A HISTOLOGIC STUDY OF THE URINARY SYSTEM OF THE NEWBORN BEAGLE DOG

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A HISTOLOGIC STUDY OF THE URINARY SYSTEM OF THE NEWBORN BEAGLE DOG

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INTRODUCTION

The histology of the urinary system of adult dogs has been thoroughly investigated and compared to that of other domestic animals. However, there is little information available concerning the urinary system of newborn dogs.

Although the development of the nephron of other animals has been studied extensively, the developing nephron of the dog has received little attention. Information concerning the remainder of the urinary system of newborn dogs is far from being complete. It is the purpose of this study to document the histology of the urinary system of the newborn beagle dog.

REVIEW OF LITERATURE

A thorough review of the literature revealed limited information concerning particular aspects of the urinary system of newborn dogs. A description of the developing glomerulus (Trabucco and Marquez, 1952) was the most informative article, and descriptions of the glomerular development in the rabbit (Lewis, 1958), rat (Jokelainen, 1963), and man (MacDonald and Emery, 1959) were available for comparison with that of the dog.

MacNider (1945) made a study of the lipoid material in the renal epithelium of animals of various ages. This material was present in the cells of Henle's loop and absent in the proximal convoluted tubules of 4-months-old dogs.

Davies (1954) reported on protein absorption in fetal and adult mammalian kidneys. He found PAS positive granules in the proximal convoluted tubules, the collecting ducts, and the ureter of fetal, newborn, and immature dogs.

Mayer and Ottolenghi (1947) stated that tubular epithelium protruded into the glomerular capsule in 1 to 12-day-old beagle dogs. This epithelium was encountered in the mature renal corpuscles of both healthy and sick dogs.

Bharadwaj (1960) reported on the penis and prostate gland in puppies. A developing os penis was present in the penis, and the prostatic and penile urethrae were lined with transitional epithelium.

Trabucco and Marquez (1952) studied the developing metanephros of dog embryos. They described the formation of the S-shaped body of the early nephron and the sanguineous lacuna which gives rise to the glomerulus.

Although the information concerning the development of the glomerulus in the dog is limited to the work of Trabucco and Marquez (1952), extensive work has been done in describing the formation and structure of the glomerulus in the rabbit, rat, and man.

Lewis (1958) described the development of the metanephric blood vessels of rabbit embryos during different stages of development. He reported that the cells which form the glomerulus are extruded from the thick, proliferative visceral epithelial cells of the glomerular capsule. Jokelainen (1963) studied the metanephros of the rat and described the development of the entire metanephric unit. He stated that the glomerulus developed in situ.

Gruenwald and Popper (1940) examined the kidneys of embryos, fetuses, and children up to 22 months of age and described the relationship of the structure and function of the glomerulus in early postnatal life. The presence of cuboidal cells in the visceral layer of the developing glomerular capsule impaired filtration because of the cell thickness. The visceral epithelium formed an unextendable sac which reduced blood flow through the glomerulus.

MacDonald and Emery (1959) studied the development of human glomeruli and described six developmental stages. The arrangement of the visceral epithelium of the glomerular capsule and the presence of a vascular pole were the criteria used to classify the different stages.

Aoki (1966) reported on the differentiation of the filtering membrane of the human glomerulus. The visceral epithelium developed from part of the vesicular wall while the capillary endothelium developed from mesenchymal cells and solid buds of interstitial capillaries which penetrated into the cleft of the late renal vesicle. A basement membrane made no appearance until the visceral epithelium and the endothelium were situated close to each other.

Jäykkä (1961) reported that the human kidney reached full functional maturity during fetal life but remained inactive until shortly after birth. This study on 16 human fetuses revealed that epitheloid cells in the walls of afferent glomerular arterioles bulged the intima of the arterioles and reduced the bore of the vessels. However, the obstruction was reported to be incomplete, and when the kidneys of babies began functioning, the epitheloid cells lost their turgidity.

MATERIAL AND METHODS

Seven male and five female newborn beagle dogs were obtained from Dr. John A. Moore of the Leukemia Transmission Studies at the Michigan State University Veterinary Clinic. The animals were killed by placing them in a gas-tight jar which contained ethyl ether. Each dog's urinary system was dissected out, and portions of a kidney were removed so that transverse, saggital, and coronal sections of the tissue could be obtained. Portions of a kidney from each dog were placed in the following fixatives: Carnoy's (Gridley, 1960), Bouin's (Gridley, 1960), Rossman's (Lillie, 1965), Baker's Formol Calcium for lipids (Lillie, 1965), and a 10% formalin solution buffered with sodium phosphate (Gridley, 1960). The tissues comprising the remainder of the urinary system were placed in Bouin's fixative (Gridley, 1960). All tissues were left in the fixative for 24 hours.

The tissues were then dehydrated and cleared in four changes of tetrahydrofuran. Infiltration with Paraplast was carried out under a vaccum of 25 mm/Hg at 58°-60° C for two hours before the tissues were embedded.

Those tissues procured for frozen sections were fixed in Baker's Formol Calcium fixative (Lillie, 1965), cut at 10 microns, and stained for lipid material with Oil Red O (Gridley, 1960).

Sections of all other tissues were cut 6-8 microns, and the following stains were used: hematoxylin and eosin, Weigert and Van Gieson's connective tissue stain (Mallory, 1944), periodic acid-Schiff reaction (Gridley, 1960), gold chloride stain (Soule, 1962), and luxol fast blue stain combined with periodic acid-Schiff reaction (Shanklin and Nassar, 1959).

The photomicrographs were taken on a Zeiss photomicroscope using ADOX KB14 film.

RESULTS AND DISCUSSION

Kidney

The unipyramidal kidney of the newborn beagle dog is bean-shaped, and its size varies with the size of the puppy. The parenchyma of the kidney is equally divided into a cortex and a medulla (Figure 1). The terminal portions of the collecting tubes of the kidney, the papillary ducts, open on the renal crest which is enclosed by the renal pelvis.

Capsule

The capsule of the kidney is composed primarily of collagenous and reticular fibers and some smooth muscle. Yadava and Calhoun (1958) reported smooth muscle in the capsule of adult dogs and Calhoun (1967) has observed smooth muscle in the capsule of 6-months-old beagle dogs. Elastic fibers are absent. Brown fat is present within the capsule at various locations around the kidney (Figure 2) and is particularly prevalent in the region of the hilus. Blood vessels are found within the capsule (Figure 3). A kidney from one dog has glomeruli and uriniferous tubules in the loose connective tissue within the capsule at the polar region (Figure 4).

Cortex

Neogenic Zone

The cortex of the kidney consists of an outer neogenic zone and an inner maturation zone. The maturation zone contains the nephron units that are capable of producing urine while all stages in the development of the metanephric nephron are present in the neogenic zone (Figure 1). Mitotic figures are found in all stages of the developing nephrons. The stroma of the neogenic zone consists of mesenchymal cells which differentiate into interstitial tissue and blood vessels (Aoki, 1966). Aggregations of red blood cells located in the stroma are similar to the small sinusoids reported by Kazimierczak (1965) in the neogenic zone of newborn pigs. PAS positive granules are scattered throughout the stroma.

Ureterogenic Collecting Tube.--The ureterogenic collecting tube extends through the maturation zone into the neogenic zone and terminates in the subcapsular region (Figure 5). This tube consists of columnar and cuboidal epithelial cells which have indefinite cell boundaries. The spherical and oval nuclei of these cells possess a distinct nucleolus and nuclear membrane and coarse chromatin material. The dilated end of the collecting tube, the ampulla, is surrounded by a group of elongated cells termed the metanephric blastemal cap (Huber, 1905).

Metanephric Blastemal Cap.--The metanephric blastemal cap consists of oval and elongated cells at the dilated end of the collecting tube. While these cells possess little cytoplasm and indefinite cell boundaries, they are easily differentiated from the surrounding mesenchymal cells because the cap as a whole appears as a definite structure (Figure 5). The cells comprising the metanephric blastemal cap possess spherical nuclei which contain a distinct nucleolus and nuclear membrane and coarse chromatin material. There is no basement membrane surrounding the metanephric blastemal cap; however, a basement membrane which reacts positively with PAS and stains positively with a reticular stain is present on the outer surface of the ureterogenic collecting tube separating the tube from the metanephric blastemal cap (Figure 5).

Osathanondh and Potter (1963) considered the simultaneous growth of the ureterogenic collecting tube and the metanephric blastemal cap in human kidneys necessary for the cap cells to differentiate into the renal vesicle. The cells of the arched portion of the cap eventually lose connection with the cells of the distal portions of the cap, and the latter continue to develop into the renal vesicle.

Renal Vesicle.--The early renal vesicle is located in the subcapsular portion of the neogenic zone and consists of epithelial cells with a centrally located oval cavity (Figure 6). The cell boundaries are indistinct and a basement membrane surrounds this structure. The epithelial cells contain spherical or elongated nuclei which possess a distinct nucleolus and nuclear membrane and coarse chromatin material.

The development of the renal vesicle consists of two phases (Jokelainen, 1963). Proliferation of the cells occurs during the first phase, and morphodifferentiation of the proliferating cells occurs during the second phase. The renal vesicle increases in size due to the proliferation of the cells during the growth phase, and as the renal vesicle enlarges the cells composing its wall nearest the ureterogenic collecting tubule increase in length (Figure 6). The change in these cells is considered to be the beginning of morphodifferentiation; however, the cells which are mainly involved in this second phase of development of the renal vesicle are the cells of the outer vesicular wall.

During the stages of morphodifferentiation the cells of the outer vesicular wall elongate while the cells of the basal portion of the renal vesicle become cuboidal in shape (Figure 7). The cells of the apical portion of the renal vesicle maintain their original shape. The elongated cells of the outer vesicular wall eventually undergo a change in position and shape. The position of the cell changes as the apical portions of these cells are directed toward the base of the renal vesicle. The nuclei appear to migrate toward the apical part of the cell.

Jokelainen (1963) described the fate of certain groups of cells which compose the late renal vesicle in rats. He found that the cells in the middle of the outer vesicular wall which change position and shape are the progenitor cells of the future visceral epithelium of the glomerular capsule and cells which resemble squamous epithelium in the lower outer portion of the renal vesicle are the progenitor cells of the future parietal epithelium of the glomerular capsule. The cells of the upper portion of the renal vesicle are the progenitor cells of the future proximal and distal convoluted tubules and the loop of Henle. Aoki (1966) reported that the proximal convoluted tubule in human kidneys arises from the group of cells which form the glomerular capsule.

"Lipped Body".--The late stage of the renal vesicle differentiates into the "lipped body" (Jokelainen, 1963). A cleft appears in the outer vesicular wall separating the progenitor cells of the future glomerular capsule from part of the progenitor cells of the tubular portion of the nephron. The progenitor cells of the tubule are located above the cleft, and the progenitor cells of the future glomerular capsule are located below the cleft. The latter group of cells constitutes the lip-like structure (Figure 8). The basement membrane appears to be continuous around the entire "lipped body," and it lines the walls of the cleft (Figure 9).There is no evidence that the cavity of the newly formed "lipped body" extends into the lip. As the "lipped body" develops its tubular portion gains cellular contact with the ureterogenic collecting tube which will become the collecting duct.

S-Shaped Body.--The "lipped body" differentiates into the S-shaped body which is characterized by the S-shaped appearance of the developing tubule and the presence of mature red blood cells within the cleft. The S-shaped body is the first stage which occurs during glomerulogenesis (Figures 10 and 11).

Maturation Zone

Renal Corpuscle.--All stages in the development of the renal corpuscle are present within the maturation zone. The parietal layer of the glomerular capsule is lined by a layer of simple squamous epithelium, but the visceral layer of the glomerular capsule consists of various arrangements of columnar, cuboidal, and simple squamous epithelium during the developmental stages. The arrangement of the epithelial cells in the visceral layer of the glomerular capsule and the presence of a vascular pole are the criteria for the classification of the developing glomeruli into six stages similar to those reported by MacDonald and Emery (1959) in fetal and newborn children (Figures 11, 12, 13, 14, 15, and 16).

