Chapter 1

Anatomy of the Reproductive System of the Bull

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Introduction

The anatomy of the reproductive system of the bull can be grouped functionally into the components of production, transport, and transfer of spermatozoa (Figure 1.1).

Production

The testicular parenchyma contains the cellular machinery for spermatogenesis and steroid production (Figure 1.2). The parenchyma is arranged in indistinct lobules of convoluted tubules called seminiferous tubules. The seminiferous tubules contain the spermatogonia from which the mature sperm cells develop. Sertoli cells are also located within the lumen of the seminiferous tubules. The Leydig cells that are responsible for the production of the male hormone testosterone are located between the seminiferous tubules in the interstitial space.[1]

Testes

The testes are housed in the scrotum. The scrotum is suspended between the thighs in the inguinal region. The scrotum consists of external and internal layers. The external layer is made up of the skin, tunica dartos, superficial perineal fascia, external spermatic fascia, cremasteric fascia, internal spermatic fascia, and parietal vaginal tunic. The skin of the scrotum and tunica dartos muscle are closely adhered whereas the fascial layers are easily separated from the skin and the parietal vaginal tunic as in a closed castration technique. The coverings of the testicle itself consist of the visceral vaginal tunic and the tunica albuginea.[2] The visceral vaginal tunic is the innermost layer of the vaginal tunic, an outpouching of abdominal peritoneum that passes through the inguinal canal into the scrotal sac. The potential space between the parietal and visceral vaginal tunic is the vaginal cavity (Figure 1.3). The purpose of the vaginal cavity is for temperature regulation of the testicle by raising it closer to the body through contraction of the tunica dartos and cremaster muscles. The tunica albuginea is a thick fibrous capsule that covers the testicle and maintains the testicular contents under pressure.[3] Internally the tunica albuginea forms the axially positioned mediastinum testis from which connective tissue septa divide the testis into indistinct lobules. This connective tissue framework supports the vasculature, nerves, parenchyma, and tubular system of the testicle. The scrotum of the bull is pendulous due to the dorsoventral orientation of the testes contained within.[1]

Spermatic cord

The spermatic cord includes the ductus deferens, vasculature, lymphatic vessels, and nerves of the testicle and epididymis.[4] Essentially the spermatic cord consists of all the tissue within the vaginal tunic so it extends from the vaginal ring within the abdominal cavity to the testicle.[5]

Transport

Spermatozoa are transported from the testicles through a tubular system consisting of the convoluted seminiferous tubules, straight seminiferous tubules, rete testis, efferent ductules, epididymis, ductus deferens, and urethra (Figure 1.4). The tubular system allows for maturation and storage of spermatozoa and provides fluid to ease movement of the spermatozoa.

Tubular transport system

The convoluted seminiferous tubules are the location of the spermatogenic process: the development of spermatogonia to primary spermatocytes, to spermatids, and finally to spermatozoa.[1] This process occurs within the wall of the seminiferous tubule. Specific regions of the

Bovine Reproduction, First Edition. Edited by Richard M. Hopper.

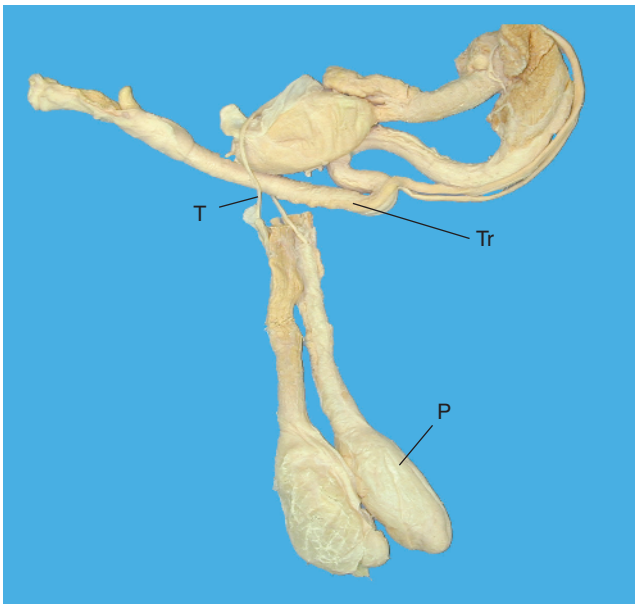

Figure 1.1 Reproductive system of the bull. P, production; T, transport; Tr, transfer.

