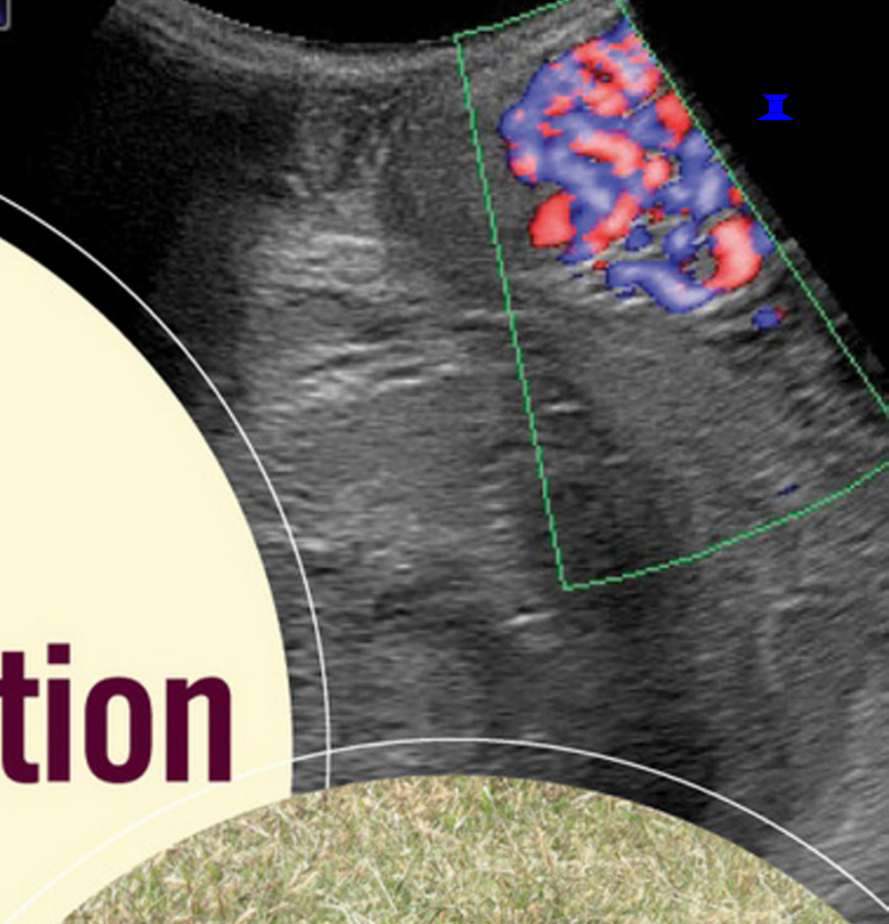

Bovine Reproduction

Richard M. Hopper

WILEY Blackwell

Bovine Reproduction

“Let our cattle bear, without mishap and without loss”
Psalms 144: 14, *New American Standard Bible*

Bovine Reproduction

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To Donna

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Preface

There is an old fable in which three penniless and hungry travelers come to a small town. Unsuccessful in finding work or even a handout, one concocts a novel plan. He goes to the middle of the village carrying three fist-sized rocks and announces with great aplomb that he is planning to make his famous "stone soup." The skeptical but curious villagers gather. Well of course he needed a kettle and some water. The inquisitive villagers wondered if that was all. "Yes," he replied, "but it is better with a little garnish to improve the flavor." One villager thought that he could spare some carrots, another some potatoes, and a third some meat. This continued with virtually everyone in the village contributing. The result of course was a wonderful soup and everyone enjoyed a fine meal, while experiencing an object lesson in cooperation.

The story bears an ironic resemblance to the development of this text. The editor, like the plucky traveler, personally short on ability and resources but acutely aware of a need, enlisted the assistance of those who possessed both. Excellent reference texts were available on equine and small animal theriogenology, but a current bovine text was much needed. The goal was to produce a text that would service the needs of the veterinary student and bovine practitioner, as well as the graduate student and resident.