In some instances the epithelium of the proximal convoluted tubules projects into a mature renal corpuscle (Figures 17 and 21). This epithelium possesses a brush border and is similar to that reported by Mayer and

Ottolenghi (1947) in 1 to 12-day-old beagle dogs and Finckh and Joske (1954) in 14 to 16-year-old children.

Ectopic glomeruli similar to those described by Moffat and Fourman (1964) in adult dogs are present in the kidney. Their most frequent location is within the connective tissue near the interlobar arteries (Figure 18).

The afferent glomerular arterioles lack the turgid epitheloid cells similar to those reported by Jäykkä (1961) in human fetuses. However, normal epitheloid cells are present.

Proximal Convoluted Tubule.--The proximal convoluted tubule of the developing nephron changes from columnar to pyramidal shaped cells as it matures. The cell boundaries are indistinct and a lumen seems to be absent in immature tubules. Maturation of the proximal tubule is characterized by a lumen and a brush border on the apical surface of the epithelial cells (Figures 15, 16, and 19). The brush border gives a positive PAS reaction. No intracytoplasmic lipid droplets are present, and no intracytoplasmic PAS granules similar to those reported by Davies (1954) are present. The cells of the more mature proximal convoluted tubules contain more granular acidophilic cytoplasm than the progenitor cells of these tubules located in the neogenic zone.

Loop of Henle.--The loop of Henle is found only in the more mature nephrons. This segment of the metanephric tubule consists of descending and ascending portions connected by a thin segment. The epithelium lining the descending portion resembles that of the proximal convoluted tubule with the exception of a decrease in the height of the cells. The thin segment extends into the medulla and is lined by simple squamous epithelium (figures 24 and 25). The epithelium lining the ascending portion resembles that of the distal convoluted tubule.

<u>Distal Convoluted Tubule</u>.--The distal convoluted tubule of the developing nephron changes from columnar to cuboidal shaped cells as it matures. The cell boundaries are indistinct and a lumen seems to be absent in the immature tubule. As in the proximal convoluted tubule, the distal convoluted tubule acquires a lumen as it matures; however, no brush border is present (Figure 19). The nuclei of the cells of the distal convoluted tubule resemble those of the proximal convoluted tubule.

<u>Macula Densa</u>.--The macula densa is the portion of the distal convoluted tubule which comes in contact with the afferent and possibly the efferent glomerular arteriole. The columnar shaped cells which form the macula densa lack distinct cell boundaries and contain elongated nuclei (Figure 20). The macula densa is present only in the more mature nephrons.

<u>Juxtaglomerular Apparatus</u>.--The juxtaglomerular apparatus consists of three different groups of cells which are in close contact with each other (Figure 20). The first group of cells are the epitheloid cells located in the tunica media of the afferent arteriole near the

glomerulus. The second group of cells compose the macula densa located in the distal convoluted tubule. The third group of cells are known as the cells of Goormaghtigh (Kroon, 1960) or glomerular hilar cells. These small elongated cells are located in the angle between the afferent and efferent glomerular arterioles and are in contact with these arterioles and the macula densea.

Medulla

The medulla of the kidney consists of the arched and straight collecting ducts and the papillary ducts. The arched collecting ducts and portions of the straight collecting ducts form medullary rays which extend into the cortex. Also, straight segments of the proximal and distal convoluted tubules and Henle's loop are located within the mudullary ray. Henle's loop extends into the medullary to the region of the papillary ducts. Variations of the positions of the above structures are present as many of the nephrons are immature.

Collecting Tubules

Arched and Straight Collecting Ducts.--Since the arched and straight collecting ducts are difficult to differentiate histologically they will be described together. As the ureterogenic collecting tube advances toward the outer part of the neogenic zone of the cortex the developing nephrons surrounding it gain attachment to this tube. This is the earliest stage of the collecting duct. A single layer of cuboidal shaped cells with distinct cell boundaries lines the ducts (Figures 22 and 23). These cells contain spherical or elongated nuclei which possess a distinct nucleolus and nuclear membrane and coarse chromatin material. PAS positive intracytoplasmic granules are present throughout the length of the straight collecting ducts.

Papillary Ducts.--The epithelial lining of the collecting tubule changes from cuboidal to columnar in the papillary duct (Figures 24 and 25). PAS positive intracytoplasmic granules similar to those reported by Davies (1954) and Liu (1962) are present in the cells lining the ducts and within the lumen of the ducts. These granules are also present in the cells of the transitional epithelium covering the renal crest and forming the renal pelvis (Figure 26).

Renal Pelvis

The renal pelvis encloses the renal crest of the kidney and leads to the ureter. Thin transitional epithelium lines the renal pelvis while a lamina propria and smooth muscle fibers are present external to the epithelium (Figure 24).

Ureter

The wall of the ureter consists of a mucosa, a submucosa, a muscularis, and an adventitia (Figure 27). The following description pertains to the entire length of the ureter.

Tunica Mucosa

Epithelium

Transitional epithelium forms the lining of the ureter. The thickness of the epithelium varies from two to five cells, and the cell boundaries are distinct (Figure 28). Intracytoplasmic PAS positive granules are present. The nuclei of the epithelial cells are spherical and they possess a distinct nucleolus and nuclear membrane and coarse chromatin material. A thin basement membrane is present beneath the epithelium.

Lamina Propria-Submucosa

The lamina propria consists of collagenous and reticular fibers (Figures 27 and 28), and the submucosa is continuous with the lamina propria. Plasma cells are present within the lamina propria and submucosa of the ureters of one puppy, but they are absent in the other ureters (Figure 28). A capillary plexus extends to the epithelium.

Tunica Muscularis

The muscularis consists of smooth muscle fibers arranged in a circular manner (Figure 27). Longitudinal arranged smooth muscle fibers are not discernible; however, Calhoun (1959) reported that the tunica muscularis of adult dogs consists of inner and outer longitudinal layers and a middle circular layer. These three layers are comprised of smooth muscle.

Tunica Adventitia

The adventitial layer consists of loosely arranged connective tissue with several blood vessels coursing through it (Figure 27). Brown fat is present in the adventitial coat of the ureters of half of the dogs.

Urinary Bladder

Tunica Mucosa

Epithelium

The epithelial lining of the urinary bladder consists of transitional epithelium. It is three to four cells in thickness in the contracted bladder and two to three cells in thickness in the distended bladder. The large, polyhedral and cuboidal cells have distinct cells boundaries (Figure 29). The spherical nuclei of these cells possess a distinct nucleolus and nuclear membrane and coarse chromatin material.

Lamina Propria-Submucosa

The lamina propria and submucosa consist of collagenous, elastic, and reticular fibers. Blood vessels course through the lamina propria and submucosa, and a capillary plexus extends to the epithelium. Although a muscularis mucosa has been reported in adult dogs (Moore and Calhoun, 1957) and in 6-months-old beagle dogs (Calhoun, 1967), no muscularis mucosa is present in newborn beagle dogs.

Tunica Muscularis

Three thick layers of smooth muscle comprise the tunica muscularis (Figure 30). The inner and outer layers are arranged in a longitudinal manner while the middle layer is arranged in a circular manner. Blood vessels course between the layers of muscle.

Tunica Serosa

The serosa consists of loose collagenous connective tissue and elastic fibers with blood and lymph vessels coursing through it. The serosa is bounded with mesothelial cells of the peritoneum and contains some brown fat, nerves, and ganglia. The peritoneum does not extend to the bladder neck; therefore, an adventitia covers this portion of the bladder.

Male Urethra

Prostatic Portion

Tunica Mucosa

Epithelium.--The prostatic urethra is lined by transitional epithelium which varies from two to four cell layers in thickness. The cell boundaries are distinct in some areas and faint in other areas. The surface cells are larger than the basal cells and bulge into the lumen (Figure 32). The nuclei of these cells are spherical or oval shaped and possess a prominent nucleolus, a distinct nuclear membrane, and coarse chromatin material.

Lamina Propria-Submucosa.--The lamina propria and submucosa are composed of collagenous, reticular, and elastic fibers. Within the lamina propria and the submucosa is an extensive capillary plexus. A venous plexus is located in the distal portion of the prostatic urethra. The prostatic urethra is surrounded by the prostrate gland composed of developing multilobular mucous acini, and connective tissue which forms the urethral submucosa (Figures 31 and 32). The ducts of the acini empty into the urethral lumen.

Membranous Portion

Tunica Mucosa

Epithelium.--The epithelium of the membranous urethra consists of a mixture of transitional and stratified squamous epithelium which varies from three to four cells in thickness. In some instances the epithelial cells appear to be differentiating into stratified columnar epithelium. Bharadwaj and Calhoun (1959) reported that stratified cuboidal or columnar epithelium lined the membranous portion of the urethra in adult male dogs. The cell boundaries of the transitional and stratified squamous epithelium are fairly distinct. The nuclei of these cells may be oval, elongated, or spherical in shape (Figure 33), and all nuclei possess a distinct nucleolus and nuclear membrane with coarse chromatin material.

Lamina Propria-Submucosa.--The lamina propria and submucosa consist of collagenous, reticular, and elastic fibers, and the venous plexus coursing through these fibers is less extensive than that of the penile urethra (Figure 33). A rich capillary plexus lies beneath the epithelium. Skeletal muscle surrounds the tunica mucosa of the membranous urethra.

Penile Portion

The proximal portion of the penile urethra is partially enclosed by developing cartilage which will become the os penis. The cartilage does not extend to the ventral side of the urethra. Within the distal pretion of the penis developing cartilage is located dorsal to the urethra.

Tunica Mucosa

Epithelium.--The proximal portion of the penile urethra is lined by transitional and stratified squamous epithelium, and near the external urethral orifice the epithelium consists of stratified squamous epithelium and occasional patches of transitional epithelium (Figures 34, 35, and 36). The thickness of the epithelium varies from three to four cells, and the cell boundaries are distinct. The nuclei of these cells are similar to those in the epithelium of the prostatic urethra.

Lamina Propria-Submucosa.--The lamina propria and submucosa consist of collagenous, reticular, and elastic fibers and contain a capillary plexus located immediately beneath the epithelium. The venous plexus located in the submucosa of the penile urethra is more extensive than that in the membranous urethra and the distal portion of the prostatic urethra.

Female Urethra

Tunica Mucosa

Epithelium

The lining of the female urethra consists of transitional epithelium in its proximal portion and predominately stratified squamous epithelium with patches of transitional epithelium near the external urethral orifice (Figure 37). The epithelium is three to four cell layers thick with distinct boundaries. The spherical shaped nuclei possess a distinct nuclear membrane and nucleolus and coarse chromatin material.

Lamina Propria-Submucosa

The lamina propria and submucosa consist of collagenous, reticular, and elastic fibers, and the submucosa possesses a venous plexus which courses throughout the length of the urethra. A predominate amount of circular smooth muscle surrounds the mucosa of the female urethra.

Brown fat is present in the connective tissue adjacent to the smooth muscle as well as blood vessels, lymphatics, and nerves.

SUMMARY

A histologic study of the urinary system of seven male and five female newborn beagle dogs is reported.

The capsule of the kidney is composed of fibrous connective tissue which contains some brown fat. Ectopic glomeruli are present in the capsule of one kidney.

The cortex of the unipyramidal kidney consists of an outer neogenic zone and an inner maturation zone. The early stages of the developing nephron are present in the neogenic zone, and the metanephric blastemal cap, renal vesicle, "lipped body," and the S-shaped body are described. Six stages in the development of the glomerulus are found in the maturation zone. The maturation zone contains the nephrons which are capable of producing urine. Ectopic glomeruli are present within the connective tissue of the kidney near the interlobar arteries. A brush border is present on the apical portion of the cells of the proximal convoluted tubules but intracytoplasmic lipid droplets and PAS positive granules are not present in these cells. The macula densa and juxtaglomerular apparatus are present in the more mature nephrons near the cortico-medullary boundary.

