THE GROSS ANATOMY AND HISTOLOGY OF THE GENITALIA OF THE DAY-OLD, THE CASTRATE AND THE MATURE MALE BOVINE

by

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INTRODUCTION

The object of this study was to examine and record the basic normal structure, both gross and microscopic, of the male bovine genital system. Pathologists, histologists, and anatomists have for many years assumed that the microscopic structure of the specific structures of the male bovine genitalia was almost identical with that of the human. In the literature there are many good and complete descriptions of the male genitalia of the human but no similar description can be found for the genitalia of the male bovine. This study was undertaken and thesis was written to be helpful for individuals who have a solid background in gross anatomy, histology, and histopathology. A study to confirm or deny assumed facts, to bring out new ideas and discoveries, and consolidate the information of both types is recorded in this thesis.

MATERIALS AND METHODS

The complete genital system including the testicles, penis, prostate gland, seminal vesicles, bulbourethral glands, prepuce, scrotum, and accessory muscles, was collected at necropsy, from the bulls killed at the slaughter house, sacrificed day old calves, and from animals used for gross anatomical study. The specimens were preserved in a 10 percent solution of formaldehyde.

A detailed gross dissection and study of each set of organs was made. Injections of the arterial system of these organs with latex or vinyl acetate solution were made to facilitate the study of the circulation of the blood to the organs. Variations from the usually accepted patterns

of circulation, nerve supply or structure were recorded for each set of organs.

When the gross studies were completed, tissue specimens for microscopic study were taken from the following sites: 1. prostate gland, 2. seminal vesicle, 3. bulbourethral gland, 4. testicle, 5. head of the epididymis, 6. body of the epididymis, 7. tail of the epididymis, 8. ductus deferens in the genital fold, 9. ampullae of the ductus deferens, 10. urethra at the colliculus seminalis, 11. pelvic urethra, 12. urethra at the anterior dorsal part of the sigmoid flexure, 13. urethra and glans one half inch from the apex of the glans, 14. prepuce above the glans, 15. preputial-skin junction, 16. body of the penis at the ischial arch, 17. body of the penis at the anterior dorsal part of the sigmoid flexure, 18. body of the penis at the posterior end of the glans, 19. retractor penis muscle, 20. retractor prepuce muscle, 21. protactor prepuce muscle, 22. crus of the penis, 23. ischiocavernosus muscle, 24. bulbocavernosus muscle, 25. urethral muscle, 26. cremaster externus muscle, 27. spermatic cord four inches above the testicle.

The tissue specimens were dehydrated with alcohols and then infiltrated, embedded, and blocked in paraffin. Sections were cut with the microtome at 5 to 7 microns and stained with hemotoxylin and eosin.

Microscopic studies were made on the tissue specimens from each animal examined. Photomicrographs were made of the areas most important in histological and histopathological studies.

REVIEW OF THE LITERATURE

Studies related to the histology of the male bovine genitalia were generally scattered through the literature with no complete study and description devoted entirely to this important system of organs.

Many of the recorded studies dealt only with one organ or structure of the system and under special circumstances. This was shown in the work of Hooker (21) who studied only the specialized interstitial cells of the testis during prenatal life. Others of this type included a study of the erectile tissue described by Deysack (8) and Harrison's (17) treatise on the comparative blood supply of the testis.

Numerous studies on sterility dealt with isolated areas of the system or abnormal conditions, either natural or experimental, which had led to the study of the pathological condition of certain parts of the genital system. Sterility studies of certain cells or parts of the bull genital system were described by Blom (4), Hill and Gasner (20), Gasner (13), Deakin (7), Hancock (16), and Laing (23).

Study of only the cellular and secreted products of the testes were recorded by Asdell (1), Herman and Madden (19), Miller and Everrette (30), Engle (10), and Perry (33).

Phillips and Andrews (34) made an age-development study but concentrated only on the spermatozoa.

Congenital abnormalities of the genitalia were described by Rollinson (35) but this work did not include any normal histology of these organs.

Bacteriological examination of various areas of the genitalia were correlated with clinical and pathological findings in work reported by

Easley, et al (9), and Kimball, et al (22). In the above investigations the histopathology has been recorded only for certain parts of the system under study.

The histology, as related to the endocrine relationships of the male genital system and the other endocrine organs of the body, has been reported by Cupps, et al (6) but again the entire system did not come under scrutiny from a normal histological standpoint.

The histopathology of small areas, needed to confirm or diagnose clinical conditions of the genitalia, was recorded in papers dealing primarily with clinical or surgical problems, by Perkins, et al (32), Fossland (11), and Milne (31).

The basic normal or abnormal development of the organs or the cells, with special reference to certain cells, areas or conditions, was described by Bascom (2), Bissonnette (3), Lillie (24), Wodsedalek (41), and Santamarina and Reece (36).

A description of testicular atrophy appeared in the textbook by Williams (40) but neither the whole system nor any normal structures were described.

Melampy, et al (29) made a complex study of the composition and histochemistry of the testicle.

The glandular accessory organs were compared, in some areas, with similar structures in many domestic animals, wild animals, and man by Macklin and Macklin (25). Again the histological picture in its entireity was not presented though the material on the individual cells was good.

Marsh and Safford (26) studied the effect of castration on the urethral development in male calves, but they gave little information on the effect of castration on the remaining parts of the genital organs.

Haq (18) described the most complete study of the epithelial structures of the bull genital tract. This study was limited also in that it did not include the basic normal structures of the other accessory parts of the genital system. Haq also mentioned the lack of any study of the normal structures of the bull as a handicap to the study of abnormal or pathological conditions.

The gross anatomy textbooks of McLeod (28) and Sisson and Grossman (38), gave accurate descriptions of the gross structures of the bull genital tract or system. The only references to histological structure in these texts were brief footnotes or statements within the formal descriptions, which were intended primarily to emphasize an anatomical structure or the function of a part.

The formal textbooks on histology were nearly all based on human structure. A few isolated statements on the male bovine genitalia were present in the works of Ham (15), Maximow and Bloom (27), Smith (37), Cowdry (5), and Greep (14), but they did not include a complete description of all parts of the male bovine genitalia.

The textbooks devoted primarily to veterinary histology included most of the domestic animals in a generalized manner as shown in the work of Trautman and Febiger (39) and Foust and Getty (12). In these texts reference to the bovine male genitalia was brief and sketchy, thus implying that most of the structures were identical or very similar in all animals.

THE TESTICLES

The testicles were paired oval glands that, in the adult, reached a size of six inches in length and two to three inches in width. They were located in the scrotum below the inguinal canals and hung with their long axis

vertical. The testicle was almost completely surrounded by the potential cavity between the layers of the tunica vaginalis. This cavity was in direct communication with the peritoneal cavity by way of the inguinal canal. The dividing line between these two cavities was at the vaginal ring.

Except at the attachment of the epididymis, the surface of the testicle was covered by the tunica vaginalis communis. This structure was basically a single layer of mesothelial cells. The tunica albuginea consisted of a layer of fibrous connective tissue that surrounded the testicle beneath the tunica vaginalis communis. Connective tissue septa extended into the gland from the tunica albuginea. The septa were extending to a more dense and concentrated area of connective tissue through the center of the organ. This concentrated area of connective tissue is named the mediastinum by Maximow and Bloom (27). The septa radiated into the testicle, dividing the organ into irregular lobules. Within the lobules were found the convoluted seminiferous tubules. Between the seminiferous tubules were the interstitial tissue and the "interstitial cells." The interstitial tissue was a continuation and modification of the connective tissue of the supporting septa. The interstitial tissue had decreased fibrous tissue elements and increased vascular elements as compared to the structure of the septa. The "interstitial cells" (cells of Leydig) were located in irregular areas between the seminiferous tubules. The cells themselves appeared to be modifications of the connective tissue cells of the area. The round to oval basophilic nucleus was the prominent feature of the oval to irregular-shaped interstitial cell. The production of male hormone has been suggested as the prime function of these cells by Maximow and Bloom (27).

The epithelium of the seminiferous tubules rested on a basement membrane which, in turn, rested on the interstitial tissue (Plate I, Fig. 2.). In the tubules of the mature animal, two basic cell types, the sustentacular cells and the spermatogenic cells, were present. The sustentacular cells (Sertoli cells) were relatively few in number as compared to the spermatogenic (germ) cells. The sustentacular cells rested on the basement membrane and extended toward the lumen of the seminiferous tubule. The nucleus was basically round to oval and lighter staining than the nuclei of the various stages of the spermatogenic cells. The cytoplasm of the sustentacular cells was very irregular and often indistinct, depending of the extent of the characteristic crowding by the spermatogenic cells.