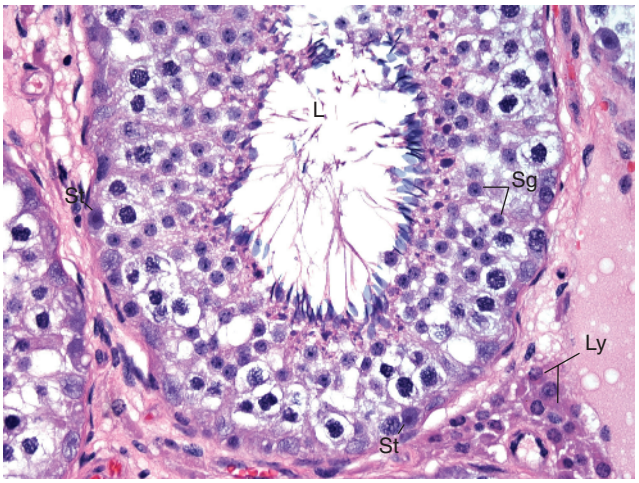

Figure 1.2 St, Sertoli cell; Ly, Leydig cells; Sg, spermatogonia; L, lumen of seminiferous tubule.

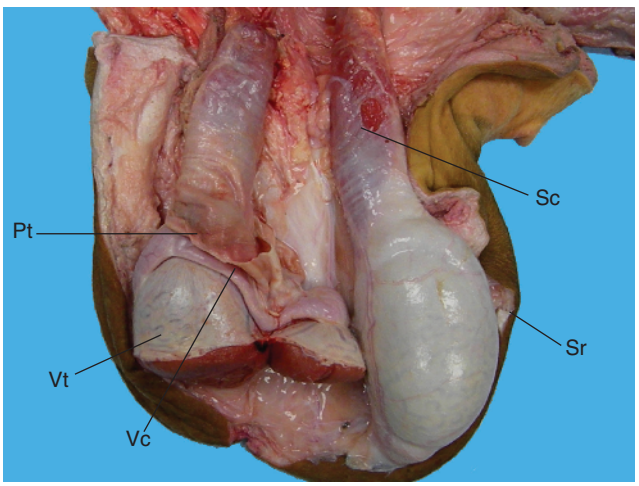

Figure 1.3 Vt, visceral vaginal tunic; Pt, parietal vaginal tunic; Vc, vaginal cavity; Sc, spermatic cord.

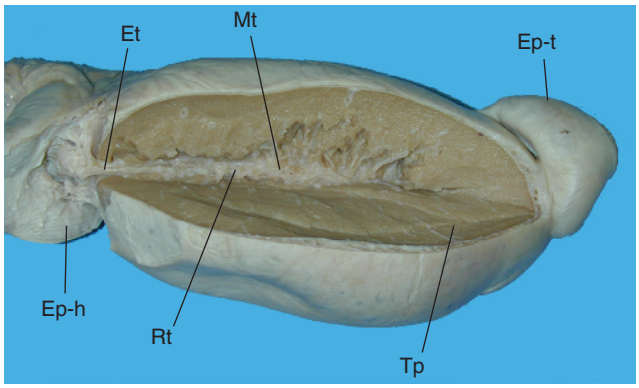

Figure 1.4 Ep-h, head epididymis; Et, efferent tubules; Mt, mediastinum testis; Rt, rete testis; Tp, testicular parenchyma; Ep-t, tail of epididymis.