The epithelium of the collecting ducts, papillary ducts, renal crest, and the ureter contains a large amount

of PAS positive intracytoplasmic granules.

The ureter is lined by transitional epithelium of varying thickness. The lamina propria and submucosa consist of collagenous and reticular fibers, and a capillary plexus extends through the lamina propria to the epithelium. The muscularis is composed of a circular layer of smooth muscle. Brown fat is present in the adventitia of half of the ureters.

The urinary bladder is lined by transitional epithelium of varying thickness. A capillary plexus is present in the lamina propria and submucosa. No muscularis mucosa is present. The muscularis consists of an outer and inner layer of longitudinal smooth muscle and a middle layer of circular smooth muscle. The urinary bladder is covered by a serosa except at the neck of the bladder, and the serosa consists of loose connective tissue and elastic fibers and contains blood vessels, lymphatics, nerves, ganglia, and brown fat.

The lining of the male urethra consists of transitional epithelium at its origin and becomes predominately stratified squamous epithelium with patches of transitional epithelium near the external urethral orifice. A venous plexus is present in the submucosa throughout the male urethra. The prostatic portion of the male urethra is surrounded by the developing prostrate gland while skeletal muscle surrounds the membranous portion. The proximal portion of the penile urethra is partially enclosed by developing cartilage as the cartilage does not extend to the ventral side of the urethra. Developing cartilage is located dorsal to the urethra in the distal portion of the penis. The developing cartilage in the penile urethra will become the os penis.

The lining of the female urethra consists of transitional epithelium in the proximal portion and stratified squamous epithelium with patches of transitional epithelium in the distal portion. A venous plexus is present in the submucosa throughout the female urethra. Circularly arranged smooth muscle surrounds the female urethra.

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FIGURES

Figure 1.--Cortex and medulla of the kidney.

1. Neogenic zone of the cortex
2. Maturation zone of the cortex
3. Medullary ray
4. Medulla

Hematoxylin and eosin x 75

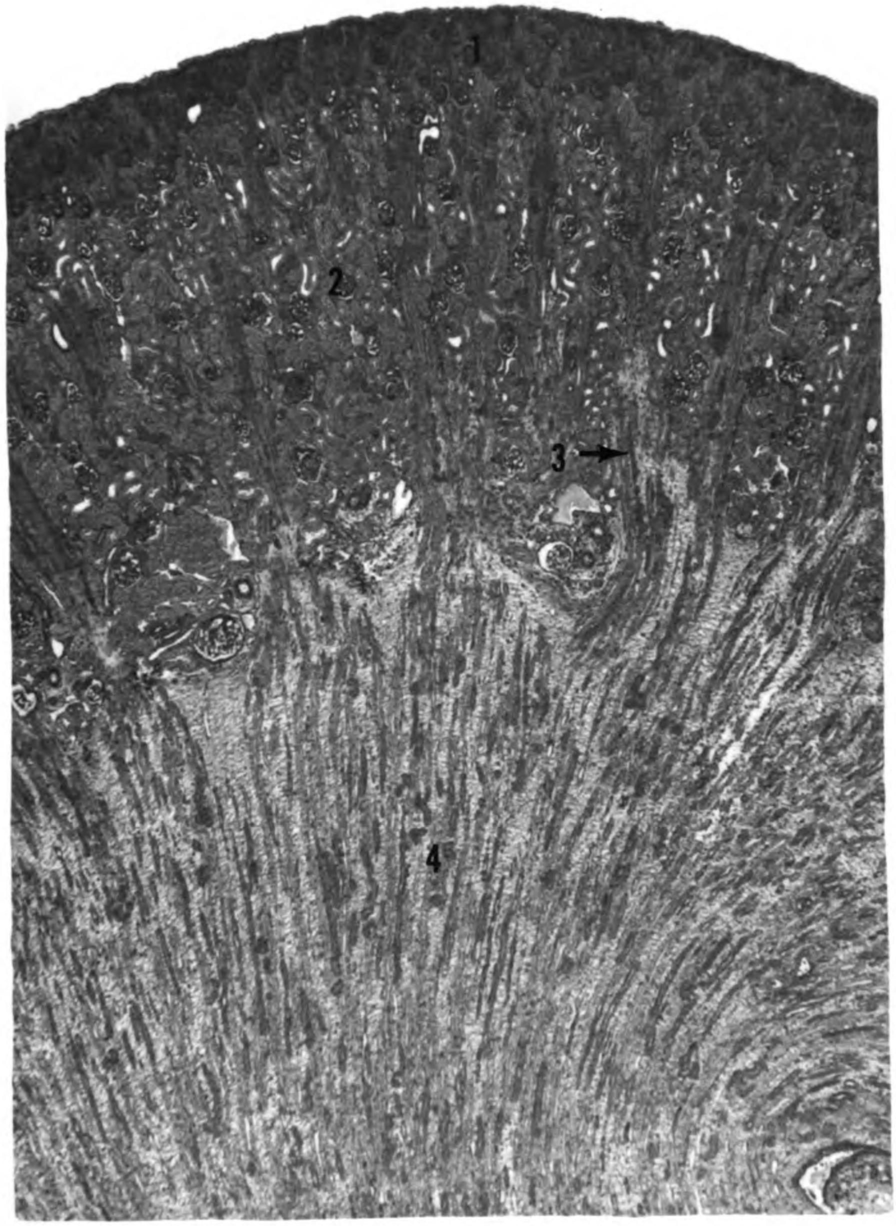
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Figure 2.--Brown fat within the kidney capsule.

1. Brown fat

2. Capsule

3. Neogenic zone of the cortex

Hematoxylin and eosin x 384

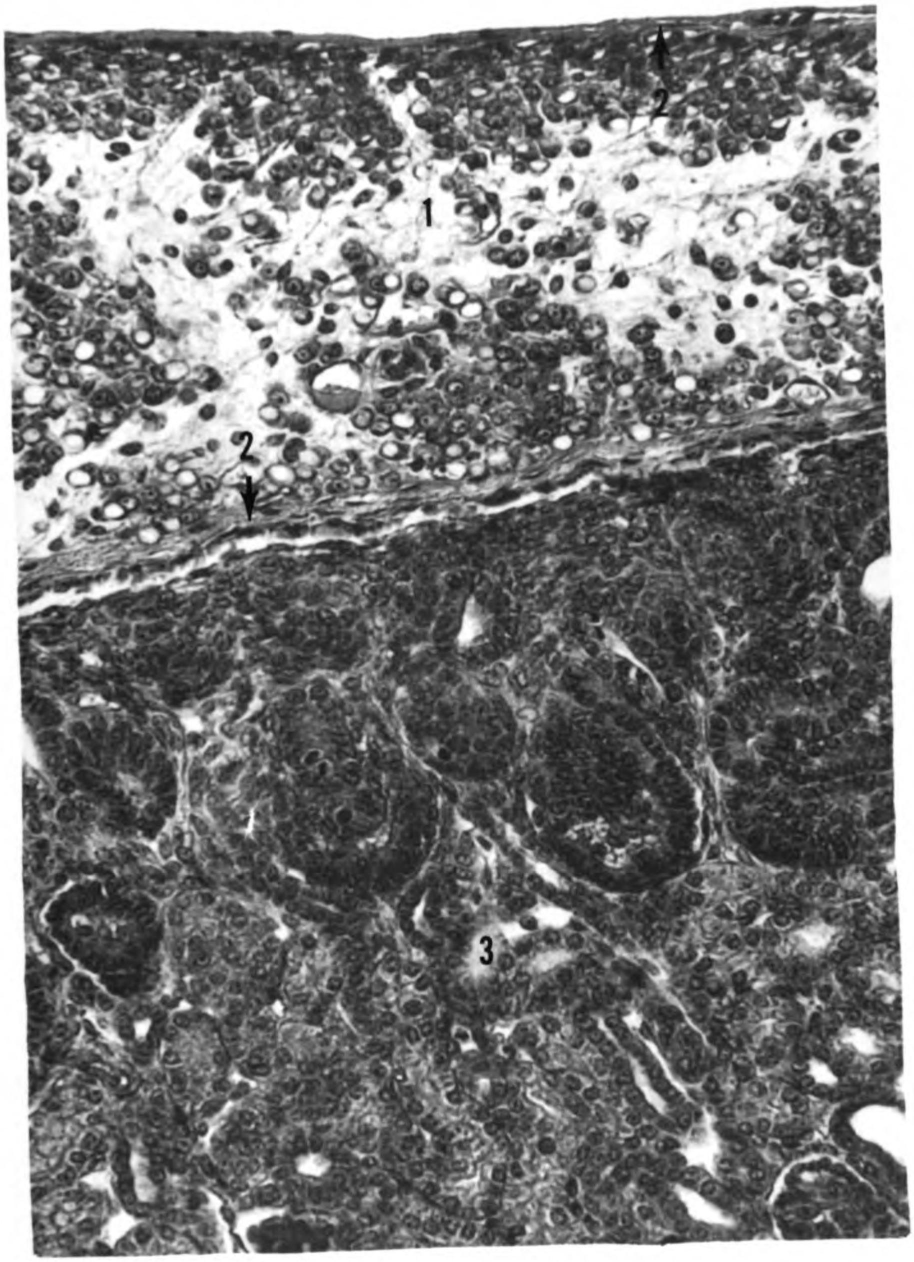
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Figure 3.--Kidney capsule.

1. Fibrous connective tissue comprising the kidney capsule
2. Artery coursing through the capsule
3. Vein coursing through the capsule
4. Neogenic zone of the cortex

Hematoxylin and eosin x 960

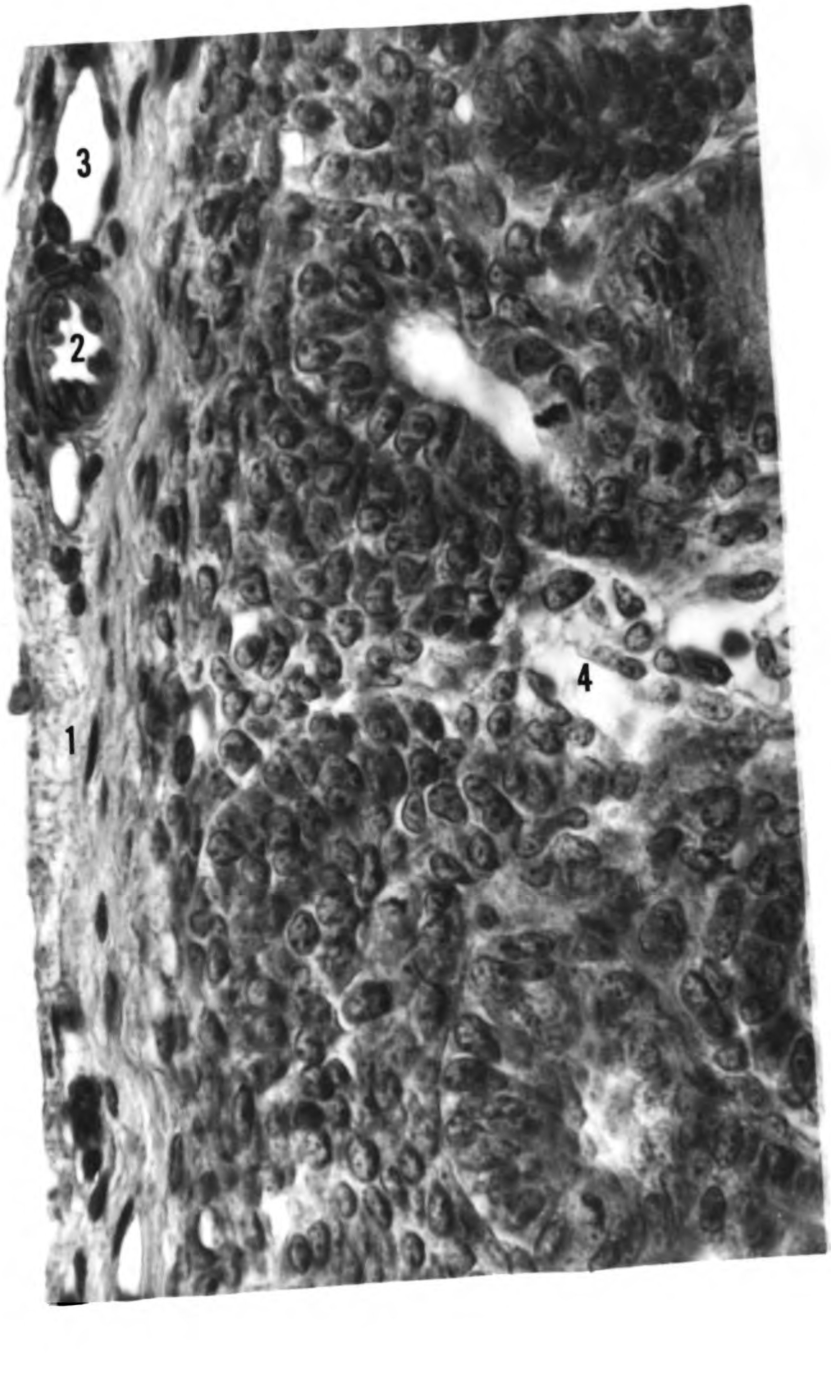
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Figure 4.--Ectopic glomeruli within the kidney capsule.

