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Anatomy of the Reproductive System in the Buck and Doe

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1.1 Introduction

Reproduction is crucial for the survival of species. It is the method used by living things to reproduce (Frandson et al. 2003). Since being domesticated, the goat has become seasonally polyestrous, meaning that it reproduces naturally at specific periods of the year. The photoperiod, rasse, and nutrition are the key determinants of this trait's variation (Delgadillo et al. 2012). Several areas of goat production are influenced by reproduction, so managing reproduction requires an understanding of this process. For survival of the species, the production of meat, milk, skin, and fiber, as well as the replenishment of breeding stock, a high rate of reproductive efficiency is crucial (Abebe 2008).

Male and female individuals in each species have specific anatomical and functional features (Nickel et al. 1973). Therefore, for easier understanding, this chapter is divided into two sections: the male reproductive system and female reproductive system in goats.

1.2 Male Reproductive System

The major function of this system is the production of spermatozoa and male sex hormone (Frandson et al. 2003). The male reproductive system consists of the following structures (Figures 1.1 and 1.2).

1) Scrotum
2) Testes
3) Epididymis
4) Ductus deferens
5) Accessory sex glands
6) Penis
7) Urethra

1.2.1 Scrotum

The testicles and nearby spermatic cord segments are located in the scrotum, which is a sac or pouch (Figure 1.1). It can take on a variety of shapes depending on the health of its subcutaneous muscular tissue. When exposed to cold, the latter constricts, causing the scrotum to rise and become thicker and wrinkled; when relaxed by heat, weariness, or debility, however, it becomes smooth and pendulous with a superior neck constriction (Frandson et al. 2003). It consists of layers which correspond with those of the abdominal wall, considered from without inward: skin, dartos, scrotal fascia, parietal layer of the tunica vaginalis (Getty 1975; Farooqui 2004; Pathak et al. 2014).

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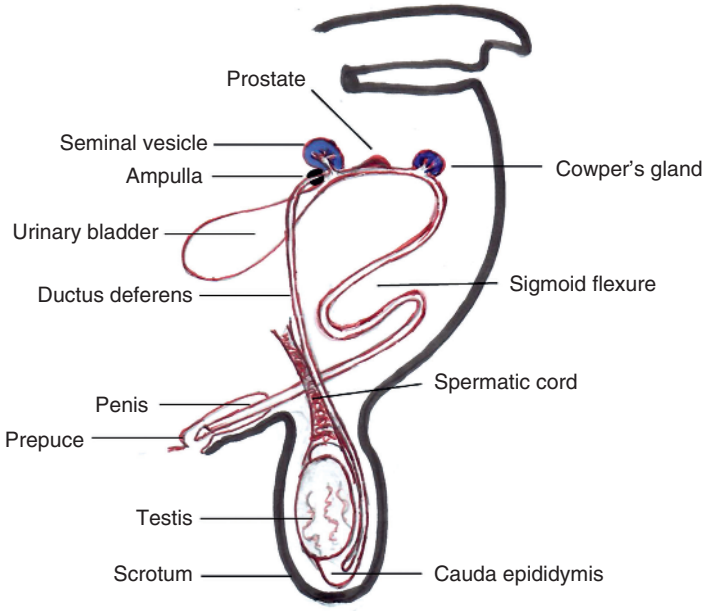


Figure 1.1 Diagrammatic presentation of the male reproductive system.

Figure 1.2 Photograph showing the organs of the male reproductive system.

The spermatic cord begins at the abdominal inguinal ring, where its constituent parts come together, extends obliquely downward through the inguinal canal, passes over the side of the penis and ends at the attached border of the testicle (Figure 1.2). It consists of the following structures.

1) Spermatic artery.
2) Spermatic vein.
3) Lymphatics.
4) Sympathetic nerves.
5) Ductus deferens.
6) Internal cremaster muscles.
7) Visceral layer of tunica vaginalis.

1.2.2 Testes

The testis is the seat of production of male germ cells. The testes are located in the inguinal region of the body and are enclosed in the scrotum (Frandson et al. 2003; Pathak 2006). They descend into the scrotum from the abdominal cavity during fetal development. Descent of the testes from the genital ridge in the fetus to an extracorporeal location after birth is a mandatory development process to ensure normal spermatogenesis in the mature testis (Farooqui 2004).