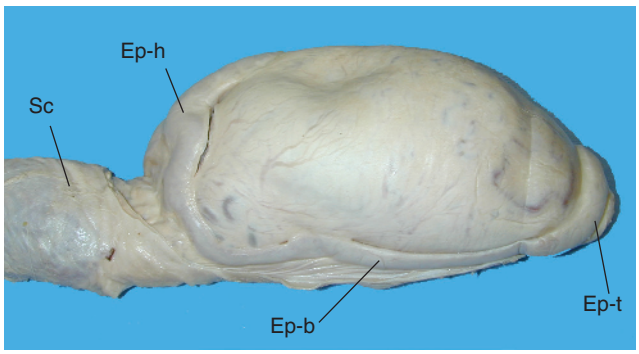

Figure 1.5 Sc, spermatic cord; Ep-h, head of epididymis; Ep-b, body of epididymis; Ep-t, tail of epididymis.

tubule are devoted to a particular stage of development, so that each stage can be identified by specific histological techniques.[6] Upon the completion of spermiogenesis, the spermatozoa are released into the lumen of the convoluted seminiferous tubule to begin transit through the straight seminiferous tubule. The straight seminiferous tubule is simply the connection between the convoluted seminiferous tubule and the rete testis. The rete testis is a "network of irregular labyrinth spaces and interconnected tubules."[2] The rete testes are located within the mediastinum testis connecting the seminiferous tubules to the efferent ducts that exit the testicle at the extremitas capitata (head). The efferent tubular system continues as the epididymis on the external surface of the testis (Figure 1.5). The epididymis is divided into a head, a body located on the medial surface, and a tail located at the distal extremitas caudate.

Ductus deferens

The ductus deferens is attached to the medial side of the testicle by the mesoductus.[5] The ductus deferens is the continuation of the tail of the epididymis (Figure 1.6). The ductus deferens enters the abdominal cavity through the inguinal canal, crosses the lateral ligament of the bladder, and before it ends at the colliculus seminalis in the urethra it widens into the ampulla.[5]

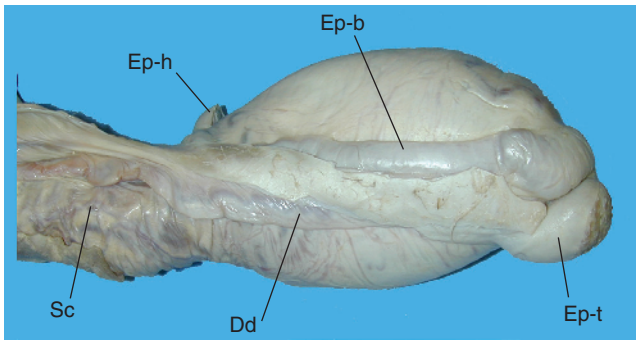

Figure 1.6 Sc, spermatic cord; Ep-h, head of epididymis; Ep-b, body of epididymis; Ep-t, tail of epididymis; Dd, ductus deferens.

Transfer

The transfer of spermatozoa from the bull to the cow is achieved by the process of intromission, which requires erection of the penis and ejaculation of sperm. The pertinent anatomy for these processes to occur includes the penis, the musculature of the penis, the vasculature, and the innervations.

Penis

The penis of the bull can be divided into a root, body, and glans penis (Figure 1.7). The root of the penis can be defined as the origin of the erectile tissue that comprises the penis as well as the origin of the muscles of the penis. The erectile tissue that makes up the bulk of the penis is the corpus cavernosum. The paired corpora cavernosa originate separately on each side of the ischiatic arch medial to the ischiatic tuberosity. These individual limbs are termed the crura of the penis. The crura pass ventromedially until they join to form the body of the penis. The corpus spongiosum is the erectile tissue that surrounds the urethra. The origin of the corpus spongiosum, called the bulb of the penis, originates between the crura along the midline of the ischiatic arch. Therefore the root of the penis is composed of the crura (corpus cavernosum) and the bulb (corpus spongiosum).

The erectile tissue is enclosed in the dense outer covering of the tunica albuginea. The tunica albuginea is a dense covering that consists of an inner circular layer and outer longitudinal layer of fibers. The inner circular layer sends trabecular scaffolds throughout the corpus cavernosum for the attachment of the cavernous endothelium.