1. Ectopic glomerulus
2. Uriniferous tubule
3. Blood vessel

Hematoxylin and eosin x 307

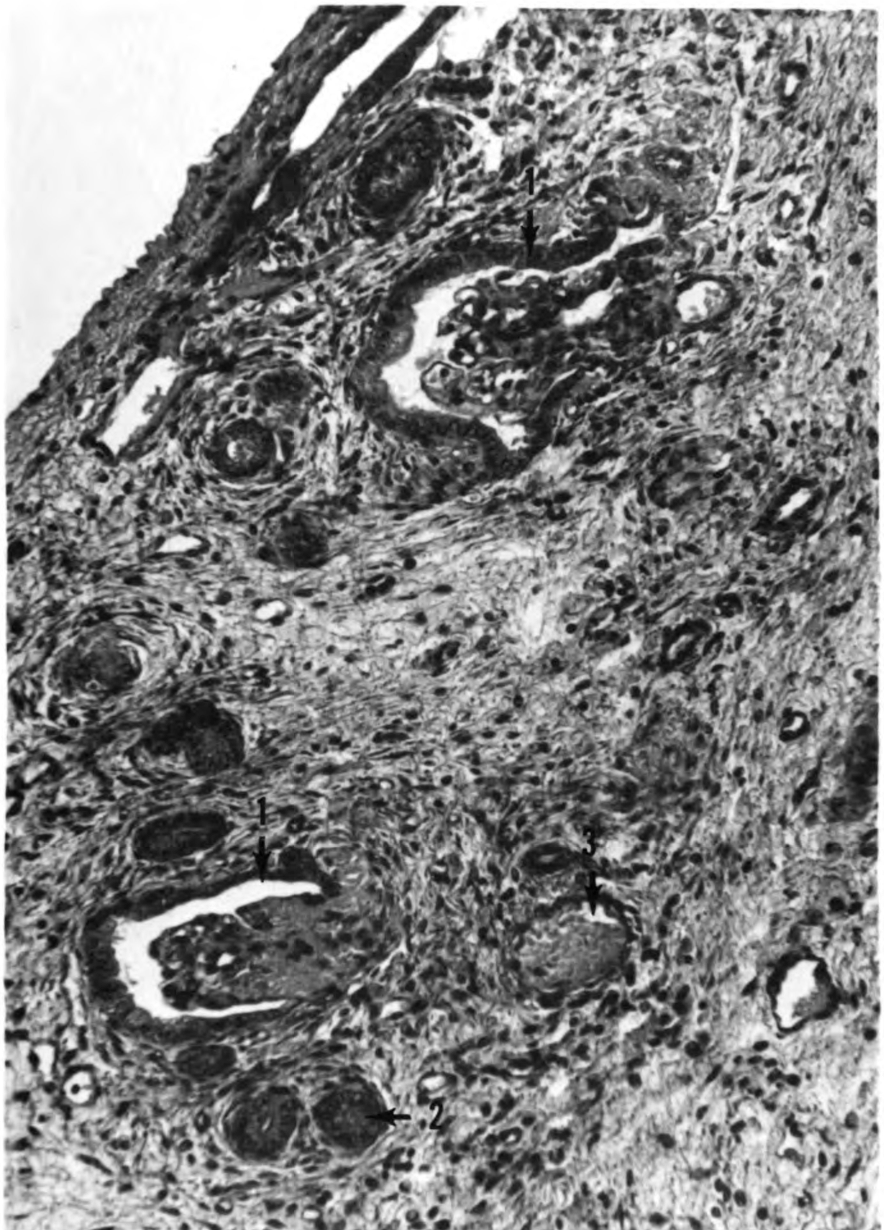
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Figure 5.--Metanephric blastemal cap in the neogenic zone of the kidney.

1. Metanephric blastemal cap

2. Ureterogenic collecting tube

3. Mitotic figure

4. Tubule of another developing nephron

5. Basement membrane of the ureterogenic collecting tube

Hematoxylin and eosin x 1228

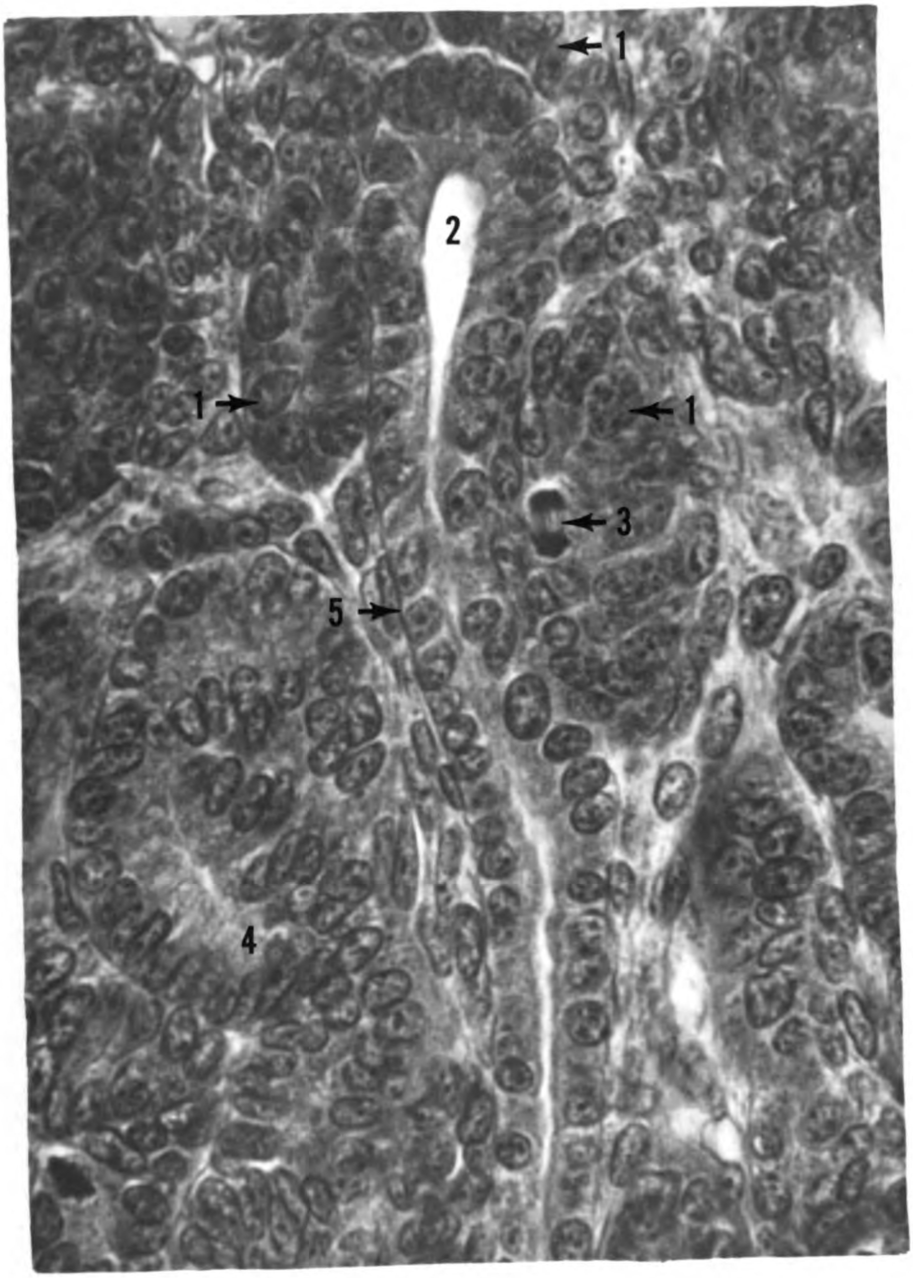
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Figure 6.--Early renal vesicle in the neogenic zone of the kidney

1. Early renal vesicle

2. Ureterogenic collecting tube

3. Kidney capsule

Hematoxylin and eosin x 1228

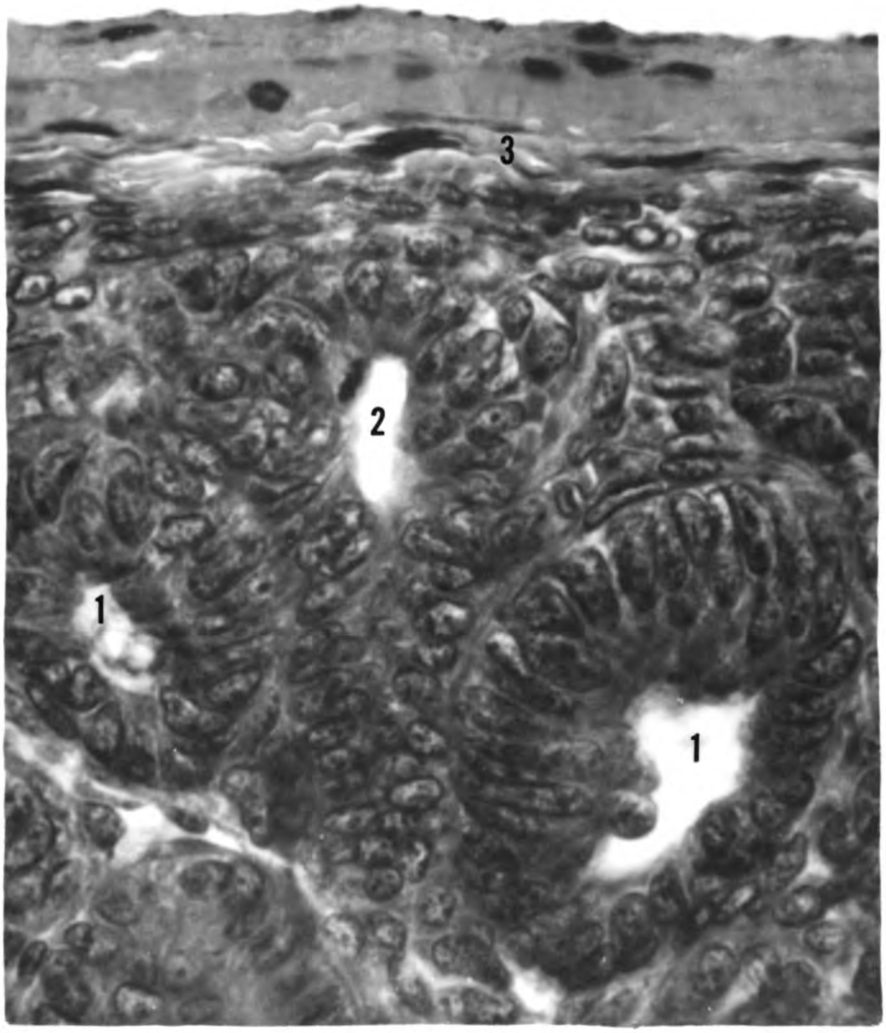
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Figure 7.--Late renal vesicle in the neogenic zone of the kidney.