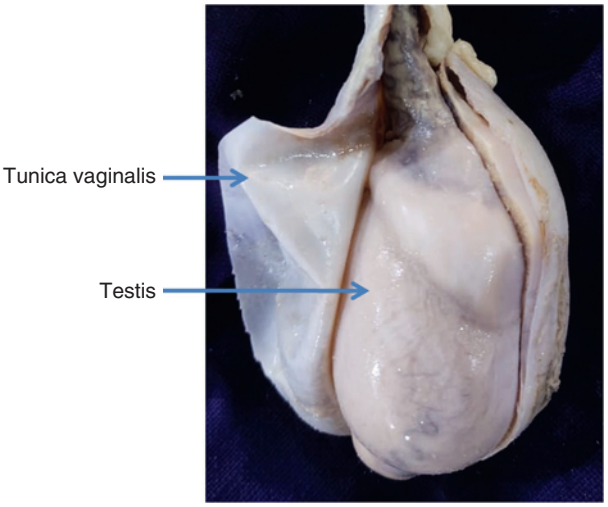


Figure 1.3 Photograph showing the testis and tunica vaginalis.

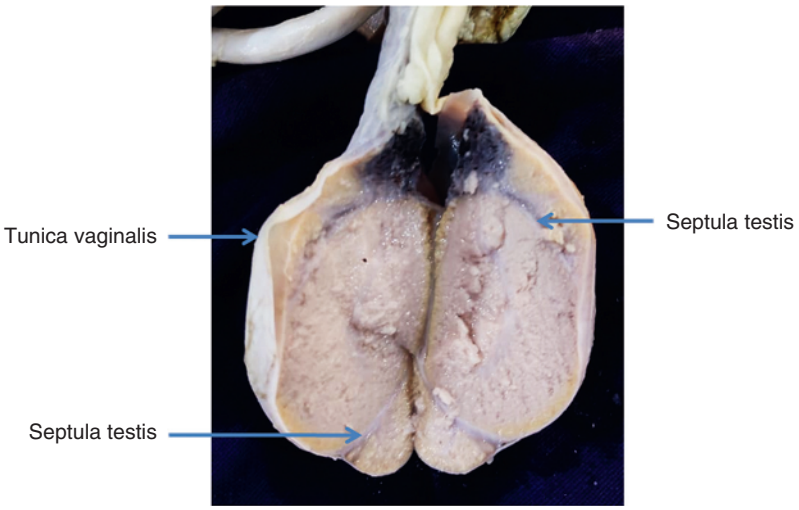
Each testis weighs about 130–160 g with an elongated oval form and the long axis nearly vertical (Figure 1.1). It comprises two surfaces, two borders and two extremities. Both the surfaces, i.e. the medial and lateral surfaces, are convex and smooth. The cranial border is free and the caudal border is attached to the epididymis. The dorsal and ventral extremities are termed the head and tail, respectively. A testicle of an average sized adult buck is 6–7, 4–5, and 4–5 cm in length, width, and thickness (in middle), respectively (Solaiman 2010). The testes are frequently of unequal size, with the left typically being larger, and their sizes fluctuate greatly. Testicular growth is extremely rapid from birth to puberty and then does not change significantly (Pathak et al. 2014). The testes of goats are broader in proportion to their length.

The tunica vaginalis, which is the visceral layer of the serous envelope surrounding the spermatic cord and testicle, covers the majority of the testicle's surface (Figure 1.3). This is reflected from the attached border of the gland, leaving an exposed area where the spermatic cord's vessels and nerves enter the testicle. The tunica albuginea, a robust capsule made of dense white fibrous tissue and unstriped muscle fibers, lies beneath the tunica vaginalis.

The spermatic artery supplies blood to the testicle. The artery is quite convoluted close to the testicle and descends in the anterior portion of the spermatic cord. It splits into many branches that enter the gland on the trabeculae and septa (septula testes) and ascend and descend on the testicular surfaces (Figure 1.4). The pampiniform plexus is a network formed by the testicular veins as they exit the testis and encircle the spermatic cord's artery. The lymphatic vessels often follow the veins' path before entering the lumbar lymph glands. The spermatic plexus, to which the vessels are primarily dispersed, is formed by the renal and posterior mesenteric plexuses, which supply the nerves.

