence of testicular fluid. The further transport of the spermatozoa is due to action of the ciliated epithelium and the action of peristaltic waves of the muscle fibers in the duct. The average duration of the epididymal journey of the spermatozoa in different species is :

Bull	10 days
Ram	13-15 days
Boar	9-12 days
Stallion	8-11 days

Storage : The epididymis is the store house for spermatozoa. The two epididymides in bull can accommodate up to 3-4 days production of spermatozoa by the testis (nearly up to 75×10^9 spermatozoa). The cauda epididymis stores nearly 50% of the extragonadal sperms. However, sperms in the epididymis remain in quiescent metabolic state.

VAS DEFERENS

The two ductus deferens or vas deferens extend from cauda epididymis to the pelvic urethra. The ducts are firm with thick muscular walls and lumen quite small. The ducts are convoluted near the cauda epididymis and then run parallel to the corpus epididymis. Later, these pass through the inguinal canal into the abdominal cavity along with other components of the spermatic card. On reaching the abdominal cavity, the vas deferens separates from the spermatic card, passes upward and backward to open into the pelvic urethra. The vas deferens is about 3 mm thick in bull and about 6 mm thick in stallion. The terminal part of the vas deferens is enlarged and is called ampulla. The ampulla is furnished with branched tubular glands. The ampulla in bulls measures about 10 to 12 cm in length and 1.0 to 1.5 cm in diameter. *There are no ampullae in dog and cat.* The ampullae open in the cranial portion of the pelvic urethra through a rounded prominence called **"colliculus seminalis"**. In the vas deferens the sperm transport is due to peristaltic waves.

ACCESSORY SEX GLANDS

1. The vesicular glands (Seminal vesicles)

The vesicular glands of the bull are paired accessory sex glands having distinct lobulations. These glands are located on the pelvic floor cranial and lateral to the ampullae. Branched tubular secretory glands present in the vascular glands add volume, nutrition and buffers in the semen. These glands open in the pelvic urethra near the opening of the ampullae (colliculus seminalis) or the duct of the vesicular gland and the ampulla may share a common ejaculatory orifice into the pelvic urethra. The approximate dimensions of the vesicular glands in different species are as follows :

	Length (cm)	Breadth (cm)	Thickness (cm)	Weight (gm)
Bull	10-15	2.0-4.0	2.0	75.0
Stallion	15-20	2.5-5.0	5.0	—
Boar	12-15	5.0-8.0	4.0	200.0
Ram	4-5	2.0	1.5	5.0

The secretions of the vesicular glands make up about 50% of the total semen ejaculate. Compared to prostatic secretions, the vesicular secretions are more alkaline. The secretion contains protein, fructose, ascorbic acid, citric acid, potassium bicarbonate, acid soluble phosphate and several enzymes. In mammals most of the seminal fructose comes from vesicular glands. The vesicular glands of the stallion are elongated pear shaped sacs and the secretions of these glands constitute gel to the ejaculate. In boar the vesicular glands are large bag like and contains a milky and highly viscous fluid. In boar the vesicular secretion has high inositol contents and also contains ergothioneine. In bulls the secretion of vesicular gland is yellow due to high riboflavin contents. *These glands are absent in dog and cat.*

2. The prostate gland

The prostate gland has different forms in different species. In bull the gland is located on the pelvic floor, on or around the neck of the bladder or the cranial portion of the pelvic urethra. The gland opens into the pelvic urethra lateral to the "colliculus seminalis" (opening of the ampullae) through many ducts. In dog there are only two excretory ducts of prostate gland.

In bull the prostrate gland surrounds the pelvic urethra and has two parts, the body of the prostate (pars propria) and the pars disseminata which surrounds the pelvic urethra. The approximate dimensions of the prostate gland in bull and boar are as follows :

	Pars propria (cm)	Pars disseminata (cm)
Bull	3 × 1 × 1	12 × 1.5 × 1.0
Boar	3 × 3 × 1	17 × 1.0 × 1.0

In ram, the prostate gland has no body and is scattered over the large portion of the pelvic urethra. In stallion, the prostate gland consists of two lateral lobes (each 7 × 4 × 1 cm) connected by isthmus (2 × 3 × 0.5 cm).