1. Late renal vesicle

2. Ureterogenic collecting tube

3. Red blood cells among mesenchymal cells

Hematoxylin and eosin x 1228


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Figure 8.--"Lipped body" in the neogenic zone of the kidney.

1. "Lipped body"

2. Ureterogenic collecting tube

3. Progenitor cells of the visceral and parietal epithelium of the glomerular capsule which form the "lip" at this stage of development

4. Red blood cells within the cleft of the "lipped body"

5. Mitotic figure

Hematoxylin and eosin x 1228

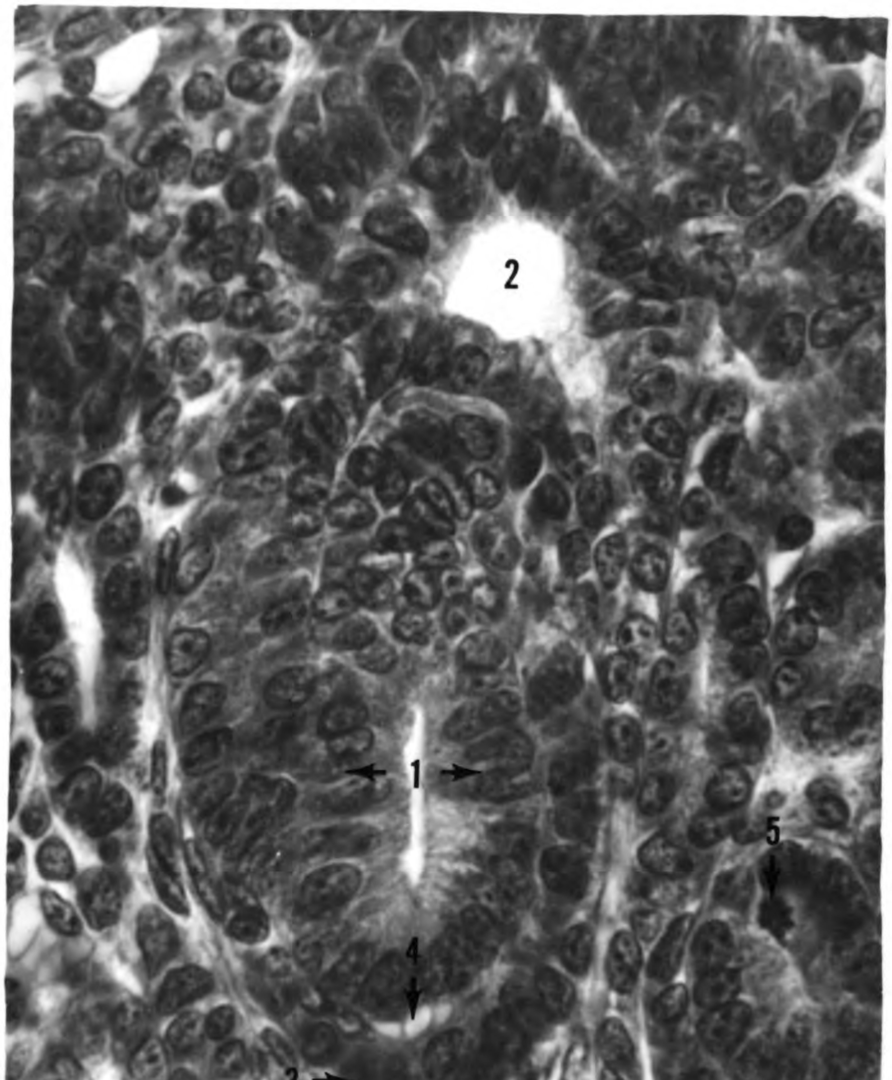
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Figure 9.--"Lipped body" in the neogenic zone of the kidney.

1. "Lipped body"

2. Ureterogenic collecting tube

3. Basement membrane which extends into the cleft of the "lipped body"

LFB-PAS x 1228


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Figure 10.--S-shaped body in the neogenic zone of the kidney.

1. S-shaped body

2. Ureterogenic collecting tube

3. "Lip" of S-shaped body

4. Progenitor cells of the metanephric tubule

5. Kidney capsule

Hematoxylin and eosin x 1228

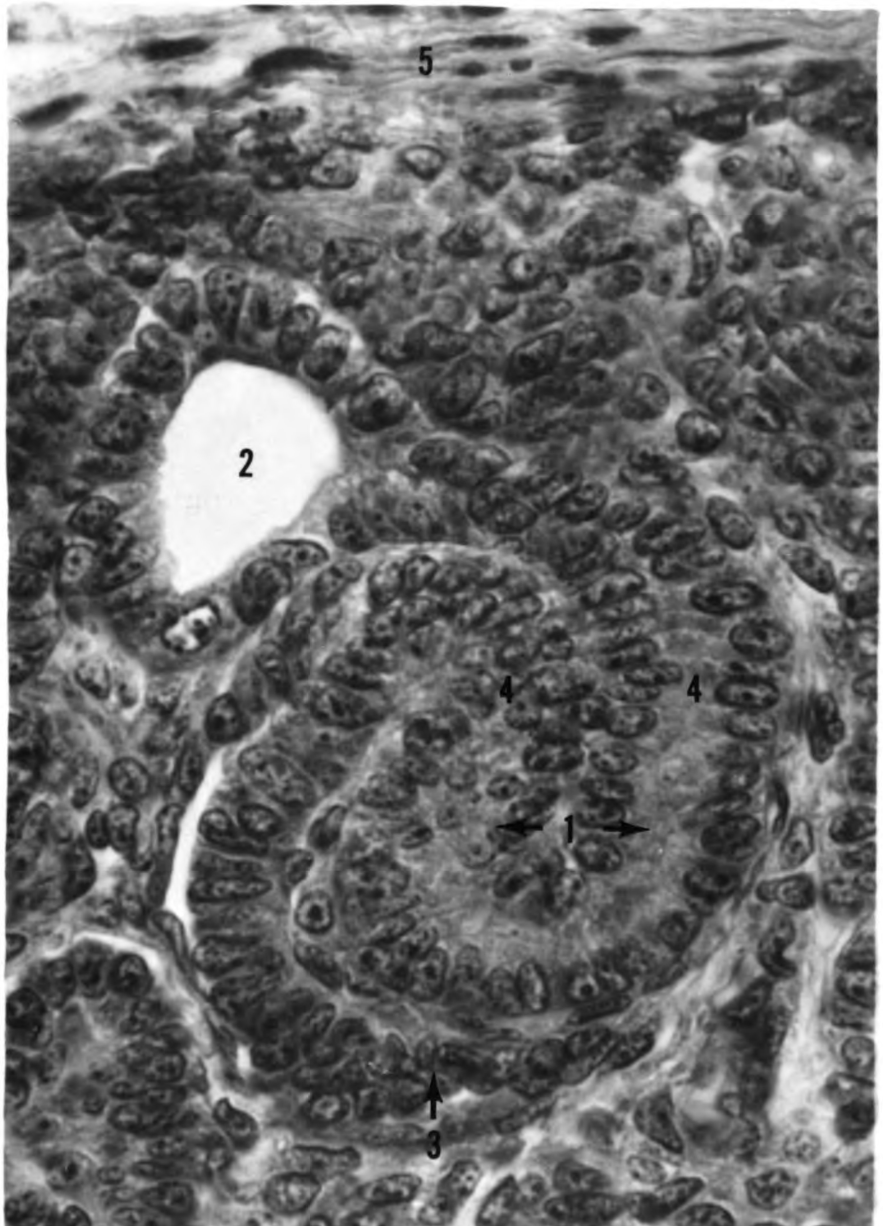
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Figure 11.--S-shaped body in the neogenic zone of the kidney. Stage I in the development of the glomerulus.

1. S-shaped body

2. Ureterogenic collecting tube

3. Red blood cells in and around the "lip"

4. Tubule of another developing nephron

Hematoxylin and eosin x 1228

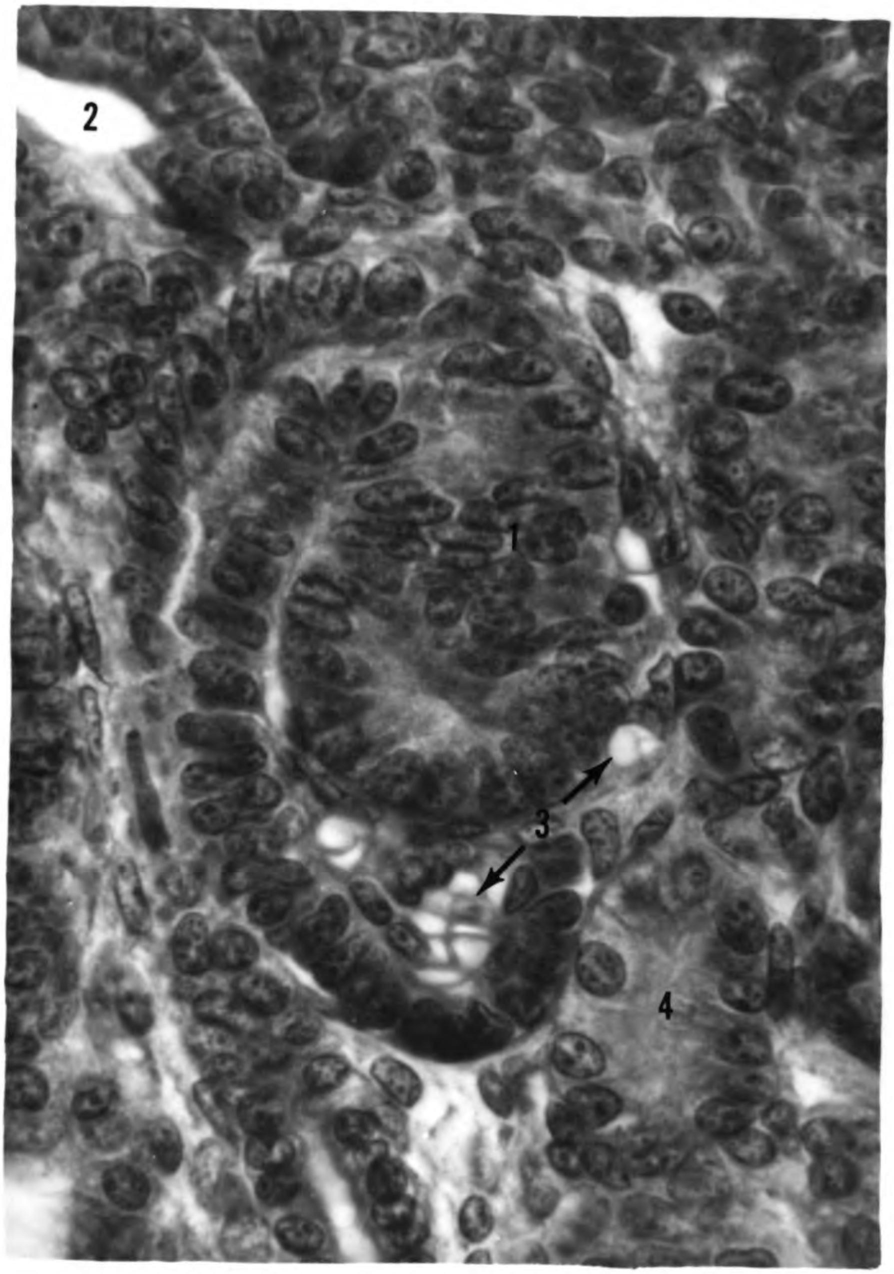
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Figure 12.--The sanguineous lacuna. Stage II in the development of the glomerulus.