The spermatogenic cells were basically arranged in three zones. The large, oval to round spermatogonia cells were usually in a single row along the basement membrane. The nuclei of these cells were large, contained much chromatin and, in some cells, were showing various stages of cell division. Toward the lumen was a zone of two to four cell layers which contained the primary and secondary spermatocytes. The primary spermatocyte was most numerous in the area closest to the zone of spermatogonia cells. The primary spermatocyte was usually the larger of the two spermatocyte cell types and was oval to round in shape with a large, round, darkly staining nucleus occupying most of the cytoplasm of the cell. The secondary spermatocyte was usually round and had a dark chromatin-prominent nucleus which did not as completely fill the cell as in the primary stage. This secondary group of cells was most numerous in the area toward the lumen beneath the spermatid cells.

The spermatids were in a zone of variable cell thickness on the spermatocyte layer and toward the lumen of the seminiferous tubule. The

EXPLANATION OF PLATE I

Fig. 1. Seminiferous tubule of immature testicle. (430X)

Fig. 2. Seminiferous tubule of mature testicle. (430X)

PLATE I

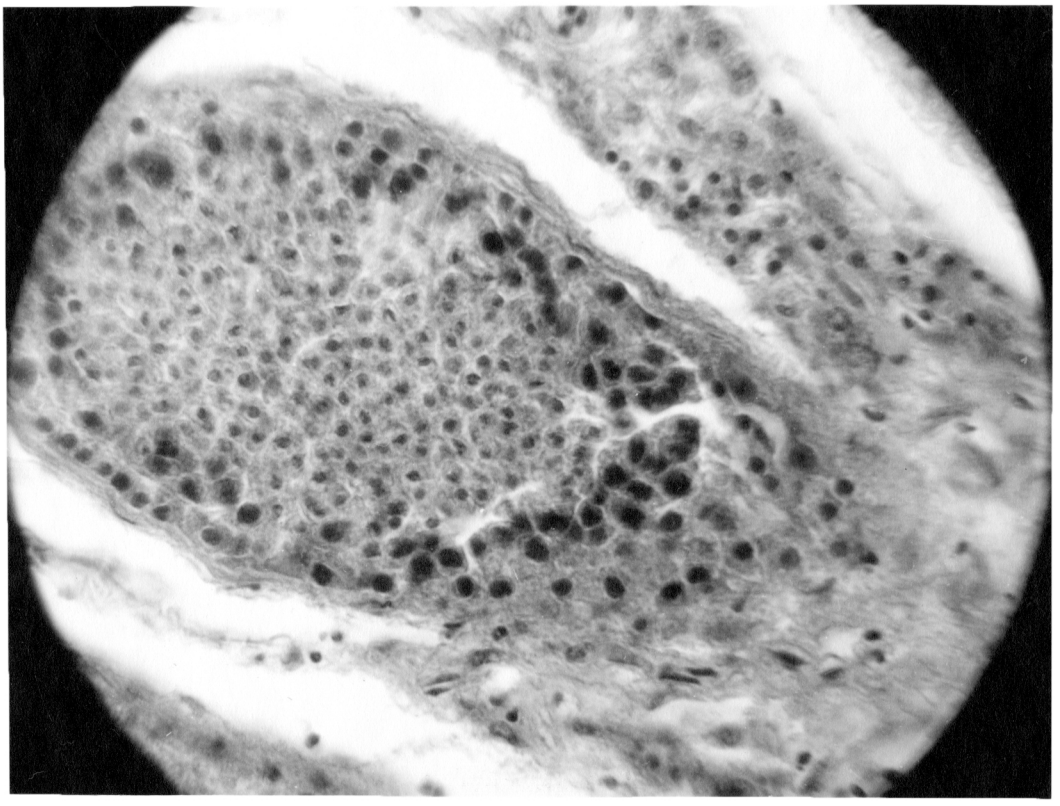

Fig. 1

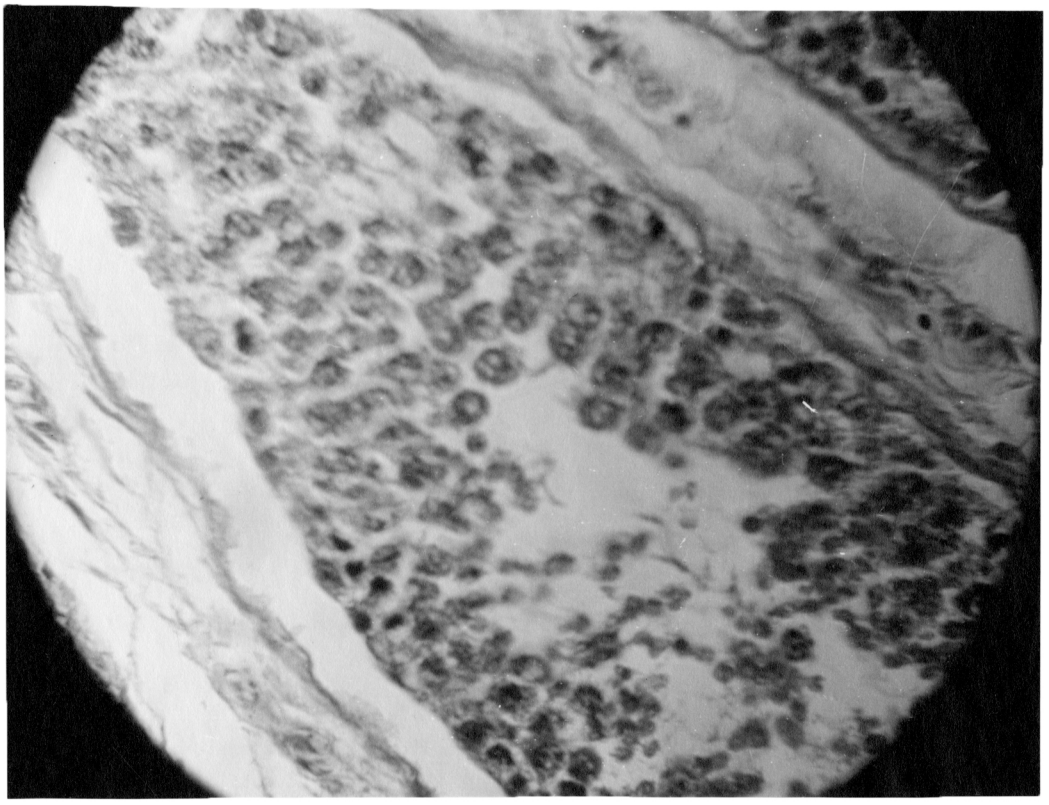

Fig. 2

spermatids were quite variable in their structure as they gradually transformed into mature spermia and, at some stages, resembled lymphocytes. Initially the spermatids were the cells which formed following division of the secondary spermatocyte. As new daughter cells they were oval to round, had round nuclei, and were basically small editions of the secondary spermatocyte. As the spermatids transformed to mature spermia they stayed in close apposition to the sustentacular cells, which nourish or support these transforming cells as well as some of the newly formed spermia. The transition in the spermatids was one in which the centrioles moved to one side, the cytoplasm reduced in amount until it was nearly nonexistant, the nucleus shrank, the chromatin condensed to become the head of the sperm cell, and a tail developed from the cell to complete the mature sperm cell.

The immature testicle had the same basic structure as the mature. Several major differences were exhibited, all of which were related to the inactivity or the immaturity of the organ. The epithelium of the seminiferous tubules was a single layer of cuboidal cells resting on the basement membrane (Plate I, Fig. 1.). The "interstitial cell" groups were not prominent though in some areas a suggestion of their future presence was detectable in groups of fibroblast-like cells with more vesiculate nuclei and more abundant cytoplasm. The lumen of the seminiferous tubules was not noticeable and this was a striking difference from the spermatozoa-filled lumens of the seminiferous tubules of the testicle from the mature bull.

The products of the seminiferous tubules left each lobule by a short duct called the straight tubule (tubule rectus). These ducts converged at the fibrous connective tissue core, which was the origin of the connective tissue septa. Within this connective tissue the ducts became very

irregular in shape and near the head of the epididymis the ductuli efferentes, a series of about 12 ducts, emerged from the connective tissue core at the proximal end of the testicle. At this point the ductuli efferentes coalesced to form a single duct which was the beginning of the epididymis.