While I would readily admit that this text could be improved with respect to the choices made vis-à-vis the organization of the book or the order of some chapters, I honestly do not believe that I could have done any better than the contributors selected. The authors of this text represent a wide array of specialties and educational and experiential backgrounds. I will forever be grateful for their assistance and immensely proud of their individual contributions. I would also like to acknowledge the efforts of my graduate assistant, Amanda Cain, who in addition to contributing a chapter, prepared the glossary of terms and index. Likewise, I would like to thank everyone at Wiley for their help. Erica Judisch, the commissioning editor, was so very helpful in guiding a novice through the early phases of this book. Susan Engelken, the managing editor for this book, was incredible to work with, always patient, always competently and quickly responding to any issue or concern. Dr Joe Phillips, the copy editor Wiley enlisted, deserves the credit for identifying errors that I missed and enhancing the readability of this text.

Additionally, I would like to acknowledge on a personal level those who have been so important to me from the standpoint of my life and career. First of all I would thank my parents, Lewis and Barbara Hopper, who were always supportive of my goals and aspirations, and my family, wife Donna and children Tricia (her husband Caleb), McRae, and Molly, who I will always consider to be my greatest accomplishments. Also, as this goes to press I can announce a wonderful addition, a granddaughter by the name of Abigail Betty Butts.

I would also be remiss to not use this opportunity to thank some of my professors and instructors at Auburn who were so influential to me professionally and important to me personally. First on this list would be Dr Robert Hudson, but also Drs Bob Carson, Howard Jones, Donald Walker, Ram Purohit, John Winkler, and Howard Kjar. Likewise, I need to thank my colleagues at Mississippi State who have alternatively both encouraged and tolerated me through this long process.

I sincerely hope the reader finds this text useful.

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SECTION I

The Bull

ANATOMY AND PHYSIOLOGY

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

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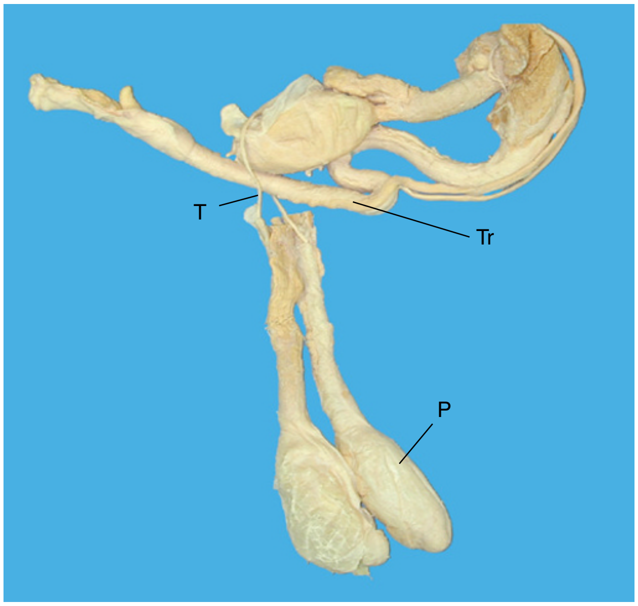

Figure 1.1 Reproductive system of the bull. P, production; T, transport; Tr, transfer.

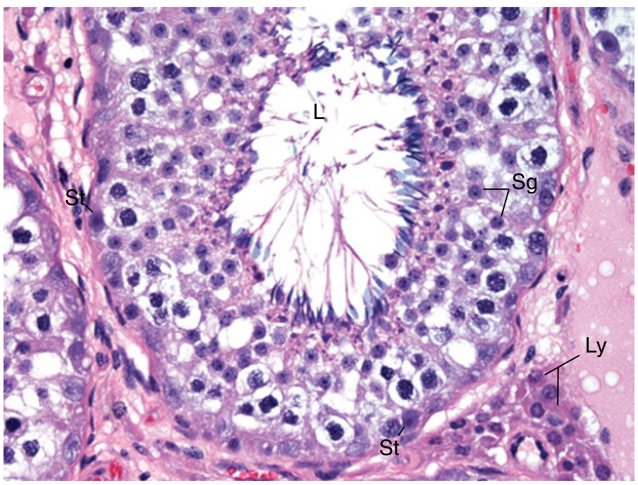

Figure 1.2 St, Sertoli cell; Ly, Leydig cells; Sg, spermatogonia; L, lumen of seminiferous tubule.