The exocrine function of the testes is spermatogenesis under the influence of follicle-stimulating hormone (FSH) and testosterone, whereas their endocrine function is the synthesis and release of testosterone by Leydig cells under the effect

Figure 1.4 Photograph (sagittal section) showing the septula testis.



of luteinizing hormone (LH)/interstitial cell-stimulating hormone (ICSH). Castration is removal of the testicles in order to reduce buck aggression (König and Liebich 2020).

The blood supply to the testes is via the internal spermatic artery and innervation occurs via the renal and mesenteric plexuses.

1.2.3 Epididymis

The epididymis serves as the chief ductal system, besides providing nutrition for growth and maturation. The epididymis is attached to the caudal border of the testicle and somewhat overlaps the lateral surface. Its dorsal enlarged end is termed the head (caput epididymis), its ventral, slightly enlarged end is the tail (cauda epididymis), and the intermediate part is the body (corpus epididymis). The head is closely connected with the testicle by the efferent ducts, in continuation of the rete testis. The efferent ducts together form the ductus epididymis which runs inside the body of the epididymis. The ductus epididymis is very flexible and almost 60 m in length in the adult buck. The tail is continued by the ductus deferens/vas deferens which is attached to the posterior extremity of the testicle by the ligamentum epididymis.

1.2.4 Ductus Deferens

The ductus deferens extends from the tail of the epididymis to the pelvic urethra. It ascends in the inguinal canal, enclosed within the spermatic cord. At the vaginal ring, it separates from the other constituents of the spermatic cord, and turns backward and inward into the pelvic cavity to reach the pelvic urethra just caudal to the neck of the bladder. The two ducts lie very close together and empty on the roof of the urethra as enlarged ampullae.

1.2.5 Accessory Sex Glands or Annex Glands

Accessory sex glands are conspicuous outgrowths of the genital tract and can be regarded as part of the male reproductive system as they play an integral role in the fertility process. In the buck, they include the vesicular gland, prostate gland and bulbourethral or Cowper's gland.

The vesicular glands are paired sac-like lobulated glands, located on each side of the posterior dorsal surface of the neck of the urinary bladder. The excretory duct dips behind the prostate and opens in a mucous membrane pouch on the side of the colliculus seminalis, either alongside or concurrently with the ductus deferens. Each gland is 3–4 cm in length. In the buck, the disseminate part of the prostate gland surrounds the wall of the pelvic urethra. The prostatic ducts open in the pelvic urethra behind the colliculus seminalis. Each gland is covered by urethral muscles which are thin dorsally and ventrally, and thick laterally. At the ischial arch, on either side of the pelvic urethra, are the spherical bulbourethral glands which are covered by the urethral muscle. Their excretory ducts open directly into the urethral recess.

1.2.6 Penis

The penis, the organ of copulation, is made of fibroerectile tissue. Its length in bucks is roughly 0.4 m (Solaiman 2010). It extends from the ischial arch to the umbilical region of the abdominal wall (Figure 1.1). It is made up of the root, body, and glans. Two crura, which converge and merge beneath the ischial arch, connect the root of the penis to the lateral portions of the arch. The bulk of the organ, the body, starts at the point where the crura converge. Two sturdy flat bands, the suspensory ligaments of the penis, which converge with the tendon of origin of the gracilis muscles, bind it to the symphysis ischii at its beginning. The expanded free end of the penis is known as the glans penis.

Just behind the scrotum, it forms an S-shaped sigmoid flexure (Figure 1.1). The corpus cavernosum penis and the corpus cavernosum urethrae are the two main erectile structures that make up the penis. With the exception of its free extremity, the corpus cavernosum penis makes up the majority of the penile mass. The urethra is surrounded by a tube called the corpus cavernosum urethrae, which is connected with the glans penis at its anterior end. The prepuce is a very short tubular sheet covering the cranial free portion of the penis in the nonerectile state. The prepuce (foreskin) is the skin sheath that encloses and protects the free part of the penis when it is not erect. It is an analogue of the female labia majora.

1.2.7 Urethra

The urethra consists of two parts: the pelvic urethra and penile urethra. The urethral muscle encircles the pelvic urethra, which is located on the floor of the pelvic cavity. The penile urethra is inserted into the body of the penis and passes between the two penis crura. The corpus cavernosum penis' ventral surface has grooves where the urethra is located. The name "process urethrae" refers to the penile urethra's terminal part, which extends 1.5 inches beyond the glans penis. Uncastrated bucks have longer and larger urethras and various penile segments than do castrated bucks (Islam et al. 2021).