1. The mushroom-shaped sanguineous lacuna containing red blood cells

2. Cuboidal and columnar epithelium forming the visceral layer of the glomerular capsule

3. Parietal epithelium of the glomerular capsule

4. Proximal tubule

Hematoxylin and eosin x 1536

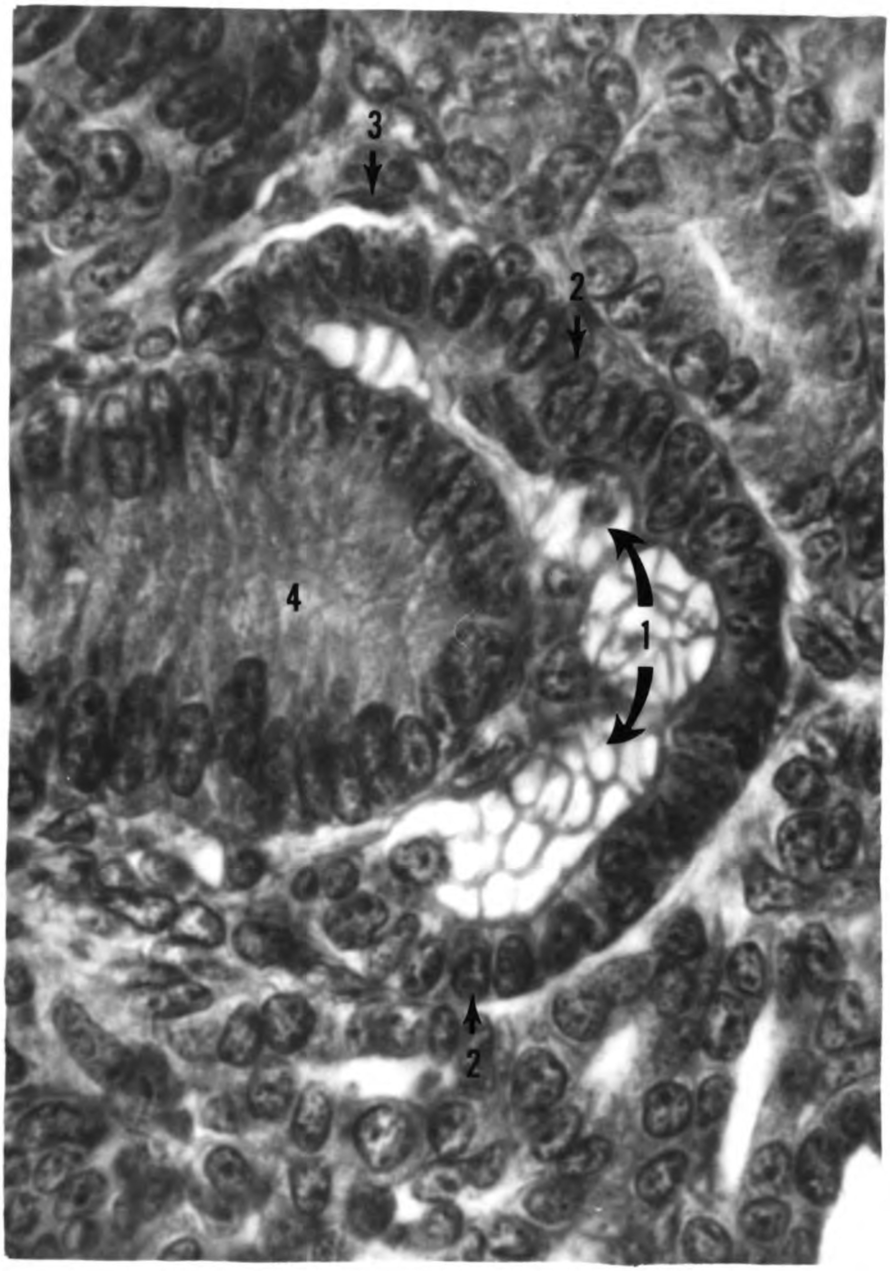
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Figure 13.--Stage III in the development of the glomerulus.

1. Visceral epithelium of the glomerular capsule composed of a single layer of cuboidal cells

2. Parietal epithelium of the glomerular capsule

3. Red blood cells

4. Proximal tubule lacking a lumen

5. Distal tubule lacking a lumen

Hematoxylin and eosin x 1536

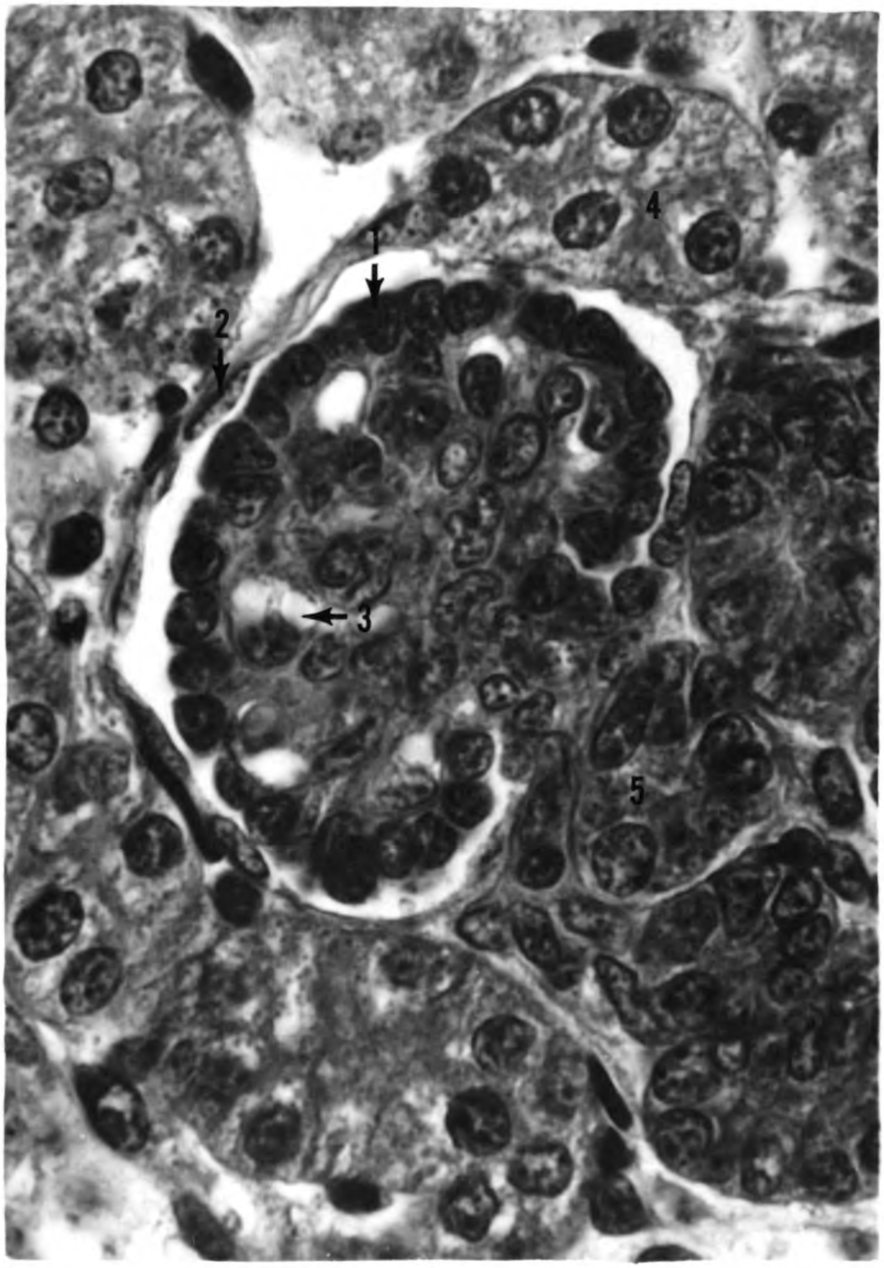
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Figure 14.--Stage IV in the development of the glomerulus.

1. Visceral epithelium of the glomerular capsule arranged in clefts

2. Parietal epithelium of the glomerular capsule

3. Red blood cells in a capillary loop

Hematoxylin and eosin x 1536

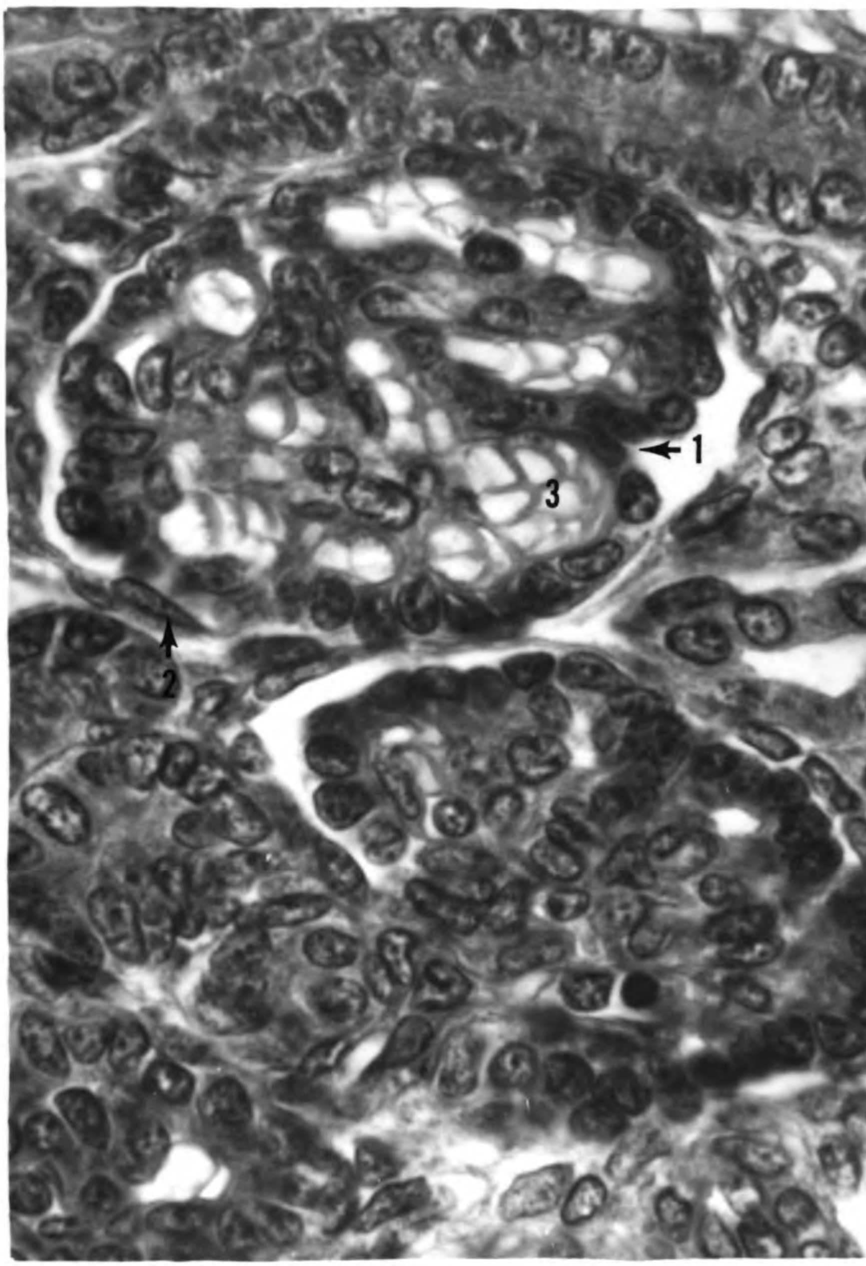
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Figure 15.--Stage V in the development of the glomerulus.