Located caudal to the root of the penis are the muscles of the penis: the ischiocavernosus, bulbospongiosus, and retractor penis muscles (Figure 1.8). The paired ischiocavernosus muscles originate on the medial surfaces of the ischiatic tuberosities overlying the crura; the muscle fibers pass ventromedially in a "V" fashion until ending a short distance on the body of the penis.[1] During erection the ischiocavernosus muscle contracts pushing blood from the cavernous spaces of the crura into the body of the penis.[7] The bulbospongiosus muscle lies caudal to the bulb of the penis, originating along the ischiatic arch and continuing until the junction of the crura.[1] The bulbospongiosus muscle fibers run transversely across the bulb of the penis and contraction of this muscle results in propulsion of the

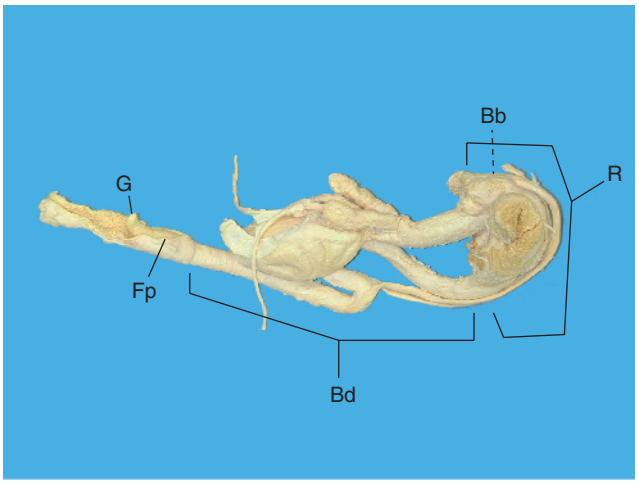

Figure 1.7 R, root of penis; Bb, bulb of penis; Bd, body of penis; Fp, free part of penis; G, glans penis.

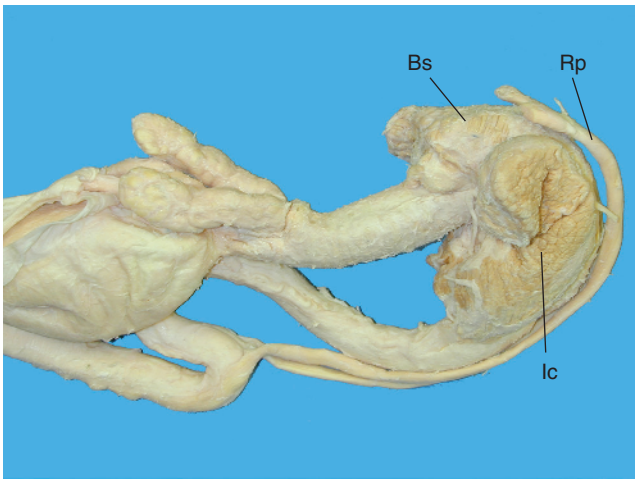

Figure 1.8 Bs, bulbospongiosus muscle; Ic, ischiocavernosus muscle; Rp, retractor penis muscle.

ejaculate through the urethra.[7] The retractor penis muscle extends from the caudal vertebrae and internal anal sphincter to insert distal to the sigmoid flexure.[8] These paired muscles relax during erection allowing the penis to extend from the prepuce and contract during quiescence, retracting the penis into the sheath.[8]

The body of the penis begins where the two crura meet distally to the ischiatic arch; it extends craniad, along the ventral body wall to become at the mid-ventral abdomen the free part of the penis (Figure 1.9). The body of the penis is bent in an "S" shape called the sigmoid flexure. The proximal bend of the sigmoid flexure opens caudally and is located near the scrotum. The distal bend is opened cranially and the short suspensory ligaments of the penis attach the penis to the ventral surface of the ischiatic arch.