1.3 Female Reproductive System

The reproductive system of the doe comprises the following structures (Figures 1.5 and 1.6).

1) Ovaries.
2) Uterine or fallopian tubes or oviducts.
3) Uterus.
4) Vagina.
5) Vulva.
6) Mammary glands.

1.3.1 Ovaries

The ovaries are ovoid or almond-shaped structures located within the pelvic cavity suspended from the roof of the cavity by the mesovarium. They may show many other morphological shapes, e.g., heart shaped, long and narrow, many-sided and almost horseshoe shaped (Lyngset 1968). In most does, the right ovary is slightly larger than the left and measures approximately 14.4–17.7 mm in length and 10.0–13.5 mm in width while the left ovary measures 14.1–17.1 mm in length and 8.0–13.3 mm in width (Gupta et al. 2011; Bijna et al. 2016; Uddin et al. 2021). However, sometimes the trend may be reversed with a larger left ovary (Doğan et al. 2020). The size of the ovary depends on the physiological status of the animal; for example, during the estrous cycle, the development of antral follicles results in an increase in size whereas regression returns it to the previous size. Similarly, the ovaries become larger during pregnancy and show a gradual increase with advancement of gestational age (Jaji et al. 2012).

Each ovary is composed of two surfaces, two borders, and two extremities. The surfaces are medial and lateral and are smooth and rounded in prepubertal animals and irregular in cycling animals. The borders are the attached and free borders. The attached or mesovarial border is convex where the ovary is enclosed in a part of the broad ligament (mesovarium) through which the vessels and nerves reach the gland. The anterior extremity (tubal) is rounded and is related to the

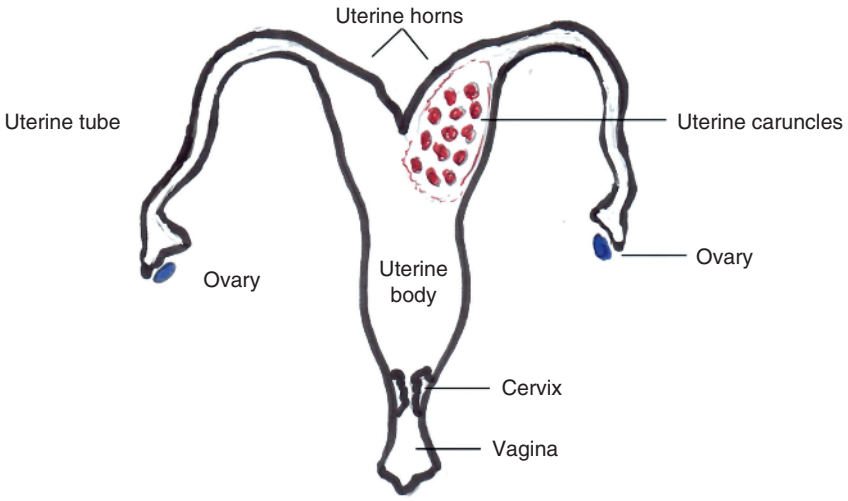


Figure 1.5 Diagrammatic presentation of the female reproductive system.

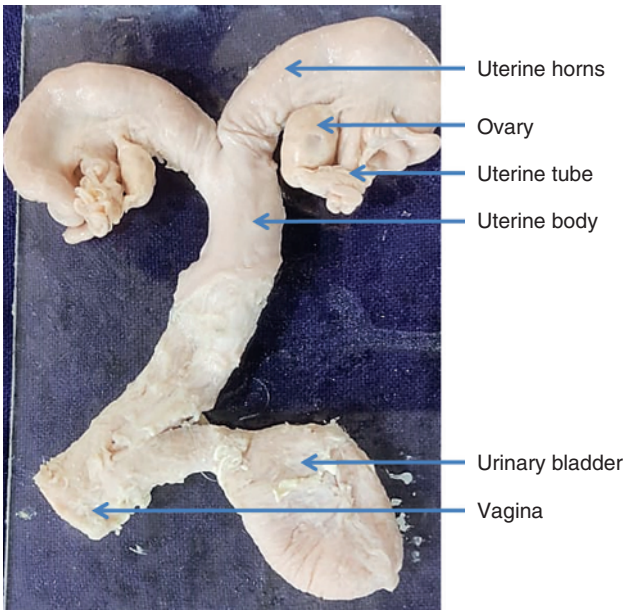


Figure 1.6 Photograph showing the organs of the female reproductive system.

fimbriated end of the oviduct. The posterior extremity (uterine) is also round, and connected with the uterine horn by the ovarian ligament. They are usually present adjacent to the lumbar wall of the abdomen. The ovarian ligament is a band of smooth muscle enclosed between the layers of the broad ligament. The ovarian stroma is a network of connective tissue. In young subjects, in the meshes of the stroma there are numerous follicles (folliculi oophori), containing oocytes in various stages of development (König and Liebich 2020; Uddin et al. 2021).