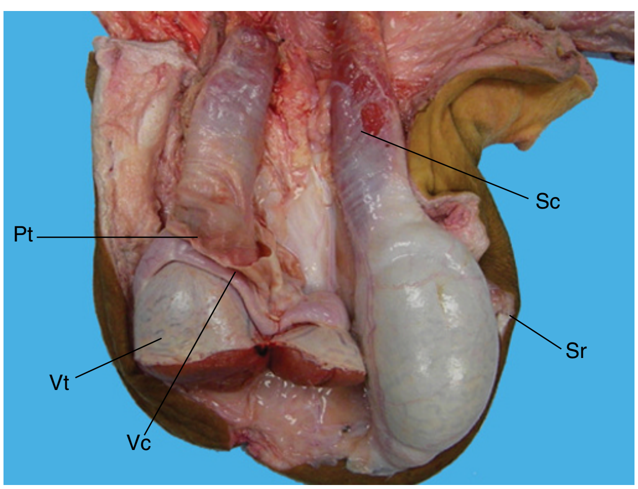

Figure 1.3 Vt, visceral vaginal tunic; Pt, parietal vaginal tunic; Vc, vaginal cavity; Sc, spermatic cord.

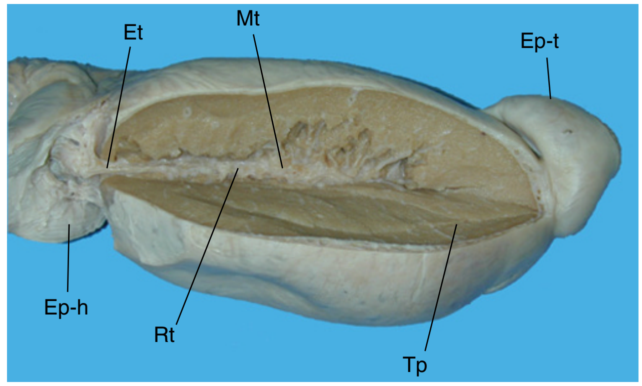

Figure 1.4 Ep-h, head epididymis; Et, efferent tubules; Mt, mediastinum testis; Rt, rete testis; Tp, testicular parenchyma; Ep-t, tail of epididymis.

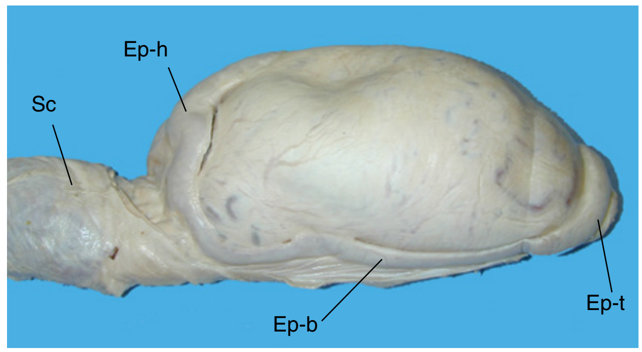

Figure 1.5 Sc, spermatic cord; Ep-h, head of epididymis; Ep-b, body of epididymis; Ep-t, tail of epididymis.