THE EPIDIDYMIS AND THE DUCTUS DEFERENS

The epididymis was a single tube-like structure that folded back and forth upon itself many times as it formed the head, body, and tail of the epididymis. The ductus deferens was a continuation of the duct system from the tail of the epididymis which continued to the colliculus seminalis at the beginning anterior portion of the pelvic urethra.

The epithelium of the duct changed somewhat, as did the wall of the duct (Plate II, Fig. 1.). As the transition occurred from the seminiferous tubule to the straight tubule, the spermatogenic cells were not found. This left the tall sustentacular (Sertoli) cell as the predominant cell in this area. In the connective tissue septum, the epithelium varied from squamous to cuboidal in the different portions of the ducts. This variable epithelium continued into the ductuli efferentes. At the head of the epididymis, the epithelium was primarily simple columnar to pseudostratified columnar, with the cells showing cilia on the free borders. The nuclei of the columnar cells were long, oval and all rested at nearly the same level. Beneath the columnar cells was a zone of polyhedral to round cells with oval to round nuclei that rested on approximately the same level with each other. This layer of cells appeared to be modified connective tissue, and the cells rested on a basement membrane which, in turn, rested on the fibrous connective tissue supporting wall of the ducts.

EXPLANATION OF PLATE II

Fig. 1. Epididymis epithelium and wall. (430X)

Fig. 2. Urethral muscle in upper left over the disseminate part of the prostate in the lower right. (430X)

PLATE II

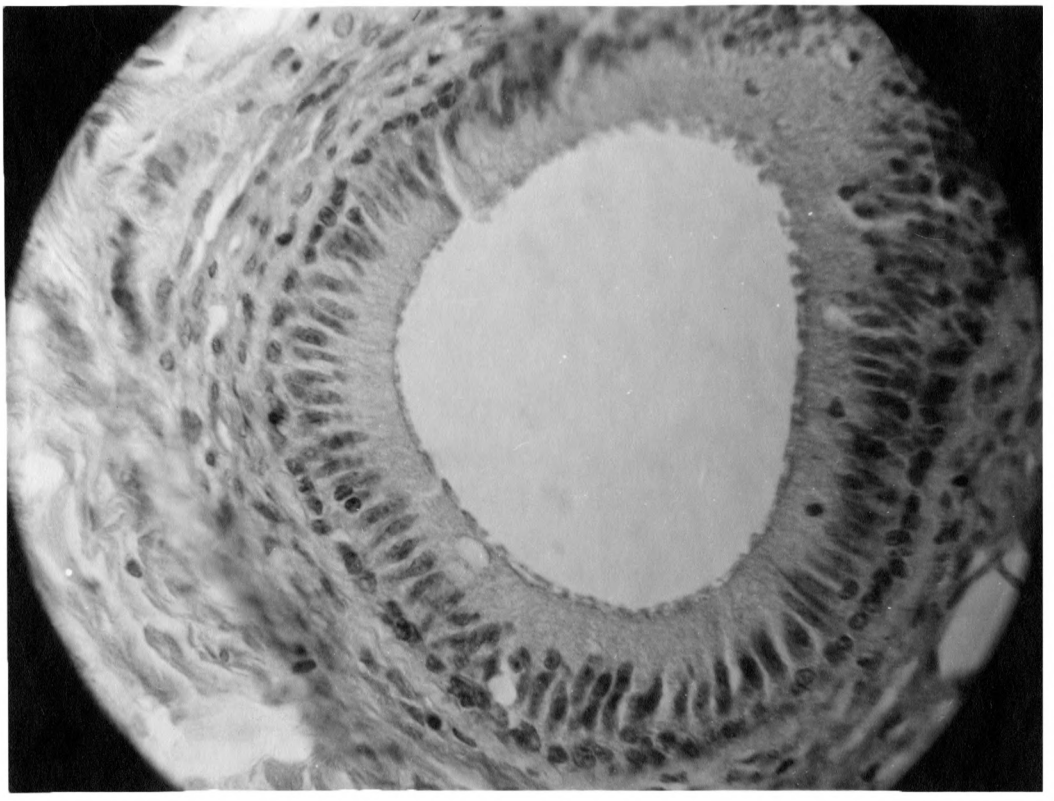

Fig. 1

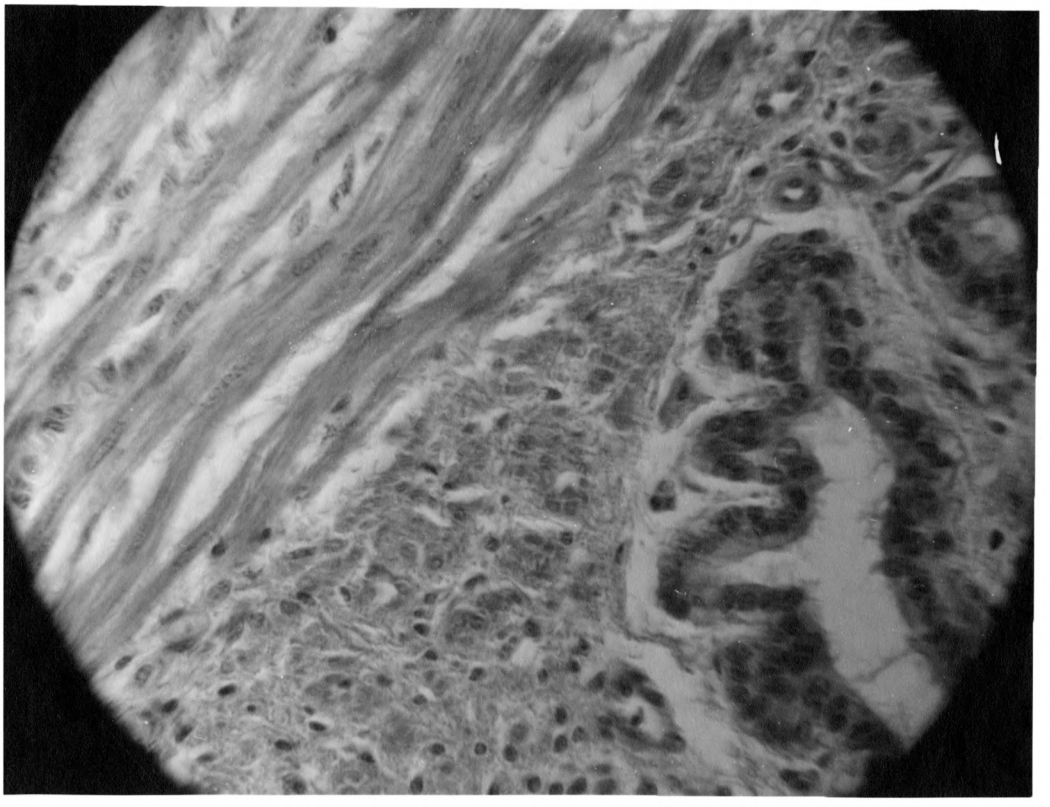

Fig. 2

Smooth muscle cells were present in a layer which encircled the wall of the duct. The tortuous bends of the epididymal ducts were held together by light, vascular connective tissue. The structure of the body of the epididymis was similar to that described for the head of the epididymis, except that the smooth muscle cell layers, which encircled the duct wall, had increased in number. The tail of the epididymis was similar to the head and the body, except that the lumen of the duct was larger, and the circular layer of smooth muscle was a more prominent feature. The connective tissue consolidating the epididymis into a single mass was very vascular and contained numerous nerve elements.

The ductus deferens was similar in basic structure to that of the epididymis. In the ductus deferens, the columnar epithelial cells were somewhat lower, and cilia, though present, were less prominent. The cells beneath the columnar layer were in several layers, thus causing a protrusion of the columnar epithelium into the lumen. The ductus deferens exhibited a much thicker wall than the epididymis and contained well developed smooth muscle layers. These layers could be distinguished as an inner longitudinal, a middle circular, and an outer longitudinal layer. The outer longitudinal layer blended with the supporting outer connective tissue of the duct. The terminal two or three inches of the ductus deferens was modified into an ampullae. This modification resulted in an increase in the external diameter with little increase in the size of the lumen. The wall in this area had become very thick as a result of many irregular folds of the epithelium. The folds contained connective tissue centers and were covered by clear, rather low columnar cells. The resulting pockets, which were basically evaginations of the epithelium, often branched and anastomosed with each other. The smooth muscle layers were still present but were less distinct.

Portions of the epithelial evaginations were found among the muscular layers and gave the appearance of glands.