The glans penis is a small restricted region at the tip of the free part of the penis[8] (Figure 1.10). The free part of the penis is the distal extent from the attachment of the internal lamina of the prepuce to the glans penis.[8] The free end of the penis is twisted in a counterclockwise direction as viewed from the right side, illustrated by the

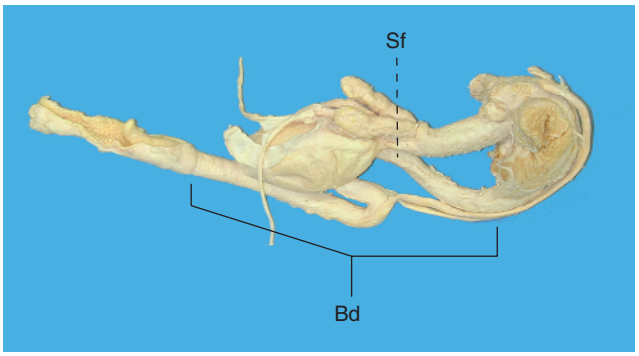

Figure 1.9 Bd, body of penis; Sf, sigmoid flexure.

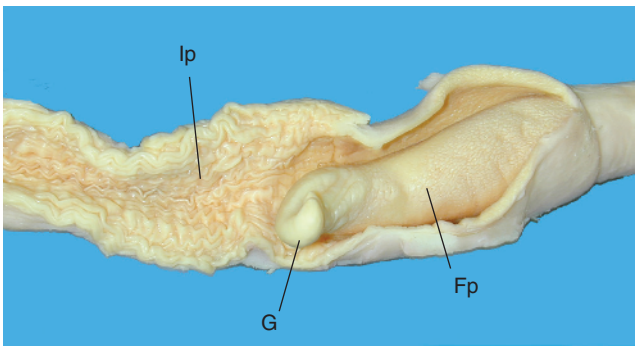

Figure 1.10 G, glans penis; Fp, free part; Ip, internal lamina of prepuce.

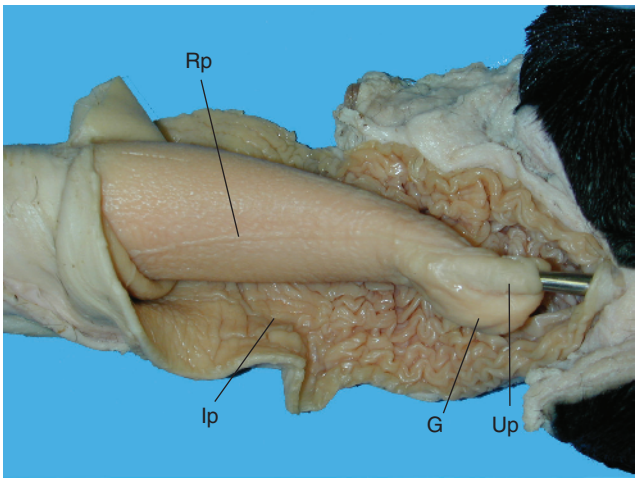

Figure 1.11 Rp, raphe of penis; Ip, internal lamina of prepuce; G, glans penis; Up, urethral process.

oblique direction of the raphe of prepuce continued as the raphe of the penis to the urethral process (Figure 1.11). The twist of the free end of the penis is due to the attachment of the apical ligament. The apical ligament of the penis is formed by the longitudinal fibers of the tunica albuginea leaving the body of the penis just distal to the sigmoid flexure and reattaching near the apex of the penis.[9]

The prepuce of the penis is composed of an external and internal fold or lamina[8] (Figure 1.12). The external lamina is the haired outer fold of skin attached to the ventral abdomen.