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]

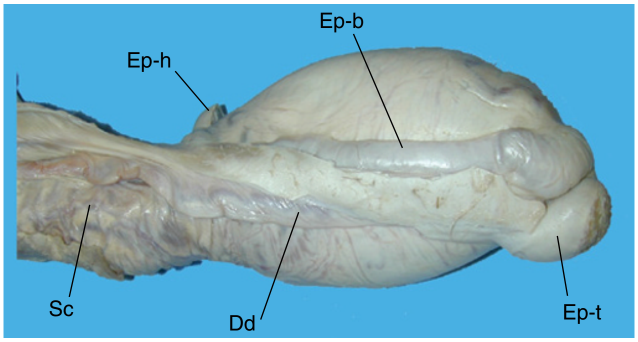

Figure 1.6 Sc, spermatic cord; Ep-h, head of epididymis; Ep-b, body of epididymis; Ep-t, tail of epididymis; Dd, ductus deferens.

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 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]

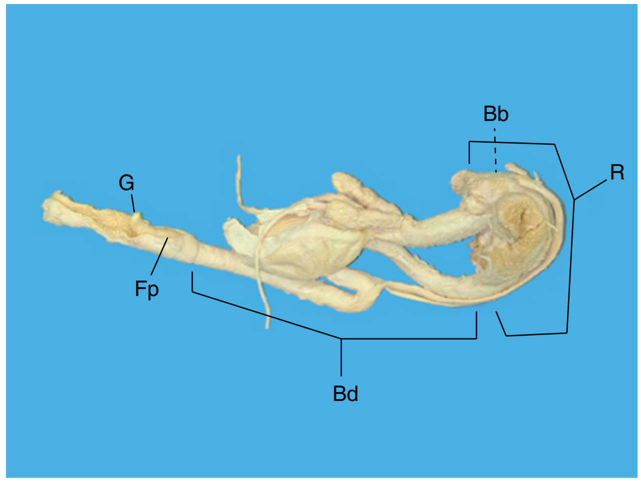

Figure 1.7 R, root of penis; Bb, bulb of penis; Bd, body of penis; Fp, free part of penis; G, glans penis.

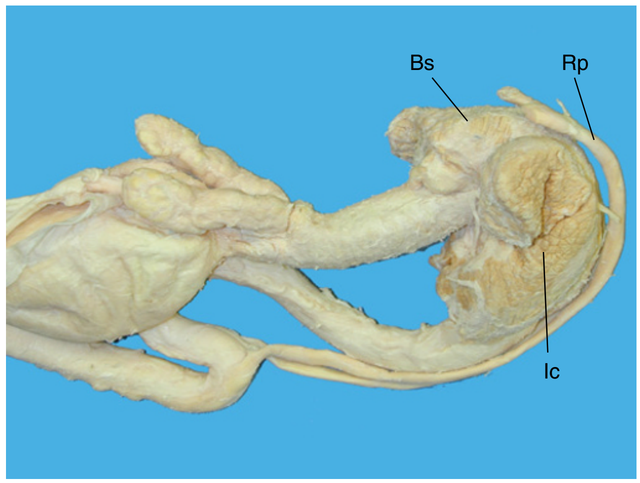

Figure 1.8 Bs, bulbospongiosus muscle; Ic, ischiocavernosus muscle; Rp, retractor penis muscle.

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

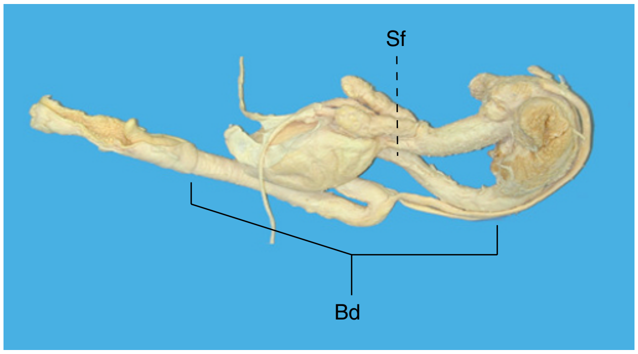

Figure 1.9 Bd, body of penis; Sf, sigmoid flexure.