THE PENIS

The penis was attached to the ischial arch by two crura. The crura joined each other at the midline to form a single body of the penis. The body of the penis was between the thighs, it emerged anteriorly beneath the inguinal area, and then was on the ventral surface of the abdomen on the midline. Posterior to the scrotum, the organ assumed an "S" shape curve, also known as the sigmoid flexure, which made the apparent length of the adult organ seem much shorter than its true 36 to 40 inches, McLeod (28). The sigmoid flexure was scarcely evident in the day-old calves but gradually developed as the animal matured. The glans penis was the terminal, free, three to four inches of the organ that was in the prepuce in the mature animal. Little or no glans penis was present in the prepuce of the day-old calves. Attached to the penis were the retractor penis muscles. These consisted of two light pink-colored bands of nonstriated muscle. Each band was about one-half inch in width, had a skeletal origin on the transverse processes of the first coccygeal vertebrae, progressed downward and forward behind the penis, bridged across the sigmoid flexure, and inserted at and anterior to the second bend of the sigmoid flexure on the ventral surface of the penis.

The prime function of the penis was as a supporting mechanism for the urethra. It was thus a very strong, fibrous, inelastic organ in the bull. The crura were heavy fibrous connective tissue cylinders which contained

erectile tissue and were covered by the striated ischiocavernosus muscle. The fibrous connective tissue layer was attached to the periosteum of the ischium. The erectile tissue of the crura continued into the body of the penis. The erectile tissue in the penis was separated by a connective tissue median septum that faded out a short distance anteriorly into the substance of the body of the penis.

The basic structure of the penis consisted of an outer layer of heavy fibrous connective tissue called the tunica albuginea. This tunic enclosed the corpus cavernosum penis, corpus cavernosum urethra, and the urethra. The corpus cavernosum penis was basically erectile tissue that had little erectile properties. The cavernous venous spaces of the erectile tissue were separated by septa which contained much fibrous tissue and had little elasticity. Two well developed arteries were running the length of the corpus cavernosum penis, in the area dorsolateral to the urethra. These arteries were continuations of the deep artery of the penis. Though the blood supply was good, the erectile property of the corpus cavernosum penis was poor due to the large amount of fibrous connective tissue in the septa between the cavernous spaces. In the region of the glans, the erectile tissue of the penis gradually was reduced in amount, and smooth muscle appeared, the connective tissue septa from the tunica albuginea became more prominent, and the fibrous anterior three to four inches of the organ, tapered to a point. The fibrous anterior part was covered by the poorly defined glans penis. The glans penis consisted of loose connective tissue, several branches of the dorsal arteries of the penis which passed into the area, a few large veins, and numerous nerves and nerve endings. There was little histological structure typical of erectile tissue present.

Beneath the tip of the body of the penis the urethral process lay attached longitudinally to the glans penis. This process contained the terminal portion of the urethra. The glans penis and urethral process were covered by stratified squamous epithelium that was continuous with that of the prepuce (Plate VI, Fig. 2.).

A gross observation by McLeod (28), that the urethral groove was converted into a urethral canal by fibrous connective tissue extensions of the tunica albuginea of the penis, was confirmed by the microscopic examinations made in this study. This canal limited the expansion of the corpus cavernosum urethra and the lumen of the urethra.

THE URETHRA

The urethra extended from the neck of the bladder to the apex of the glans penis and consisted of a pelvic and an extra pelvic part. This structure served as a duct for the conveyance of urine and the products of the testicles and accessory genital glands along the penis and out of the body. The urethra originated at the neck of the bladder and was surrounded by the striated urethral muscle and the disseminate part of the prostate gland. This muscle and gland surrounded the pelvic part of the urethra for the entire length. The ductus deferens, seminal vesicles and prostate glands emptied their contents through the dorsal wall into the lumen of the pelvic part of the urethra. This portion of the urethra was called the colliculus seminalis or semen collecting portion. The extrapelvic part of the urethra extended the entire length of the penis and was surrounded by erectile tissue, the corpus cavernosum urethra, and fibrous connective tissue.

The epithelium of the pelvic urethra (Plate III, Fig. 1.) was transitional. The superficial cells were flat, the middle layer polyhedral and the basal layer of cells were low columnar or cuboidal. The epithelium rested on a layer of fairly loose, vascular connective tissue. The venules in this area were large, thin walled and represented a form of erectile tissue. Smooth muscle fibers, continuous with those of the disseminate part of the prostate gland, were present in the outer part of the connective tissue layer. The striated urethral muscle surrounded both the urethra and the prostate gland in this area.

The epithelium was transitional at the sigmoid flexure but usually appeared to be thicker than that of the pelvic urethra as the epithelium was relaxed and thrown up into prominent longitudinal folds with connective tissue centers. The tissue surrounding the urethra was very vascular, forming cavernous erectile tissue. The connective tissue in the area was quite fibrous. The area closest to the urethral epithelium was composed mostly of small, cavernous, venous spaces. Farther out, and continuing to the heavy fibrous connective tissue layer of the shaft of the penis, the venous spaces became larger cavernous sinus-like structures.

In the urethral process the epithelium (Plate III, Fig. 2.) was transitional, thick, thrown into longitudinal folds and in mature animals contained many lymphocytes. The erectile tissue surrounded the urethra in a definite but poorly developed layer. Nerve fibers in the erectile tissue and in the connective tissue were characteristic of this area. The epithelium changed to stratified squamous at the terminal end of the urethral process and was continuous with the epithelium covering the glans and lining the prepuce.

EXPLANATION OF PLATE III

Fig. 1. Urethra in pelvis. (430X)

Fig. 2. Urethra in urethral process. (430X)