Depending on the stage of development, the oocyte is surrounded by one or many layers of follicle cells, i.e., primordial and primary follicles (single layer) and secondary and mature follicles (multilayered), forming the stratum granulosum, and by a condensation of the stroma termed the theca folliculi. A few follicles get recruited (depending on the breed) and show further development to become mature. The antrum of the mature follicle is filled by a fluid, the liquor folliculi. At one point, a collection of granulosa cells encloses the oocyte (cumulus oophorus–oocyte complex), connecting it with the follicle wall. Such follicles (folliculi oophori vesiculosi) enlarge to a diameter of 1 cm or more as they mature, becoming visible to the naked eye. The fully developed follicles are superficially situated and project slightly from the surface of the ovary. In cycling goats, these follicles rupture to release the oocyte (ovulation) and result in the formation of corpus/corpora luteum/lutea (CL). The CLs initially develop and in absence of fertilization, regress to become the corpus/corpora albicans (a fibrous scar). Therefore, in old animals, the ovaries commonly consist largely of fibrous tissue. The other follicles/oocytes which were not recruited regress and are phagocytized later (Eurell and Frappier 2006).

1.3.1.1 Vessels and Nerves

The ovarian arteries are paired and originate from the abdominal aorta. They are relatively large and flexible and reach the attached border of the ovary by passing between the layers of the mesovarium. The veins are large and numerous. They form a plexus similar to that of the spermatic cord. The lymph vessels pass to the lumbar glands. The nerves are derived from the sympathetic system through the renal and aortic plexuses. They accompany the arterial branches.

1.3.2 Uterine Tubes/Fallopian Tubes/Oviducts

The paired uterine tubes act as excretory ducts of the ovaries, as they convey the oocyte from the ovary to the uterus. They are not in direct continuity with the ovary but rather partly in continuity with, and partly attached to, it. Each flexible uterine tube ranges between 10.0 and 16.0 cm in length and approximately 0.2 cm in diameter and extends from the uterine extremity of the ovaries to the uterine horn. The right tube is slightly longer than the left in most does (Talukder et al. 2015). The ovarian end of the tube is funnel shaped and fimbriated, and then it widens considerably to form the ampulla tubae. Each is enclosed in a peritoneal fold, derived from the lateral layer of the broad ligament (the mesosalpinx). The uterine extremity of the tube communicates with the cavity of the uterine horn by a minute orifice, the ostium uterinum tubae. The ovarian extremity is expanded and somewhat funnel shaped, and is therefore termed the infundibulum tubae uterinae. The ovarian extremity of the tube appears normally to be applied to the ovary, so that the extruded oocytes pass into it and are conveyed to the uterus (Gupta et al. 2011; Doğan et al. 2019; Uddin et al. 2021).

1.3.2.1 Vessels and Nerves

The arterial supply to the oviduct is from branches of the uteroovarian artery. The veins are satellites of the arteries. The lymph vessels pass with the ovarian vessels to the lumbar glands. The nerves have a similar origin to those of the ovary.

1.3.3 Uterus

The uterus is a hollow musculomembranous tubular organ, which is continuous with the uterine tubes anteriorly and opens into the vagina posteriorly. Overall, the uterus in does is bicornuate (Kumar et al. 2020). It is situated chiefly in the posterior aspect of the abdominal cavity but extends a short distance into the pelvic cavity (in nonpregnant animals). It is suspended in the sublumbar region and the lateral walls of the pelvic cavity by the broad ligaments (two folds of peritoneum).