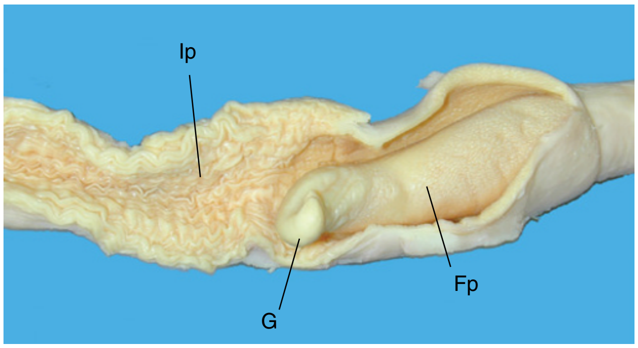

Figure 1.10 G, glans penis; Fp, free part; Ip, internal lamina of prepuce.

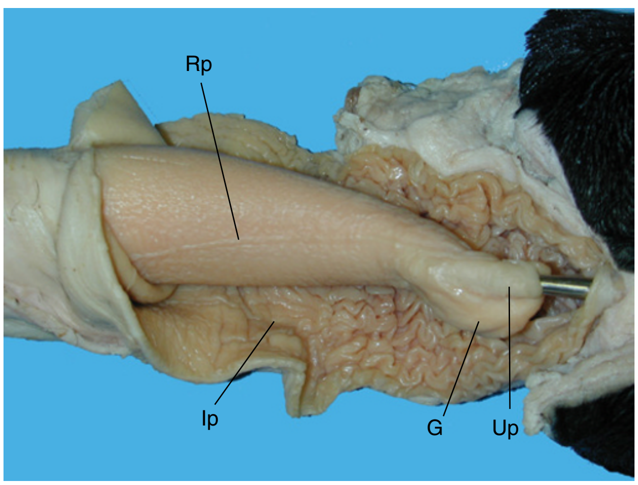

Figure 1.11 Rp, raphe of penis; Ip, internal lamina of prepuce; G, glans penis; Up, urethral process.

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.

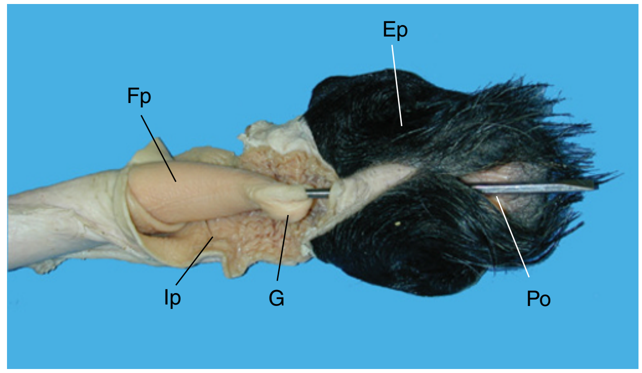

Figure 1.12 Fp, free part penis; G, glans penis; Ip, internal lamina of prepuce; Ep, external lamina of prepuce; Po, preputial orifice.

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]

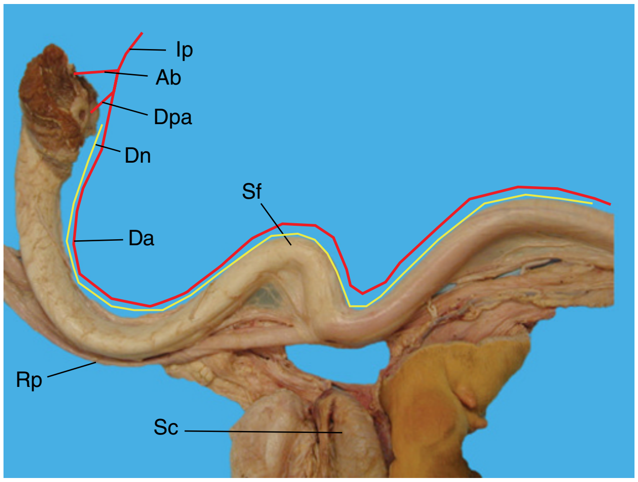

Figure 1.13 Ip, internal pudendal artery; Ab, artery of the bulb of the penis; Dpa, deep artery of the penis; Da, dorsal artery of the penis; Dn, dorsal nerve of the penis; Rp, retractor penis muscle; Sc, spermatic cord; Sf, sigmoid flexure.