In dog the size of the prostate gland varies greatly and may be quite large in older dogs. Some disseminate lobes are present in the urethral wall.

The prostatic secretions are rich in enzymes that resemble interior milieu of the cells rather than the external milieu of the cells e.g. glycolitic enzymes, proteinases, phosphatases, glycosidases, nucleases and nucleotidases. In dog the pH of the prostatic secretion is 6.5 and there are no reducing sugars. However, canine prostate secretion contains citric acid and acid phosphatase. Canine prostate secretion has high concentration of zinc. Zinc concentration in the seminal plasma is chiefly due to prostatic secretion.

3. The bulbourethral glands (Cowper's glands)

In bull, the bulbourethral glands are the paired glands lying on either side of the pelvic urethra in the region near the ischial arch. In bull, these glands are embedded under the bulbospongiosus muscle. These gland are ovoid in bull, stallion and ram and are large and cylindrical in boar. *These glands are absent in dog.* In cat these are of the size of the prostate. The dimensions of the bulbouretheral gland in different species of animals are as follows :

	Diameter (cm)	Length (cm)
Bull	1.5-3.0	—
Stallion	2.5-5.0	—
Ram	0.5-1.0	—
Boar	2.5-3.0	12.0

In bull and boar each gland opens in urethra through a single duct, but in stallion each gland opens into the urethra through 6 to 8 secretary ducts. In bulls, the dribbling seen from the prepuce prior to mounting are secretions from the prostate and bulbourethral glands. These secretions delete harmful substances if present in the urethra and clean it prior to semen ejaculation. The typical rubber like white substance is filled in the Cowper's glands of the boar that is essential for gel formation in boar semen.

URETHRA

The urethra in males is the common passage for the excretion of urine as well as for the transportation of semen. The urethra has three distinct parts (pelvic part, bulb of urethra and the penile part). In bull, the pelvic part of urethra is about 20 cm in length and is situated on pelvic floor. The pelvic urethra is enclosed by heavy urethral muscle. The bulb of urethra is extra pelvic part situated at ischial arch and is bending ventral to the pelvis. The penile urethra runs inside the penis proper. **Urethral glands** are seen in man. These gland are absent in bull and stallion. However in boar, urethral glands are distinct.

PENIS

The penis is the copulatory organ in males. The penile body is largely composed of corpus cavernosum penis. The corpus cavernosum penis arises as a pair of crura or roots from the ischial arch under ischiocavernosus muscle. The carpus cavernosum penis is enclosed by a thick layer of tunica albuginea, which is made up of collagen fibres. Several trabeculae are sent from tunica albuginea to enter into the corpus cavernosum penis for the support of cavernous (cave like) tissue. Ventral to the corpus cavernosum penis and surrounding the penile urethra is smaller corpus spongiosum penis (also called corpus spongiosum urethrae) as shown in Fig. 1.6. The carpus

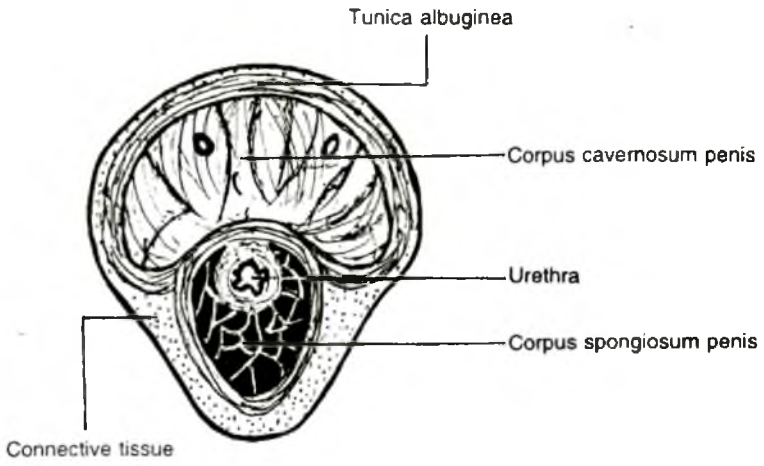

Fig. 1.6. Schematic diagram of the cross section of the penis of bull near caudal end.