PLATE III

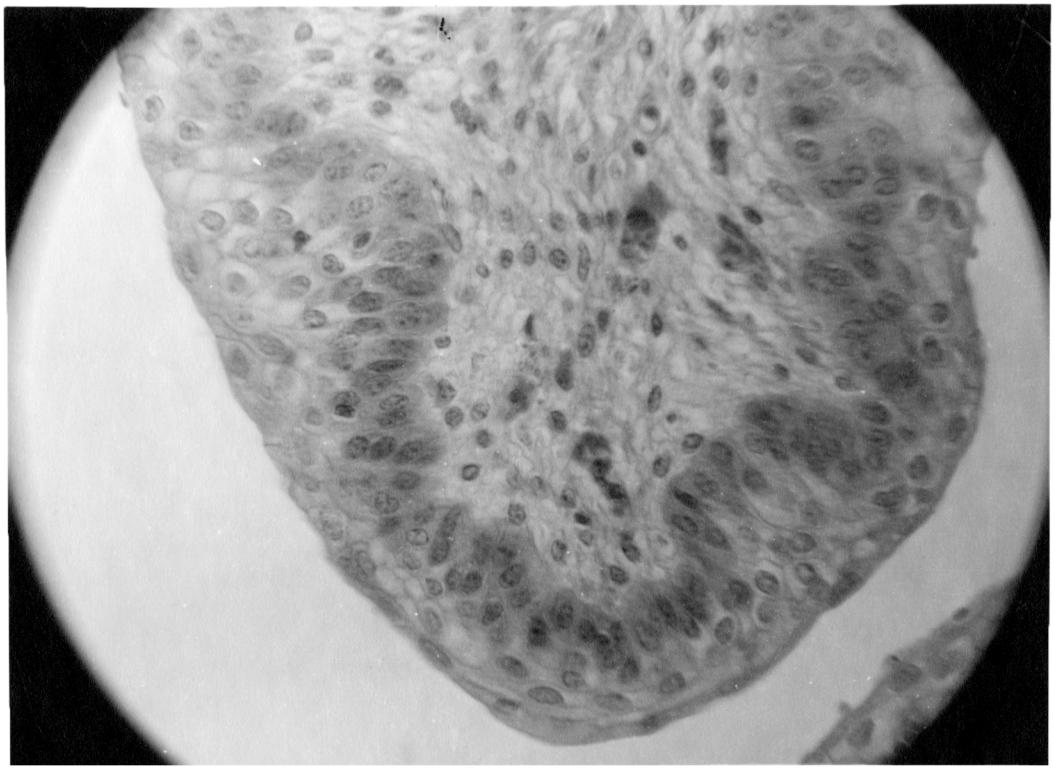

Fig. 1

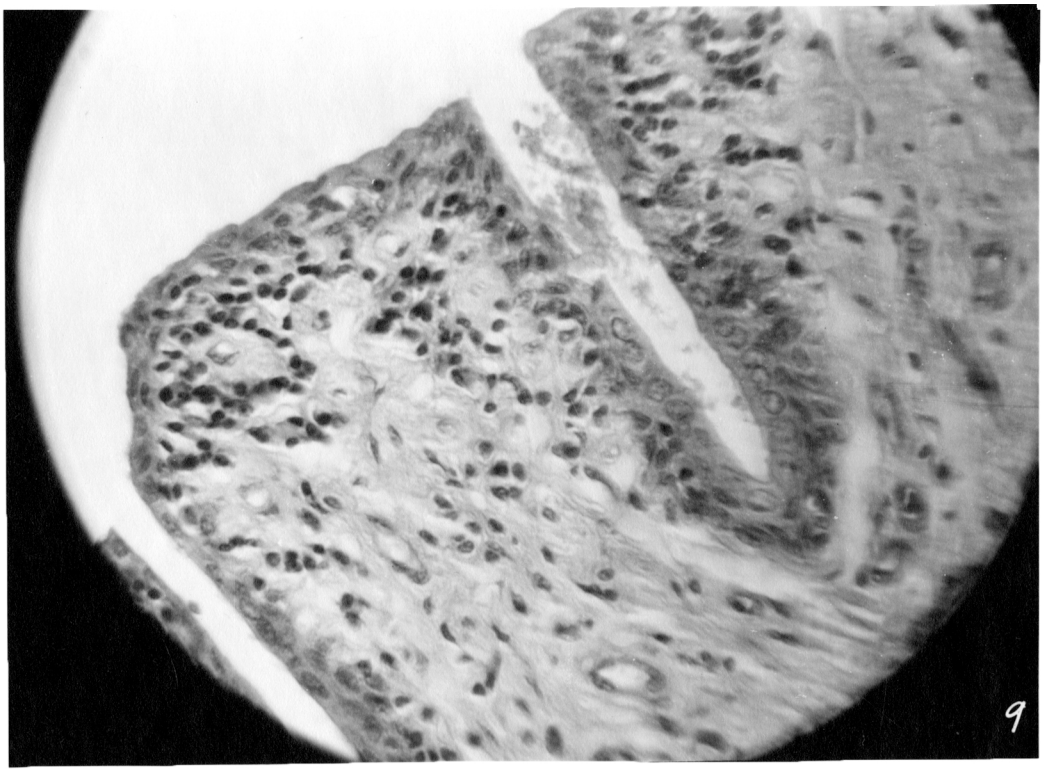

Fig. 2

THE PROSTATE GLAND

The prostate gland was single but consisted of two parts. The body portion was a small transverse elevation on the dorsal surface of the urethra-bladder junction. The disseminate part surrounded the urethra and was itself surrounded by the urethral muscle (Plate II, Fig. 2.).

The gland was composed of many tubuloalveolar glands that emptied by numerous prostatic ducts into the dorsal wall of the lumen of the pelvic urethra. The secreting portions of the glands were round, oval, or irregular in shape as seen in the sections. Folds or papillae of epithelium with central cores of connective tissue were found projecting into the lumen of the secreting parts of the glands. Portions of the folds occasionally appeared free in the cavities of the secreting portion. The glandular epithelium was high columnar in the active gland of the mature animal, Plate IV, Fig. 2., and low columnar in the immature gland of the day-old calf and in the castrate (Plate IV, Fig. 1.). The nuclei of the glandular epithelium were all at approximately the same level in the basal third of the cells in active cells and in the basal half of the cells in immature or inactive cells. In the active cells, the cytoplasm exhibited numerous eosinophilic secretory granules. Groups or masses of these granules were also occasionally observed on the free surface of the cells. When secretory granules were numerous and the cytoplasm full, the nuclei were pushed toward the base of the cell and became slightly flattened. The epithelial cells lay upon a layer of connective tissue which contained capillaries and elastic fibers. The connective tissue varied with a seemingly greater amount in immature or inactive glands and less in mature active glands. No basement membrane was apparent.

EXPLANATION OF PLATE IV

Fig. 1. Immature prostate gland, disseminate part. (430X)

Fig. 2. Mature prostate gland, disseminate part. (430X)

PLATE IV

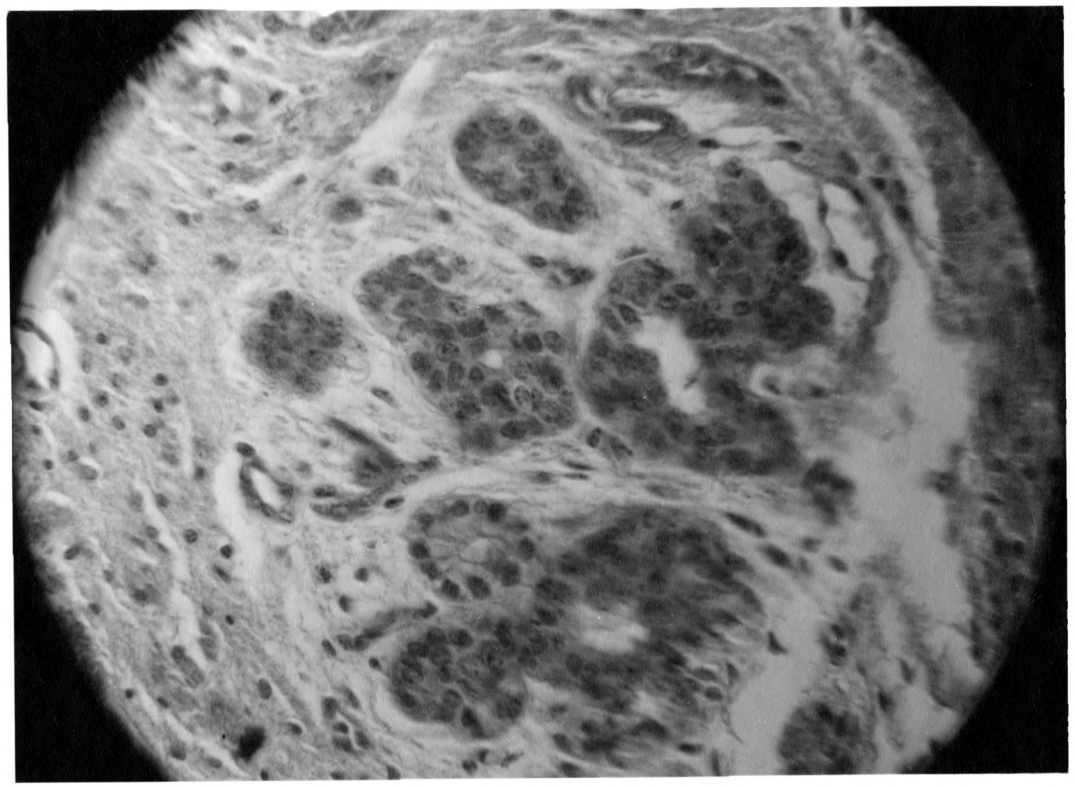

Fig. 1

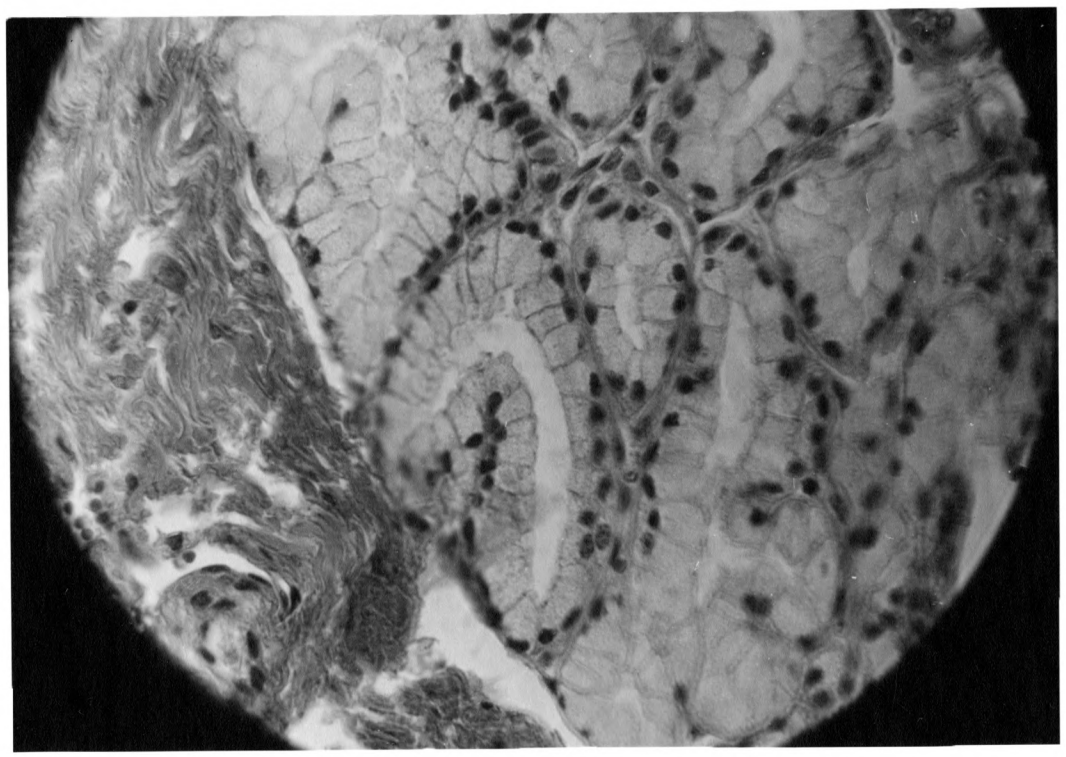

Fig. 2

The striated urethral muscle surrounded the disseminate portion of the prostate and muscular septa extended in toward the urethra. Many nerve fibers and some small arteries and veins were present in the connective tissue on the dorsal and lateral surface of the urethral muscle and, in the dorsomedial area, in the muscle itself.