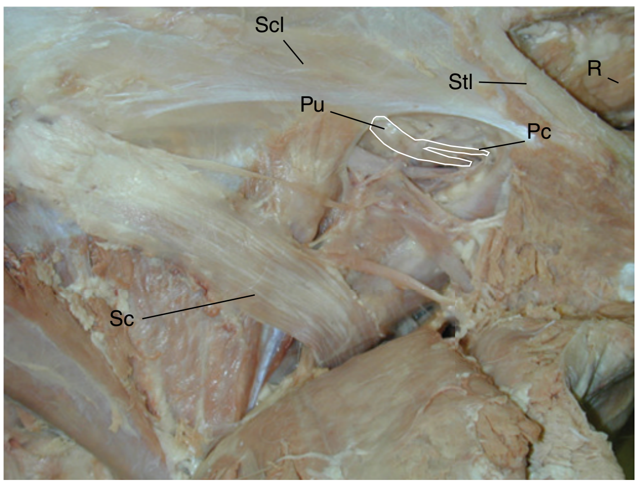

Figure 1.14 Sc, sciatic nerve; Pu, pudendal nerve; Pc, proximal cutaneous branch of pudendal nerve; Scl, sacrosciatic ligament; Stl, sacrotuberous ligament; R, rectum.

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).

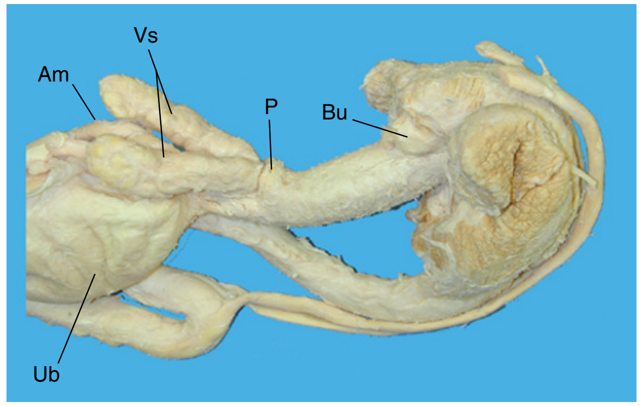

Figure 1.15 Am, ampulla; Vs, vesicular glands; P, prostate; Bu, bulbourethral gland; Ub, urinary bladder.

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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Chapter 2

Endocrine and Exocrine Function of the Bovine Testes

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Introduction

The normal bovine male reproductive system consists of paired testes retained within a sac or purse-like structure known as the scrotum, which is formed from the outpouching of skin from the abdomen and consists of complex layers of tissue. The testes are accompanied by a number of supporting structures including spermatic cords, accessory sex glands (prostate, bulbourethral, paired vesicular glands), penis, prepuce, and the male ductal system. The testicular duct system is extensive and comprises the vas efferentia found within the testes, the epididymis, vas deferens, and the urethra, all of which are located external to the testes. The reader is referred to the excellent chapter on the anatomy of the reproductive system of the bull in this book (Chapter 1). The primary functions of the testes are to produce male gametes (spermatozoa) and the endocrine factors, such as steroid (testosterone) and protein hormones (inhibin, insulin-like peptide 3), that help regulate reproductive function of the bull in concert with hormonal secretions from the hypothalamus (gonadotropin-releasing hormone) and pituitary glands (luteinizing hormone, follicle-stimulating hormone). The testes consist of parenchymal tissue that supports the interstitial tissue and includes the steroid-producing Leydig cells, vascular and lymphatic system, and the seminiferous tubules within which the germinal tissue develops with the support of the nurse cells more commonly known as Sertoli cells. Chapter 4 discusses in detail the endocrine factors responsible for testicular development and initiation of spermatogenesis in the bull, and thus this chapter focuses more on the regulation and function of the adult testes. This chapter will not undertake a treatise of those conditions that disrupt testicular function but rather will focus, as practically as is possible, on what is known of the endocrine and exocrine function of the bovine testes. Much of the endocrine and exocrine function of the testes is similar across mammalian species, and where specific information is absent for the bovine, examples will be given from other domestic species when possible. It has not been possible to cite the many significant contributions to the field of endocrine and exocrine function of the testes. Thus, where and when possible, the reader is referred to selected citations for additional reading.