It consists of two horns (cornua uteri), the body (corpus uteri), and the neck (cervix uteri). The uterine horns are long, coiled, and entirely situated in the abdomen. They appear to vary considerably in position; commonly they are pressed up against the sublumbar muscles by the intestine (cecum, left parts of large colon, small colon, and small intestine). They are cylindrical when moderately distended and are approximately 4–5 inches long and 1–1.5 inches in diameter (nonpregnant animal) but reach up to 15–18 inches in length and 4–5 inches in diameter or even more during pregnancy and are highly variable depending upon the size and number of fetuses (Doğan et al. 2020). Morphometrically, the horn which has fetuses inside is larger than the other. The anterior extremity of each horn receives the isthmus of the uterine tube. Posteriorly, they increase slightly in caliber, converge and continue with the body. The dorsal border is slightly concave and is attached to the sublumbar region by the broad ligament while its ventral border (margo liber) is convex and free.

The body of the uterus is situated partly in the abdominal, partly in the pelvic cavity. It is cylindrical but considerably flattened dorsoventrally, so that in cross-section it is elliptical (Kumar et al. 2020). Its average length is 1–3 inches and its diameter is 1–2 inches in the nonpregnant animal while it reaches 9–10 inches in length and 10–12 inches in diameter during pregnancy (Doğan et al. 2020). Dorsally, it is related to the rectum and other parts of the intestine while it rests on the urinary bladder ventrally. The portion where the uterine horns originate from the body is called the fundus (fundus uteri) which is the wide anterior part. The neck of the uterus is the constricted posterior part which joins the vagina and possesses two openings (os/osteum uteri) – the internal and external os. It is about 1.5–2 inches long and 0.5–1.5 inches wide. It increases in dimension to reach 3–4 inches in length and 4–5 inches in diameter at parturition (Jaji et al. 2012; Doğan et al. 2020). The openings are closed by mucous plugs during the nonestrous (resting) period.

1.3.3.1 Attachments

Two large peritoneal folds, the broad ligaments of the uterus, hold the body and horns to the abdominal and pelvic walls. They extend to the dorsal border of the cornua and the lateral edges of the uterine body on either side from the sublumbar area and the lateral pelvic walls. They contain connective tissue, a significant quantity of smooth muscle fibers that are continuous with those of the uterus, the arteries and nerves of the uterus and ovaries, as well as connective tissue. The round ligament of the uterus, which projects from the lateral layer of each and folds into the parietal peritoneum above the abdominal inguinal ring, has its anterior extremity above the cornu's extremity and resembles a long, round appendix. It is a replica of the gubernaculum testis and contains muscles, blood vessels, and nerves. Due to its continuity with the vagina, the anterior section of the neck is in a more permanent position than the rest of the organ.

The contraction of the uterine wall and the folds of the mucous lining in the nonpregnant state completely obliterate the uterine cavity. It connects to the uterine tube at the end of each cornu by a minute opening on a small papilla. The cervical canal (cavity of cervix) is often sealed off by mucous folds and plugs. It has two orifices: one that opens into the body (orificium internum uteri) and one that opens into the vagina (orificium externum uteri).

1.3.3.2 Vessels and Nerves

The major arterial supply is from the uterine branch of the uteroovarian artery, which passes in the broad ligaments. It also gets a branch from the internal pudic artery. The veins form pampiniform plexuses and are satellite to the arteries. The lymph vessels are numerous and travel to the internal iliac and lumbar glands. The nerves are derived from the sympathetic through the uterine and pelvic plexuses.

1.3.4 Vagina

The vagina is the horizontally oriented musculomembranous tubular connection between the neck of the uterus (external os) and the vulva or vestibule and is located in the pelvic cavity. It is about 2.5–3.0 inches in length and, when slightly distended, about 1.5–2.0 inches in diameter (Uddin et al. 2021). It is connected laterally to the pelvic wall, ventrally to the

urine bladder, and dorsally to the rectum. The peritoneal rectogenital pouch often reaches between the rectum and vagina for a short distance. As a result, the majority of the vagina is retroperitoneal and is encircled by a venous plexus, a quantity of loose connective tissue, and a varied amount of fat. The lumen of the cavity is a transverse slit under normal circumstances because of the apposition of the walls, which is more obvious when the rectum is full (Getty 1975). The intravaginal portion of the uterus neck occupies a considerable portion of the anterior end of the vagina, reducing the cavity to an annular recess known as the fornix vaginae. The transverse fold that covers the external urethral orifice serves as the only line of demarcation between the posterior section and the vulva in very young animals; this fold is extended on either side to produce the hymen, which narrows the entry to the vagina (König and Liebich 2020).