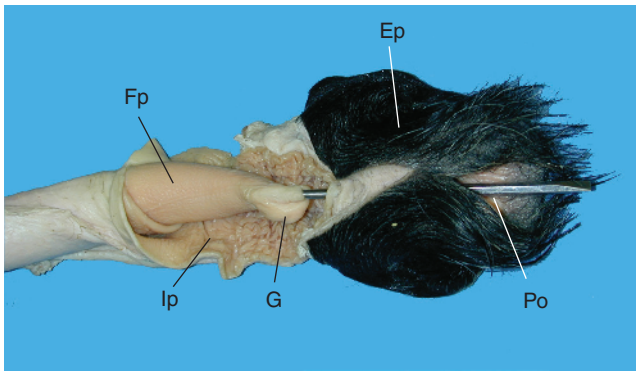

Figure 1.12 Fp, free part penis; G, glans penis; Ip, internal lamina of prepuce; Ep, external lamina of prepuce; Po, preputial orifice.

The haired skin terminates at the preputial orifice where the external fold turns inward to line the preputial cavity as the internal lamina. The internal lamina serves to attach the external lamina to the penile epithelium.

Blood supply

Before ejaculation can occur the testis must produce spermatozoa. This requires an adequate blood supply for the metabolic demands of cellular division for spermatogenesis and steroidogenesis. The arterial blood supply to each testis is provided by a testicular artery, a direct branch of the abdominal aorta arising caudal to the renal arteries. The testicular artery crosses the lateral abdominal wall and then passes ventrally through the inguinal canal.[10] As the testicular artery approaches the testis it begins to spiral with the nearby tortuous pampiniform plexus of the testicular vein forming a vascular cone. This arterial/venous arrangement is an effective thermoregulatory apparatus.[11]

An adequate blood supply to the penis and associated muscles is required for the processes of erection, ejaculation, and tissue maintenance. This comes by way of the internal iliac artery. The internal iliac artery is a direct continuation of the abdominal aorta at the entrance to the pelvic cavity. The umbilical artery, a branch of the internal iliac, supplies the ductus deferens and the bladder.[4] The prostatic artery leaves the internal iliac and supplies the prostate, vesicular glands, ductus deferens, ureter, and urethra.[4] As the internal iliac continues through the pelvic cavity it divides into the caudal gluteal and internal pudendal.[10] The internal pudendal gives off the ventral perineal artery, urethralis artery, and continues as the artery of the penis.[10] The artery of the penis gives off the artery of the bulb of the penis, which supplies the bulbospongiosus muscle and the cavernous spaces of the corpus spongiosum[12] (Figure 1.13). The deep artery of the penis is another branch of the artery of the penis that enters the crus of the penis and supplies the erectile tissue, the corpus cavernosum.[12] After the deep artery branches off, the artery of the penis continues as the dorsal artery of the penis which passes along the dorsal aspect of the penis toward the glans penis and prepuce. It is responsible for maintenance of penile tissue during quiescence.[13]

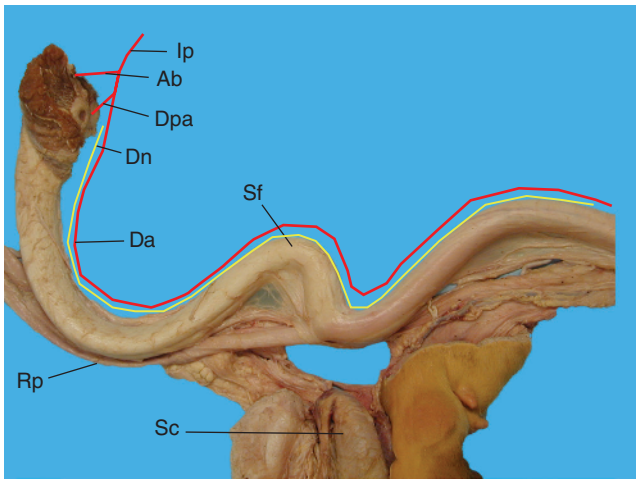

Figure 1.13 Ip, internal pudendal artery; Ab, artery of the bulb of the penis; Dpa, deep artery of the penis; Da, dorsal artery of the penis; Dn, dorsal nerve of the penis; Rp, retractor penis muscle; Sc, spermatic cord; Sf, sigmoid flexure.