Historical perspective

It has been evident for many centuries that the testes exercise control over the characteristics of the male body. The results of castration in domestic animals and human males made this very clear, but provided no clues as to the mechanism of control. Pritchard[1] noted from Assyrian records dating some 15 centuries BC that the castration of men was used as punishment for sexual offenders, which suggests that the effect of castration on fertility and behavior was recognized at that time. Knowledge of the effects of castration of livestock dates back to the Neolithic Age (*c*. 7000 BC) when animals were first thought to have been domesticated.[2] The effects of castration were understood by Aristotle (300 BC) who provided very detailed and clear descriptions of testicular anatomy and function.[3] It was not until the seventeenth century that a detailed account of testicular and penile anatomy was presented by Regnier de Graaf[4] in a treatise on the male reproductive organs. De Graaf indicated the existence of the seminiferous tubules and suggested that the production of the fertile portion of the semen occurred in the testes. The first microscopic examination of the testes was undertaken by Antonie van Leeuwenhoek in 1667 where he demonstrated and reported the presence of germ cells in the seminal fluid.[5]

Detailed study of the testis began in the mid-nineteenth century. In 1840, Albert von Köllicker discovered that spermatozoa develop from cells residing in the testicular (seminiferous) tubules. This major discovery was followed by Franz Leydig's[6] description of the microscopic characteristics of the interstitial cells. Later, Enrico Sertoli,[7] an Italian scientist, correctly described the columnar cells running from the basement membrane to the lumen of the

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

tubuli seminiferi contorti (seminiferous tubules) of the testes, and Anton von Ebner is credited with introducing the concept of the symbiotic relationship between Sertoli cells and the developing germinal cells.[8,9]

The first clear demonstration that the testes are involved in an endocrine role was made by Arnold Berthold in 1849, while studying the testes of the rooster. He concluded that the regulation of male characteristics was brought about by way of blood-borne factors. The most compelling evidence for an endocrine function of the testes being associated with Leydig cells was presented by two French scientists, Bouin and Ancel in 1903. They reported that ligation of the vas deferens in dogs, rabbits, and guinea pigs was followed by degeneration of the seminiferous tubules, but no castration effects were observed and no degenerative changes of the interstitial cells, and thus concluded that internal secretions of the testes were synthesized by the Leydig cells.[10] By the mid 1930s it was clear that the male hormone emanating from the testes was testosterone[11] and that the function of the testes was controlled by pituitary hormones.[12,13] Smith[12] demonstrated that the pituitary gland must secrete substances (now known as gonadotropins) responsible for the stimulation of testicular growth and maintenance of function in the rat. Greep and Fevold[14] restored Leydig cell function in hypophysectomized rats with crude preparations of luteinizing hormone (LH) and reestablished the male secondary sex characteristics. Further evidence was elucidated in favor of a steroid secretory function for Leydig cells from a study on postnatal development in bulls where changes in testicular androgen levels paralleled the differentiation of these cells.[15] Using cell culture techniques, Steinberger *et al*.[16] provided direct evidence that the Leydig cells are the primary source of steroid hormone synthesis in the testes. Later, it became apparent that the Leydig cells are essential for providing the androgenic stimuli that are required for the maintenance of spermatogenesis in the germinal epithelium.[16, 17]