1.3.4.1 Vessels and Nerves

The arterial supply to the vagina is derived from the branches of the internal pudic arteries. The rich venous plexus drains into the internal pudic veins. The lymphatics join the internal iliac lymph glands. The innervation is basically sympathetic nerves derived from the pelvic plexus and supported by numerous ganglia located in the adventitia (König and Liebich 2020).

1.3.5 Vulva

The final section of the female genital system is known as the vulva. It opens externally at the vulvar cleft (rima vulvae) below the anus and is continuous with the vagina in the front. The vulva and vagina are not physically separated from one another. It measures 1–1.5 inches in length and approximately 1.5 inches in width. It is guarded by paired vertically oriented and rounded vulvar lips (labia vulvae) joining together at dorsal (at an acute angle) and ventral (rounded) commissures behind and below the ischial arch. It is related dorsally to the rectum and anus, ventrally to the pelvic floor, and laterally to the sacrosciatic ligament, the semimembranosus muscle and the internal pudic artery. When the labia are drawn apart, a rounded body is seen occupying a cavity in the ventral commissure which is called the glans clitoridis, the homologue of the glans penis, and the cavity in which it lies is the fossa clitoridis. The roof of the fossa is formed by a thin fold which overlies the glans clitoridis and is attached centrally to it (Gupta et al. 2011).

The external urethral orifice is covered by a fold of mucous membrane, the free edge of which is directed backward. The clitoris is the homologue of the penis and consists of similar parts (except the urethra and its muscle). The corpus clitoridis is attached to the ischial arch by two crura and its glans is in the form of a rounded and enlarged free end located in the fossa clitoridis in the ventral commissure of the vulva (Gupta et al. 2011). It is covered by a thin layer of pigmented skin that is continuous with and resembles the skin that lines the fossa; together, these two components make up the prepuce of the clitoris. The clitoris possesses erectile tissue similar to the corpus cavernosum penis. The ischiocavernosus is a weak muscle and is a homologue of the same muscle in the male. The bulbus vestibuli and the clitoris veins are connected by an intermediary plexus on either side.

1.3.6 Urethra

The female urethra is a small musculomembranous tube connecting the urinary bladder and the vagina. It lies centrally on the pelvic floor and is related dorsally to the vagina where it opens in the floor of the vaginal vestibule through a urethral orifice. The lumen is wider than the male urethra. The lumen has many mucosal folds based on the muscular wall. The urethral muscle (M. compressor urethrae) embraces the urethra and is continuous with the constrictor vestibuli. It is covered by a fibroelastic membrane (Getty 1975).

1.3.7 Mammary Glands

The mammary glands are anatomically related to the integumentary system but functionally they are closely associated with the reproductive system, therefore they are usually described with them. The mammary glands are modified cutaneous glands present in the udder which is located in the inguinal region. They are externally divided in two halves by a median intermammary groove where each half is composed of a mammary body and a teat. The mammary body is conical and its base is slightly concave and slopes cranioventrally in adaptation to the ventral abdominal wall. The lateral surface is convex and covered by a movable skin and fine hairs, while the medial surface is flattened.

Each half is internally made up of a single mammary unit, which contains the cavity system, duct system, and mammary glandular parenchyma. The lobulated lactiferous tissue aggregate at the base of each half makes up the mammary glandular parenchyma. The lactiferous ducts open irregularly into the corresponding sinus. The ducts are divided by slightly elevated folds on the interior layer of the duct system; these folds either extend for a brief distance or rise to the level of the lactiferous sinus. An annular fold partially divides the glandular and papillary portions of the lactiferous sinuses. The lactiferous sinus' glandular portion is a large, irregular pouch that receives the lactiferous duct openings (Adam et al. 2017).

The teat is funnel shaped with a wide base and narrow apex, and is directed cranioventrally and slightly laterally. The teat sinus is a funnel-shaped cavity, while the teat canal is a small narrow passage running for about 1.5–2.0 inches. The canal is lined by fine longitudinal ridges and opens externally via a teat orifice (Adam et al. 2017).

1.3.7.1 Vessels and Nerves

The arteries are derived from the external pudic artery, which enters the gland at the posterior part of its base. The veins form a plexus on either side of the base of the gland, which is chiefly drained by the external pudic vein. The lymph vessels are numerous and pass to the superficial inguinal and lumbar lymph glands. The nerves are derived from the inguinal nerves and the posterior mesenteric plexus of the sympathetic system.

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