1. Visceral epithelium of the glomerular capsule arranged in irregular groups of cells

2. Parietal epithelium of the glomerular capsule

3. Red blood cells

4. Proximal tubule possessing a lumen

Hematoxylin and eosin x 1536

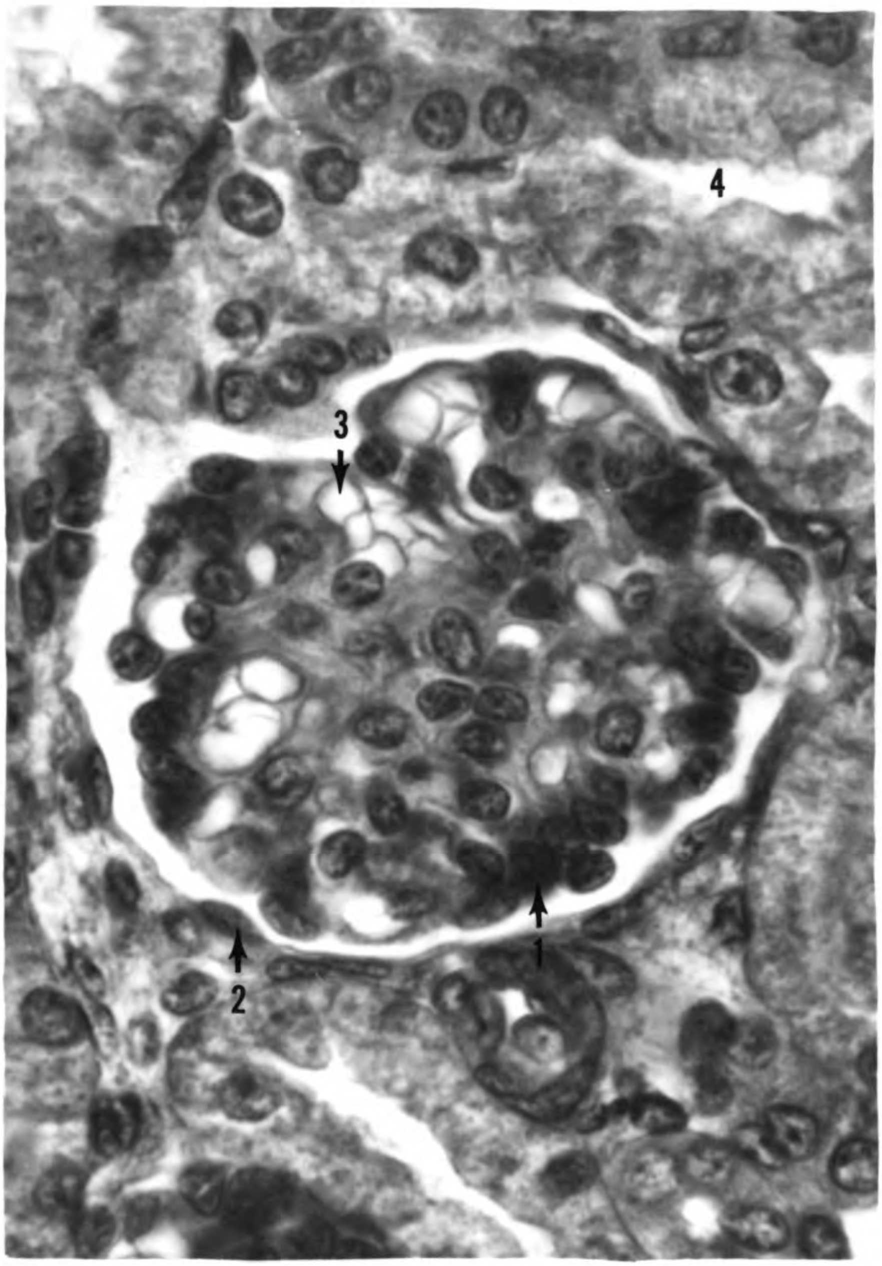
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Figure 16.--Stage VI in the development of the glomerulus. A mature glomerulus.

1. Visceral epithelium of the glomerular capsule

2. Parietal epithelium of the glomerular capsule

3. Red blood cells

4. Distal tubule possessing a large lumen

5. Proximal tubule possessing a large lumen

Hematoxylin and eosin x 1536

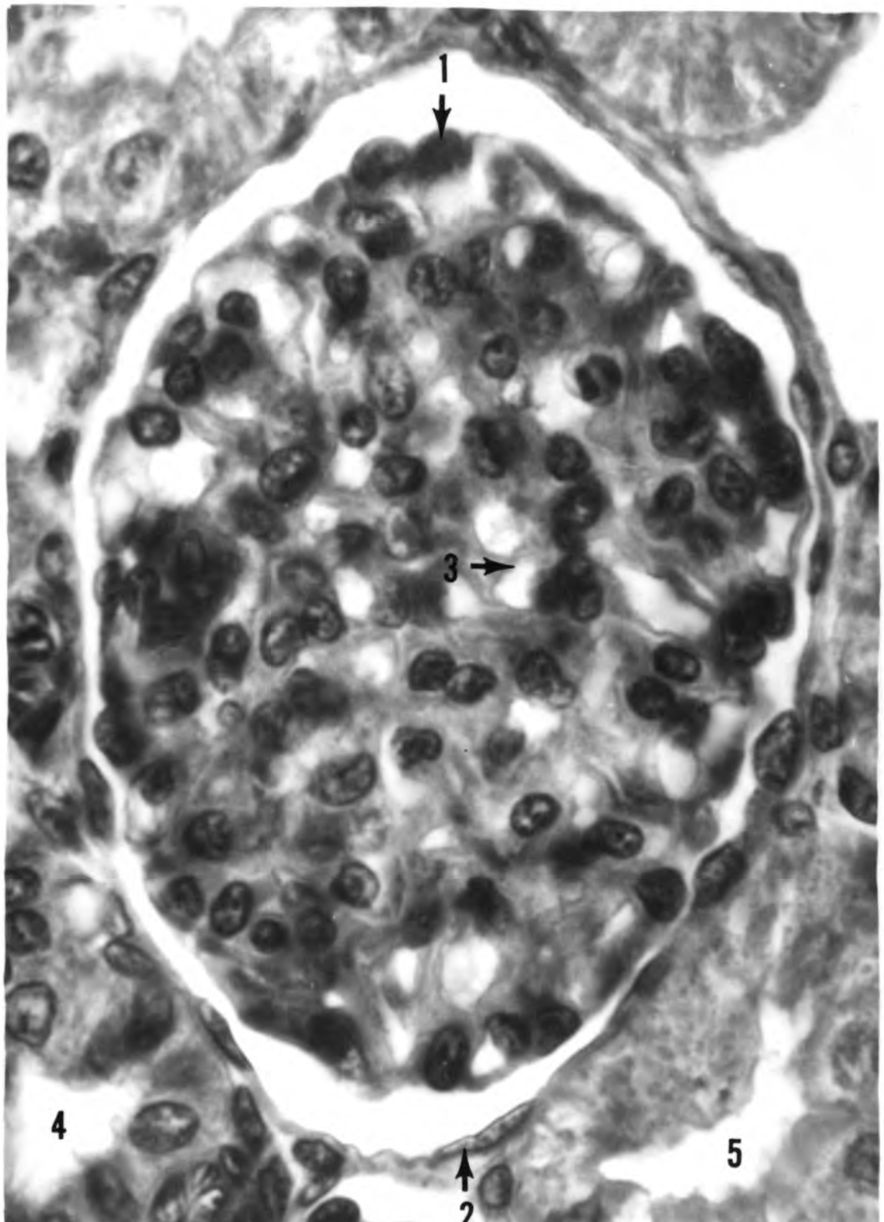
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Figure 17.--Mature glomerulus with cuboidal epithelium extending into the renal corpuscle at the urinary pole.

1. Cuboidal epithelium within the renal corpuscle

Hematoxylin and eosin x 1200


1

Figure 18.--Ectopic glomerulus near an interlobar artery.

1. Ectopic glomerulus
2. Proximal convoluted tubule
3. Interlobar artery
4. Medulla
5. Nerve fiber
6. Lumen of renal pelvis

Hematoxylin and eosin x 300

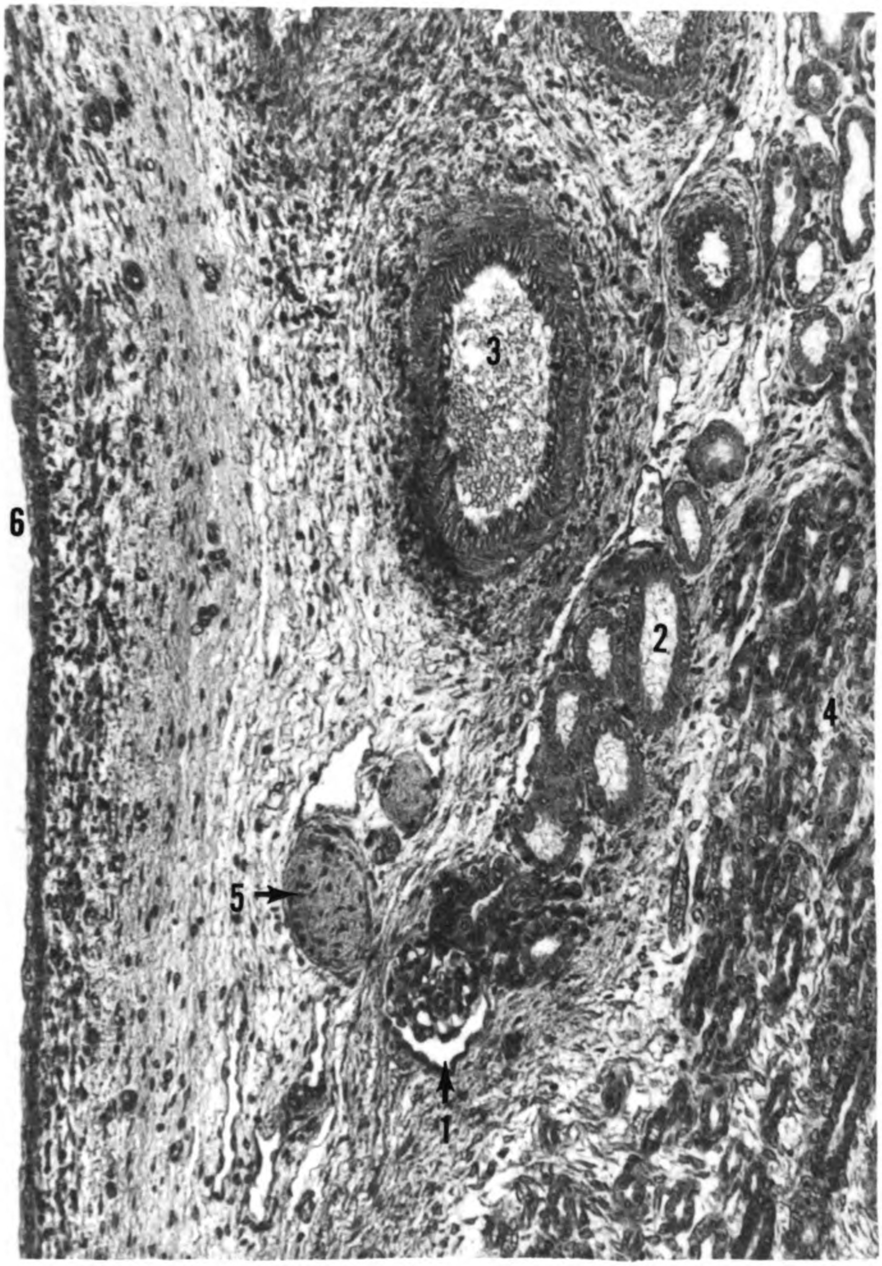
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Figure 19.--Afferent arteriole entering a glomerulus located in the maturation zone of the cortex.