THE SEMINAL VESICLES

The seminal vesicles were paired tubular glands which extended forward and laterally from the urethra-bladder junction. They lay in the genital fold, which was a fold of peritoneum, partially dorsal to the ampullae of the ductus deferens and along the dorsolateral part of the empty urinary bladder. These glands were four to five inches in length, in the mature animal, and presented a lobulated appearance.

A duct from each gland passed under the body of the prostate to open into the dorsal surface of the urethra, with the ductus deferens at the colliculus seminalis.

The lumen of the glands was not distinctly outlined because the mucous membrane was folded, producing outpocketings and irregular spaces which may anastomose. The epithelium was primarily high columnar cells which appeared pseudostratified in the mature active gland (Plate V, Fig. 1.). In inactive glands, and in the castrate, the glandular epithelial cells were low columnar to cuboidal in shape. The nuclei rested in a fairly even row in the basal one-half of the active cells. A basement membrane was not found, the epithelium rested upon a layer of connective tissue containing elastic fibers and capillaries and, in its deeper part, smooth muscle fibers. The outer surface of the glands was confined by a layer of connective

EXPLANATION OF PLATE V

Fig. 1. Mature seminal vesicle. (430X)

Fig. 2. Mature bulbourethral gland. (430X)

PLATE V

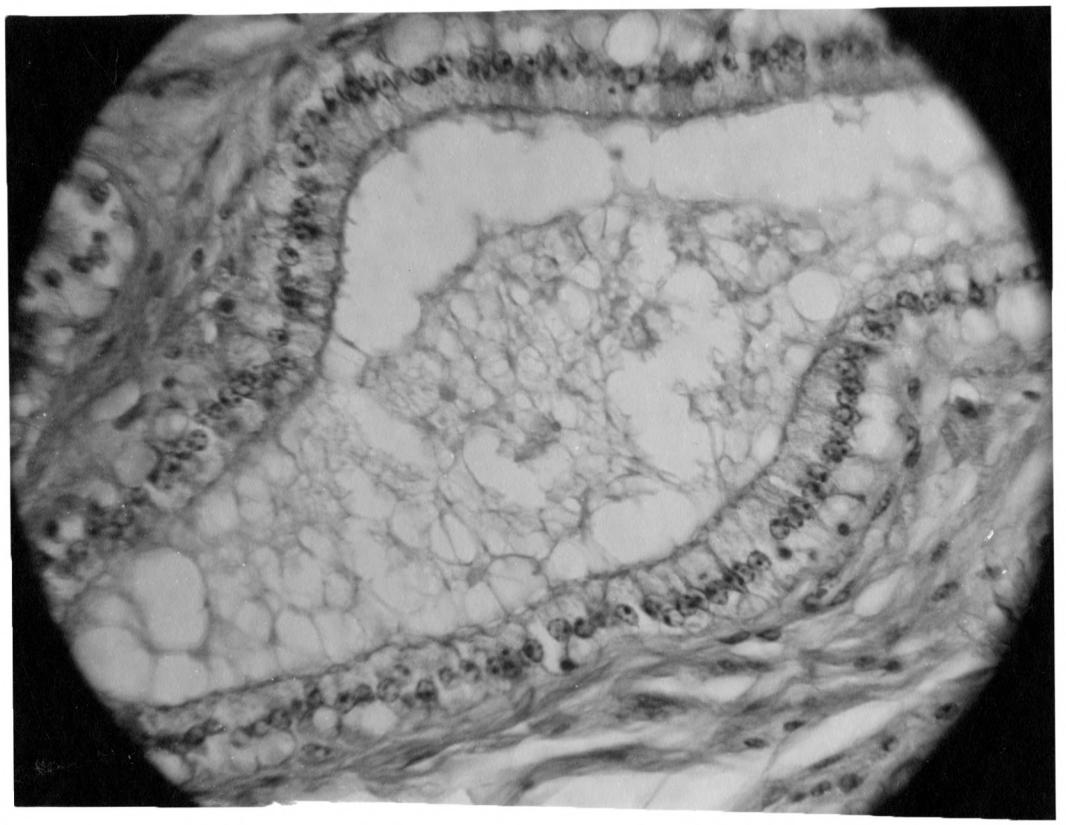

Fig. 1

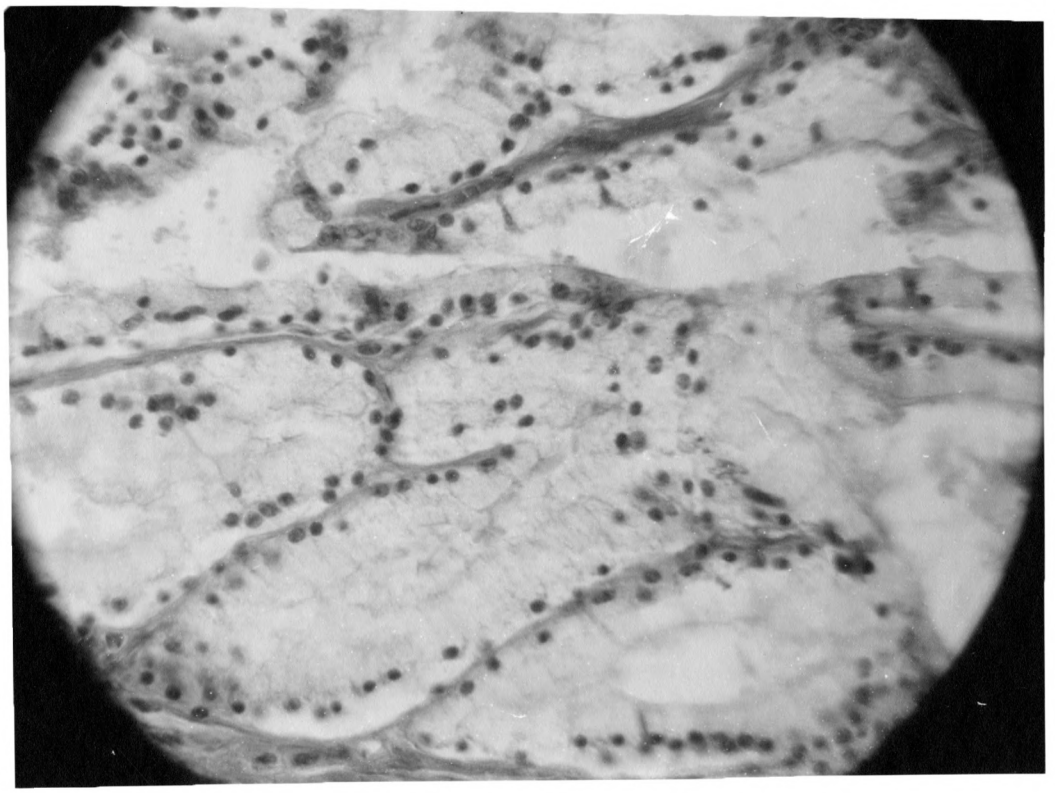

Fig. 2

tissue and smooth muscle from which septa extended into the submucosal areas of the gland itself.

The secretion, in an active gland, appeared as a lightly eosinophilic mass partially or completely filling the lumen of the secretory areas. The secretory mass was not homogeneous but exhibited many irregular densely packed globules. When the mass was pulled away from the secreting cells, the secretory globules were seen in the distal portions of the secreting cells or on their surfaces. Occasionally, basophilic, calcified concretions were observed in the lumen of the secretory portion of the glands from mature animals.