The testis

The bovine testes are paired, capsulated, ovoid-like structures located in the inguinal region and suspended in a pendulous scrotum away from the abdominal wall. The proximal relationship of the testes to the abdominal wall varies and may depend on season and ambient temperatures. The cremaster muscle plays an important role in thermal regulation of the testis. The size of the testis varies with breed, but typically the adult testis weighs 300–400 g and is about 10–13 cm long and 5–6.5 cm wide.[18] The tough fibrous capsule covering each testis consists of three tissue layers: the outer layer, the tunica vaginalis; the tunica albuginea, which consists of connective tissue composed of fibroblasts and collagen bundles; and the inner layer, the tunica vaginalis, which supports the vascular and lymphatic systems.[19] The capsule is the main structure that supports the testicular parenchyma, the functional layer of the testes, which consists of the interstitial tissue and seminiferous tubules. The interstitial tissue is found in the spaces between the seminiferous tubules and consists of clusters of Leydig cells, which are primarily responsible for steroid hormone biosynthesis and secretion, along with vascular and lymph vessels that supply the testicular parenchyma. The seminiferous tubules originate from the primary sex cords and contain the germinal tissue (spermatogonia, the male germ cell) and a population of specialized cells, the Sertoli cells, which not only support the production of spermatozoa but also form tight junctions with each other, creating one of the most important components of the blood–testis barrier.[20] This structure prevents the entry of most large molecules and foreign material into the seminiferous tubules that may disrupt normal spermatogenesis. The most important substances synthesized by the testes and released into the vascular system are peptide and steroid hormones. However, fluids from the seminiferous tubules may pass into the interstitial tissue via the basal lamina, where they may enter the testicular lymphatic and vascular systems, or into the tubule lumen via the apical surface of the Sertoli cells.[19]

The scrotum and spermatic cords

The scrotum is composed of an outer layer of thick skin and three underlying layers, the tunica dartos, the scrotal fascia, and the parietal vaginal tunica. The scrotal skin is extensively populated with numerous large adrenergic sweat and sebaceous glands that are highly endowed with thermal receptors and nerve fibers. Neural stimulation from the thermal receptors enables the tunica dartos, which consists of smooth muscle fibers and lies just beneath the scrotal skin, to contract and relax in response to changes in temperature gradients and facilitates the cooling of the scrotal surface via scrotal glandular sweating.[19] Thus the scrotum plays an important role not only in housing and protecting the testes but also has a role in thermoregulation of the testes. The spermatic cord connects the testes to the body and provides access to and from the body cavity for vascular, neural, and lymphatic systems that support the testes. In addition, the spermatic cord accommodates the cremaster muscle, the primary muscle supporting the testes, and the pampiniform plexus, a complex and specialized venous network that wraps around the convoluted testicular artery.[21] This vascular arrangement is very important in temperature regulation of the testicular environment. The plexus consists of a coil of testicular veins that provide a counter-current temperature exchange system: this is an effective mechanism whereby warm arterial blood entering the testes from the abdomen is cooled by the venous blood leaving the testes. Testicular arteries originate from the abdominal aorta and elongate as the testis migrates into the scrotum.[19] In cattle and other large domestic ruminants these arteries are highly coiled, reducing several meters of vessel into as little as 10 cm of spermatic cord.[19] The arterial coils and venous plexus are complex structures that form during fetal life in cattle.[19,22] Because of the pendulous nature of the bovine scrotum, testicular cooling is facilitated by the contraction and relaxation of the cremaster muscle, which draws the testes closer to the abdominal wall during cooler ambient temperatures and vice versa during warmer temperatures. Figure 2.1 shows bright-field and thermal images of the bovine testes that demonstrate the change in temperature from the neck to the tip of the scrotum as the testes thermoregulate during elevated environmental temperatures. Scrotal and testicular thermoregulation is a complex process