spongiosum penis in enlarged at ischial arch to form the penile bulb. The bulb is covered by bulbospongiosus muscle (also called bulbocavernosus muscle). The two corpora (corpus cavernosum penis and corpus spongiosum penis) have several spaces (blood sinusoids) regarded as enlarged capillaries and are continuous with veins in the penis. Distention of these spaces with blood, causes penile erection. In bull, ram, and boar the penis is characterized by S-shaped curve, the sigmoid flexure. The sigmoid flexure is post-scrotal in bull and ram and pre-scrotal in boar. Sigmoid flexure is absent in horse. Inchiocavernosus muscle or erector penis muscle is a short paired muscle and helps penile erection by its compressing and pumping action. The retractor penis muscle is a smooth muscle and arises from sacral or first and second coccigeal regions, divides and meets again under the anus and attaches to the penis at the distal end of the sigmoid flexure with fibers extending dorsally on the penis. The thickened dorsal portion of this fibrous sheath is known as dorsal apical ligament of the penis. The retractor penis muscle draws the penis back into sheath by acting on sigmoid flexure.

The penis of the **bull** is about 90 cm in length from its root to the tip of the glans. The diameter is about 4 to 5 cm on erection. The glans penis is 7.5 to 12.5 cm long and is rather pointed. The glans penis (terminal part) is pointed and slightly twisted. After intromission the spirally arranged fibrous penile and prepenile prepuce is stretched and this causes the penis to spiral (Fig. 1.7). The penis of the bull is fibroelastic and the erectile tissue is too less compared to stallions.

The penis of the **stallion** has large amount of the erectile tissue. The length is about 50 cm and the diameter about 2.5 to 6.0 cm when not erect. A length of about 15 to 20 cm lies free in the prepuce. The length of the penis increases to about double and of the glans penis to about triple on erection. There is a prominent urethral process in the glans penis (Fig. 1.7) encircled by a shallow groove called as fossa glandis which forms urethral sinus or diverticulum, dorsal to the urethral process. The diverticulum (sinus) is often filled with smegma and carries infection, causing contagious equine metritis. The retractor penis muscle is not as strong as in bulls.

The penis of the **ram** is about 30 cm in length and 1.5 to 2.0 cm in diameter and is characterized by urethral process, which extends 4 to 5 cm beyond the glans penis (Fig. 1.7).

The penile length of the **boar** is about 45 to 55 cm. There is no glans penis but the cranial portion is twisted counter clockwise (Fig. 1.7).

The penile length of **dog** during non-erect condition varies from about 6.5 to 24 cm depending upon the size of the dog. The penis of dog has two separate corpora cavernosa (separated by a medial septum). The cranial free portion of the penis contains a bone called "os penis" which is grooved ventrally for urethral passage. The glans penis of the dog consists of two parts. The proximal one third part of the glans is "bulbus glandis" and the distal two third part is "pars longa glandis". The proximal part "bulbus glandis" usually becomes engorged with blood after the penis enters the vagina of the bitch and the withdrawal of the penis is not possible for some time after service until erection subsides.

The penis of the **cat** is short and is directed caudally and ventrally. The urethra lies dorsally in the penis. The os penis is either absent or short. The bulbus glandis is also absent. The glans penis is also absent but the terminal part (about 1 cm) contains several spines (about 120) pointing backward (Fig. 1.7). Because of the pain caused by these spines the queen emits a loud cry after service.