As the ducts from the secreting areas joined to form larger ducts, the epithelium became lower until the primary duct was lined by stratified epithelium.

THE BULBOURETHRAL GLANDS

The bulbourethral glands were paired, oval structures located on either side of the median plane at the pelvic outlet. These glands were covered by the urethral muscle. A single duct from each gland passed backward and downward to join the urethra at or below the ischial arch.

The bulbourethral glands were basically of the tubuloalveolar type. The secreting portions were oval, round to irregular in shape and were arranged in small lobules. The lobules were, in turn, organized into lobes and the lobes into the complete gland.

The epithelial cells were basically columnar and, in an active gland, the nucleus of the cells was in the basal portion (Plate V, Fig. 2.). In immature animals, or the inactive glands of the castrate, the cells were low columnar to cuboidal in shape and the lumen of the secretory areas of

the gland were collapsed or reduced in size. The cytoplasm of tall active cells was filled by many mucoid-like droplets. If the secretion was retained in the lumen of the alveoli, the columnar cells appeared somewhat compressed or flattened, due to pressure of the secretion.

No basement membrane was observed and the epithelium rested on a layer of connective tissue that was similar in structure to that of the seminal vesicles. This subepithelial layer contained elastic fibers, capillaries, and a variable amount of muscle. The surrounding muscle was the striated urethral muscle. The connective tissue septa of the gland proper contained smooth muscle fibers. The capsule surrounding each gland was fibrous connective tissue from which septa extended into the gland to form the supporting structure.

The duct system developed from a junction of the lumens of the tubular secreting portions. The columnar secreting cells, initially high, became shorter and fewer, but the number of cell layers increased as the ducts approached the urethra. The epithelium became stratified just before the ducts joined the urethra.

THE PREPUCE

The prepuce was a cylindrical, hairless modification of the skin which protected the glans penis. It was basically a long, narrow pouch into which, in the mature animal, the penis protruded from the posterior. The anterior end was open, and through this opening the penis protruded during erection and the urine passed during urination.

The epithelium lining the prepuce was stratified squamous, hairless, and had a lightly cornified superficial layer (Plate VI, Fig. 1.). The epithelium was several cell layers thicker than that of the neighboring skin.

EXPLANATION OF PLATE VI

Fig. 1. Epithelium of the prepuce. (430X)

Fig. 2. Epithelium of the glans. (430X)

PLATE VI

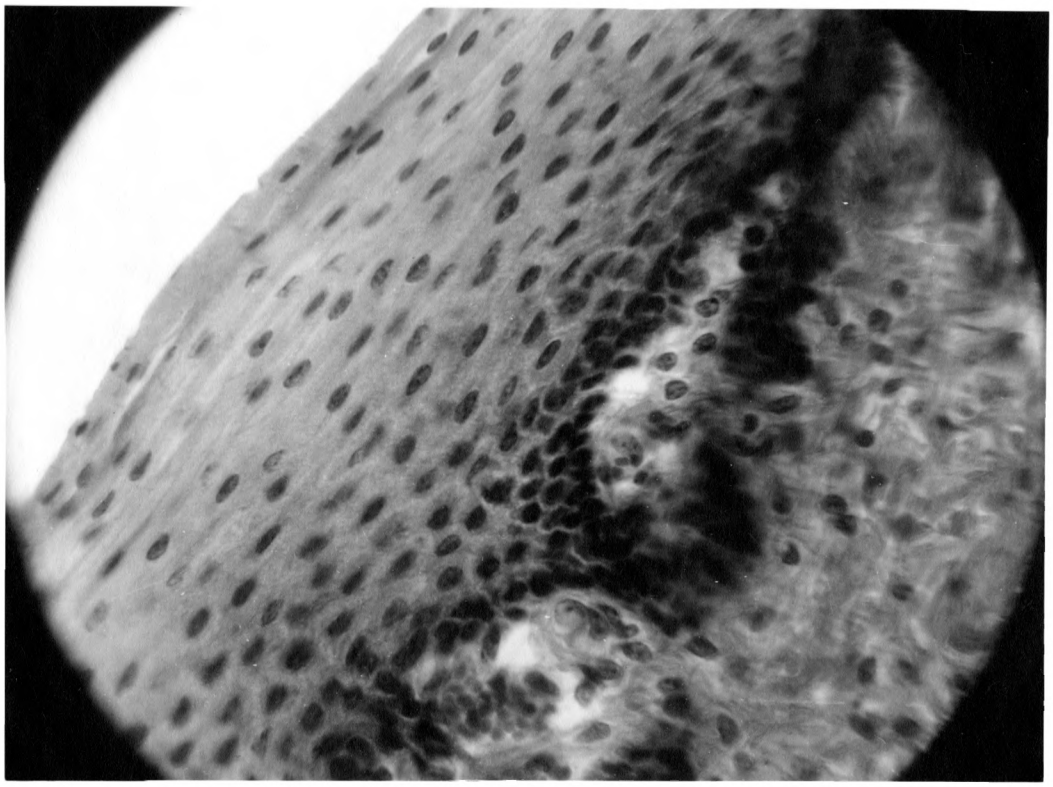

Fig. 1

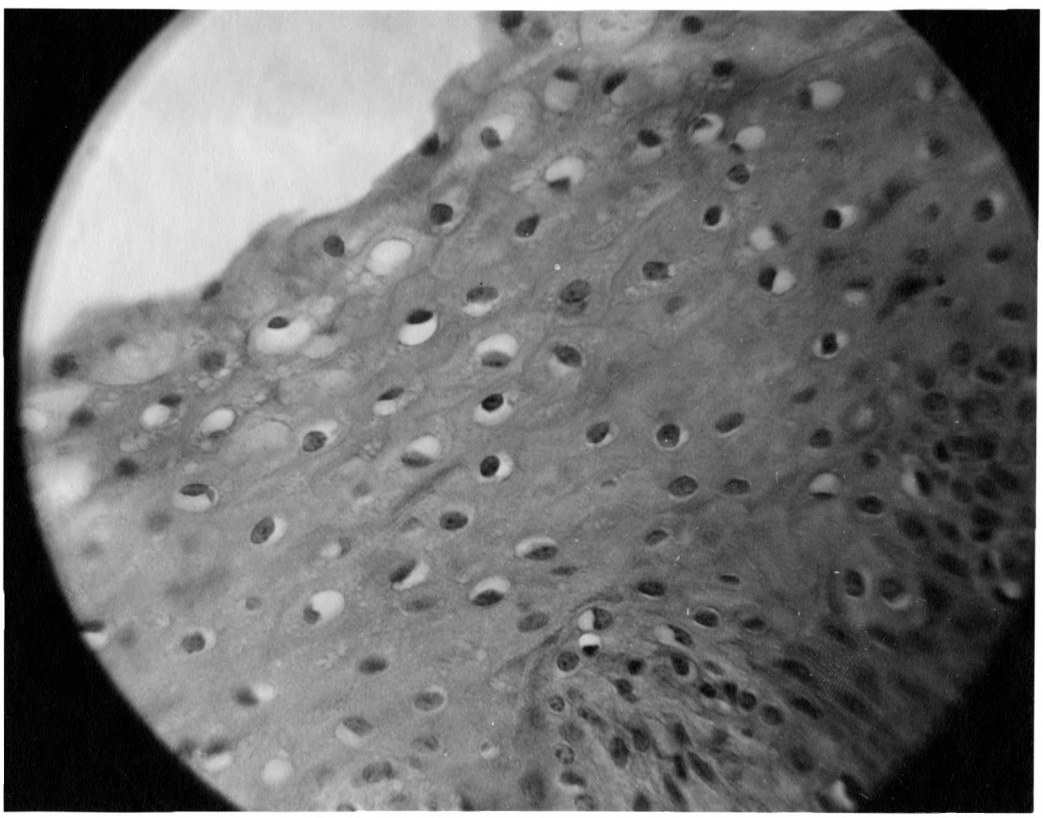

Fig. 2

The subepithelial tissue was a loose areolar connective tissue that gave the prepuce much flexibility. There was a sharp change in the epithelium at the preputial-skin junction and at the anterior urethral orifice on the urethral process. In the first area, the stratified squamous epithelium of the prepuce joined with the stratified squamous epithelium of the skin, where hair and sebaceous glands were added. The stratified squamous epithelium over the glans met the transitional epithelium of the urethra at the urethral orifice. There was no sharp line of change as the preputial epithelium was reflected over the glans but the epithelium was slightly thicker over the glans proper. The subepithelial tissue was denser, and the epithelium more firmly attached as the apex of the glans was approached. McLeod (28) states that when erection occurs, the prepuce is laid over the shaft of the penis, thus protecting the penis with the stratified squamous epithelium of the prepuce.