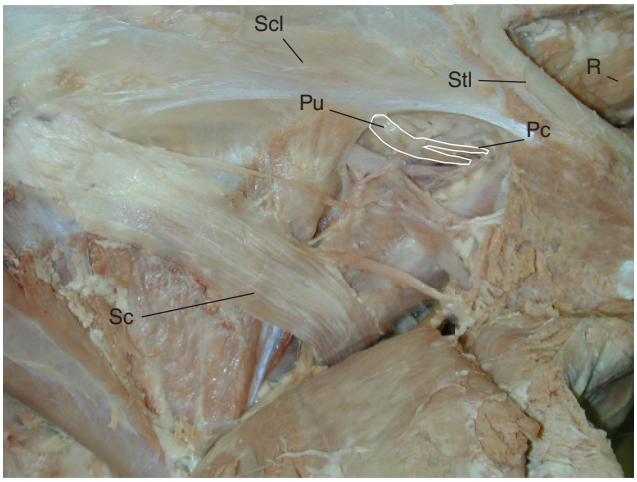

Figure 1.14 Sc, sciatic nerve; Pu, pudendal nerve; Pc, proximal cutaneous branch of pudendal nerve; Scl, sacrosciatic ligament; Stl, sacrotuberous ligament; R, rectum.

Nervous supply

The innervation of the external genitalia of the bull consists of the pudendal nerve and its branches. The pudendal nerve carries motor, sensory, and parasympathetic nerve fibers.[4] The pudendal nerve passes through the pelvic cavity medial to the sacrosciatic ligament and divides as it approaches the lesser ischiatic notch of the pelvis into proximal and distal cutaneous branches supplying the skin of the caudal hip and thigh.[4,8] The pudendal nerve continues through the ischiorectal fossa, terminating in a preputial branch, a scrotal branch, and finally the dorsal nerve of the penis.[6] The pelvic nerve provides parasympathetic innervations from the sacral plexus.[1] The hypogastric nerve contributes sympathetic fibers from the caudal mesenteric plexus to the genital system[1] (Figure 1.14).

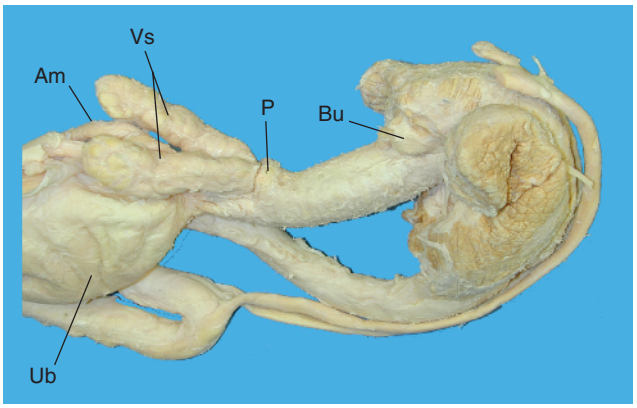

Figure 1.15 Am, ampulla; Vs, vesicular glands; P, prostate; Bu, bulbourethral gland; Ub, urinary bladder.

Accessory glands

The accessory genital glands of the bull include the vesicular gland, ampulla of the ductus deferens, and the prostate and bulbourethral glands (Figure 1.15). The bilateral vesicular gland is the largest accessory gland in the bull and contributes the greatest volume to the ejaculate. It is a lobated gland of firm consistency. It lies dorsal to the bladder and lateral to the ureter and ampulla of the ductus deferens.[1] The body of the prostate lies dorsal to the urethra between and caudal to the vesicular glands. The disseminate part of the prostate is concealed in the wall of the urethra and covered by the urethral muscle.[1] The ampulla, vesicular glands, and prostate all empty their contents into the urethra through the colliculus seminalis. The bilateral bulbourethral gland lies on each side of the median plane dorsal to the urethra; it is mostly covered by the bulbospongiosus muscle. Its duct opens into the urethral recess[1] (Figure 1.15). The urethral recess is a blind pouch that exits dorsally into the penile urethra at the level of the ishiatic arch. The presence of this structure makes it difficult to pass a catheter retrograde into the bladder.

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