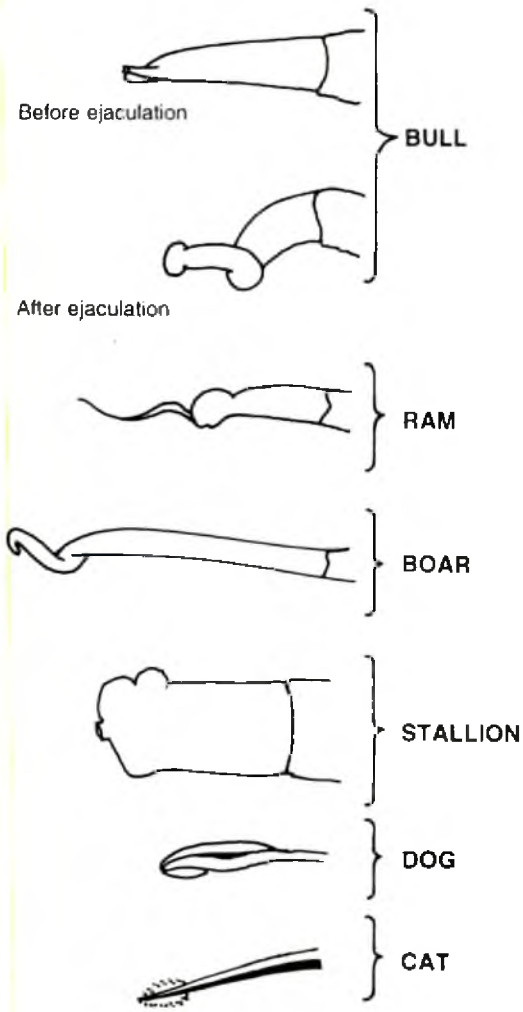

Fig. 1.7. Diagrams showing free end of penis in bull, ram, boar, stallion, dog and cat.

PREPUCE

The prepuce is the invaginated fold of skin surrounding the free end of the penis, when not erect.

- The prepuce in the **bull** is about 35 cm long and 4 cm in diameter. The prepucial orifice is 5 to 7 cm behind umbilicus and is surrounded by tuft of hair. In the bulls of Indian breeds, the prepuce is in the form of pendulous sheath.
- The prepuce of the **horse** makes a double fold. The prepucial cavity is 15 to 20 cm deep and then there is second fold to form the prepuce proper. Prepucial ring is prominent in between the two prepucial folds.
- The prepuce of **ram** is similar to bull but is relatively short.
- The prepuce of **boar** has a diverticulum (pouch) dorsal to the prepucial orifice. This diverticulum is filled with urine, secretions and dead cells and thus produces typical odour.

BLOOD AND NERVE SUPPLY

The **testicle** is supplied blood from internal spermatic artery originating directly from aorta. The internal spermatic veins run parallel to the internal spermatic artery except near testis where it is more convoluted and tortuous to form pampiniform plexus, which plays important role in the thermoregulation of the testes. The nerve supply to the testis is through fibers from renal and caudal mesenteric plexus. These fibers run close to the internal spermatic artery.

The blood to the **scrotum** is supplied by the external pudendal artery (also the internal pudendal artery in cat and boar). The nerve supply to the scrotum is by genital nerve (which is a branch of genito-femoral nerve arising from second to fourth lumber nerves and perineal nerve).

The blood supply to the **penis** is through internal pudendal artery (to the root of the penis, obturator artery (to the body of the penis) and the external pudendal artery which gives rise to dorsal artery of the penis after passing through the inguinal canal. The nerve supply to the penis is from autonomic nerves from pelvic plexus and from pudendal and hemorrhoidal nerves. The pudendal and hemorrhoidal nerves are the motor nerves for retractor penis muscles. The dorsal nerve of the penis is a branch of pudendal nerve and supplies sensory fibers to the glans penis. These sensory fibers provide the afferent side for the reflex of erection and ejaculation. The reflex centers for erection and ejaculation are located in the lumber portion of the spinal cord.

The blood supply to the **accessory sex gland** in large animal is from internal pudendal artery. In dog the supply to accessory sex glands is from prostatic artery (a branch of urogenital artery arising from internal iliac artery). The nerve supply to the accessory sex glands is through autonomic nerves from hypogastric nerve and pelvic plexus.