THE SCROTUM

The scrotum was a sac of skin hanging below the external inguinal ring. It enclosed the testicles and their associated structures. The scrotum had a constricted area near its attachment and a septum dividing the sac into two equal compartments on each side. The wall of the sac consisted of a thin layer of skin on the outside, a layer of smooth muscle cells, a layer of fascia and the tunica vaginalis communis, which was the serous inner layer.

THE MUSCLES

The cremaster externus muscle appeared as a band of striated muscle that attached to the tunica vaginalis communis over the testicle. The muscle

passed upward through the inguinal canal in such a way that it functioned in raising and lowering the testicle in the scrotum. This muscle is thought by some to be a band of muscle from the posterior part of the internal abdominal oblique muscle.

The cremaster internus muscle was within the spermatic cord. This muscle was a group of indistinct smooth muscle fibers that ran parallel to the structures of the spermatic cord. Microscopically, its attachments were indistinct, and it apparently functioned to shorten the spermatic cord when the testicle was raised by the cremaster externus muscle.

The bulbocavernosus muscle surrounded the bulbous part of the extra pelvic urethra at the ischial arch. This striated muscle was in transverse strands around the urethra and was anchored at each side of the urethra by attaching to the tunica albuginea of the body of the penis.

The retractor penis muscles were paired nonstriated muscles that were in two long bands. These muscles began at the first coccygeal vertebrae and inserted on the ventral part of the body of the penis ahead of the sigmoid flexure. The muscle fibers were gradually inserted into the body of the penis and could be found anteriorly as far as the posterior part of the glans penis.

The protractor prepuce muscles were paired striated muscles that began in the abdominal fascia near the umbilicus and attached to the preputial fascia near the preputial orifice.

The retractor prepuce muscles were paired striated muscles that originated in the abdominal fascia near the external inguinal ring and inserted in the preputial fascia, behind the insertions of the protractor prepuce muscles.

The ischiocavernosus muscles were striated muscles that originated on the tuber ischii, covered the crura of the penis, and inserted on both the crura and the body of the penis.

THE BLOOD SUPPLY

The blood supply to the testicle was from the internal spermatic artery, which was a branch of the abdominal aorta. The internal spermatic artery supplied the testicle by passing through the inguinal canal with the spermatic cord.

The scrotum received blood from branches of the external pudic artery. The largest of these branches were in the septum of the scrotum. Branches from the external pudic, called the subcutaneous abdominal, also supplied the loose connective tissue of the scrotal and preputial area, the prepuce, and the preputial muscles.

The penis received blood from the internal pudic artery which, at the root of the penis, divided into three branches: 1. the artery of the bulb, which supplied the corpus cavernosus urethra, 2. the deep artery of the penis, which supplied the corpus cavernosus penis, and 3. the paired dorsal arteries of the penis, that were loosely attached along the dorsal part of the penis and from which branches supplied the body of the penis and glans. The internal pudic artery also supplied a small branch to the bulbourethral gland and muscle near the ischial arch.

The seminal vesicles, prostate, and pelvic urethra received blood from the urogenital artery, which was a branch of the internal iliac artery. A small branch of this artery followed along and supplied the ductus deferens.

THE NERVE SUPPLY

The cremaster externus muscles and the scrotum received nerve supply from the inguinal nerve, a branch of the third lumbar nerve, as the nerve passed through the inguinal canal.

The testicle, seminal vesicle, prostate gland, and bulbourethral gland were innervated by nerves of the autonomic nervous system.

The penis was innervated by the dorsal nerve of the penis, which was a branch of the pudic nerve. The pudic nerve also supplied the innervation for the ischiocavernosus, bulbocavernosus, and retractor penis muscles.

DISCUSSION

The material used in this study was from apparently normal animals or from animals that were necropsied for other conditions, which did not involve the genital system. A history of sterility was present in a few cases prior to necropsy. The sterility specimens were used only in the gross anatomical studies to insure the inclusion of only apparently normal tissue in the microscopic observations.

The majority of the assumptions previously made by men in the field, that basic structure was similar in most of our domestic animals, were found to be correct.

This study produced information, which was not available or could not be assumed. This information was as follows: 1. the sigmoid flexure was not present in a day-old calf but developed as the animal matured, 2. the glans penis of a day-old calf was not present in the prepuce but as the animal grew, the penis protruded further and further forward into the prepuce, 3. the urethra, surrounded by fibrous connective tissue, was lying in an enclosed canal rather than a groove, 4. microscopically, the fibrous

connective tissue surrounding the urethral canal was found to be continuous with the connective tissue of the tunica albuginea of the penis, 5. microscopically, the accessory genital organs of a castrate more closely resembled the organs of an immature calf than the organs of a mature animal, 6. the erectile properties of a bull penis were found to be limited not only by the heavy fibrous tissue tunica albuginea, but also by extensive fibrous tissue septa within the erectile tissue, 7. the retractor penis muscle inserted from the ventral part of the sigmoid flexure all the way forward to the glans penis, 8. the preputial and penial epithelium were similar in structure, but varied slightly in the thickness and in the density of the subepithelial tissue attachment, 9. lymphocytes in the epithelium of the anterior part of the urethra were not uncommon.

SUMMARY

A review of the literature revealed many assumptions from sources not based on a study of the male bovine genital system. The review also disclosed that all the studies which were made on the male bovine genital system were incomplete, included only portions of the system, or were for some specific problem or experiment. This made a study as reported in this thesis valuable to fill in the existing deficiencies in the available information.

Gross examinations were made of fixed and injected specimens from twenty animals and stained microscopic sections of twenty-seven areas from eleven animals. Animals represented in the group for microscopic study included two day-old calves, two eighteen to twenty-four month old castrates, and seven mature animals.

A discussion of the gross and microscopic structures of the male bovine genital system was presented with the following major areas considered:

1. the testicle, 2. the epididymis and ductus deferens, 3. the penis, 4. the urethra, 5. the bulbourethral glands, 6. the seminal vesicles, 7. the prepuce, 8. the muscles, 9. the blood supply, 10. the nerve supply.

The differences between similar structures in the day-old calf, the castrate, and the mature animal, were pointed out and described.

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THE GROSS ANATOMY AND HISTOLOGY OF THE GENITALIA OF THE DAY-OLD, THE CASTRATE AND THE MATURE MALE BOVINE

by

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The object of the study was to examine the basic normal structure, both gross and microscopic, of the bovine male genitalia. The numerous sterility problems related to portions of the genital system of the bull have been studied for many years with no one recorded source of information regarding what was essentially the normal. Much of the existing information was assumed from work on other animals and was not always accurate or complete. The day-old calf and the castrate were included in the study to give some of the developmental factors of the normal under these ages or conditions. The work described in this thesis was to confirm or deny the assumed facts and bring out new facts not previously described or recorded.

The genitalia were collected from twenty male bovine subjects in the day-old, the castrate and the mature categories. The specimens were preserved and vascular injections made for gross anatomical studies. Samples of tissue from twenty-seven different areas of eleven sets of genitalia were removed for microscopic study. The tissue sections were dehydrated, embedded in paraffin, sectioned and stained. Photomicrographs were made of the glandular tissue and the epithelium to show significant features.

The basic gross and the microscopic structure for each of the organs or structures of the bovine male genital system was described. Differences, when significant, between the same areas in the day-old calf, the castrate and the mature animal are emphasized.

It was found that most of the assumed facts, regarding the gross and the microscopic structure of the male bovine genitalia, were not entirely incorrect. New facts found or emphasized were: 1. the similarity in structure of the accessory glands of the castrated animal and of the day-old calf; 2. microscopically the urethral groove was found to be enclosed

by connective tissue to form a urethral canal; 3. the sigmoid flexure was not present in the penis of the day-old calf and the glans penis was not in the prepuce at this age; 4. the lack of erectile properties of the penis was shown to be due to the large amount of connective tissue within the erectile tissue as well as the connective tissue surrounding the organ; 5. the insertion of the retractor penis muscle was found to extend to the glans penis; 6. the similarity of the epithelium of the glans penis and the prepuce; 7. the presence of lymphocytes in the epithelium of the anterior part of the urethra of mature animals was found to be apparently normal.