1. Afferent arteriole

2. Distal convoluted tubule

3. Proximal convoluted tubule with a prominent brush border

4. Basement membrane of the tubule

5. Basement membrane of the glomerulus

PAS x 960

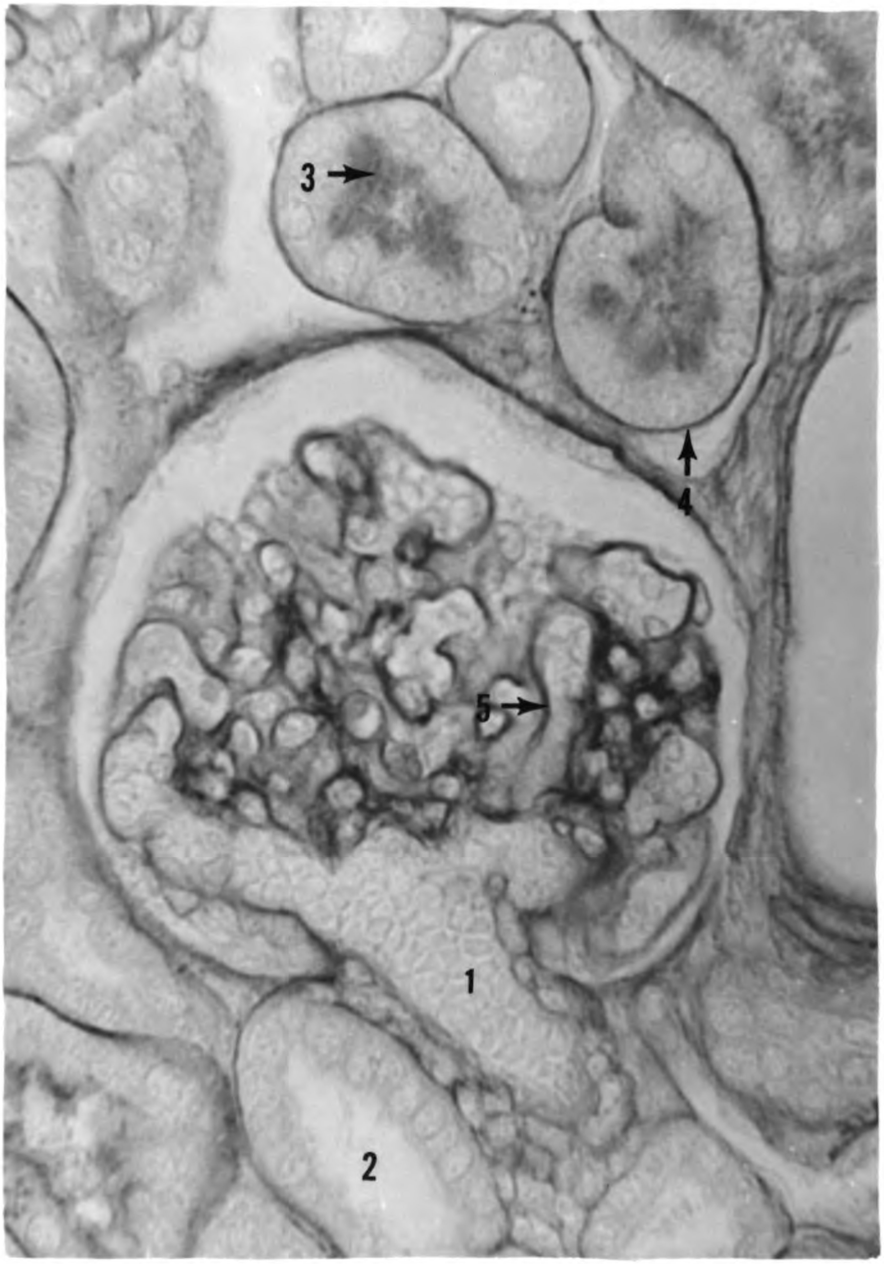
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Figure 20.--Kidney cortex.

1. The developing juxtaglomerular apparatus

2. Macula densa

Hematoxylin and eosin x 960

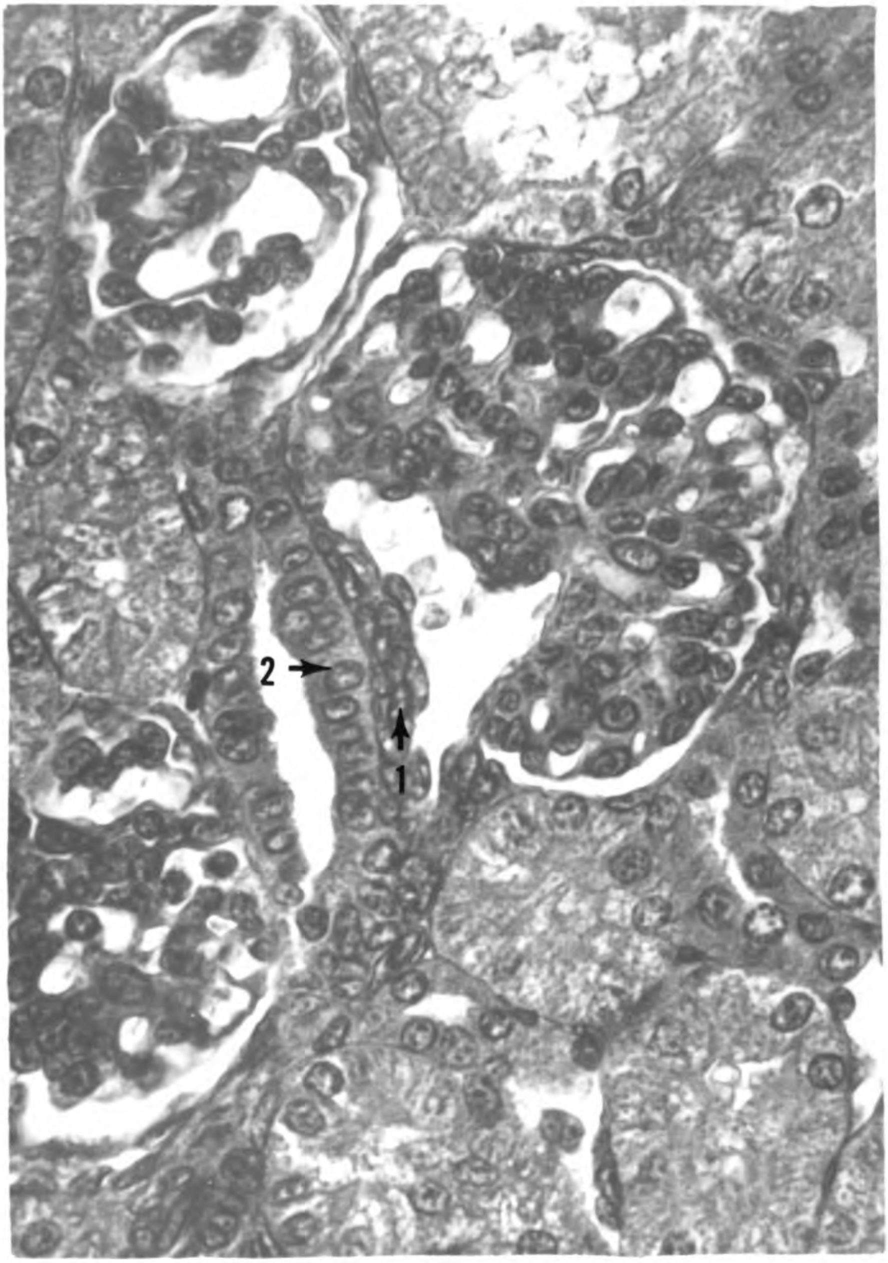
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Figure 21.--Reticular fibers within the cortex of the kidney.

Soule's gold chloride stain x 960

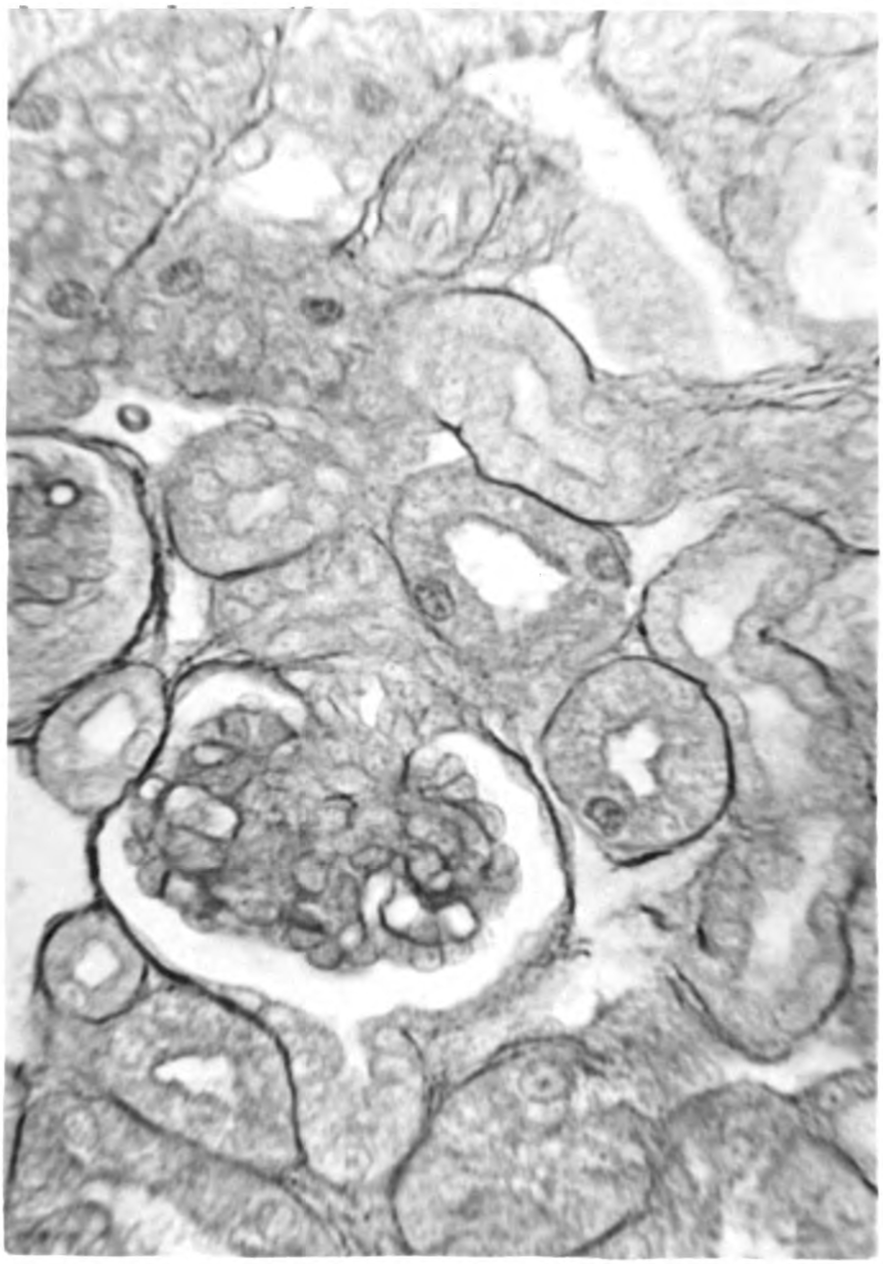

Figure 22.--Medulla of the kidney.

1. Straight collecting duct
2. Loop of Henle
3. Capillary

Hematoxylin and eosin x 760

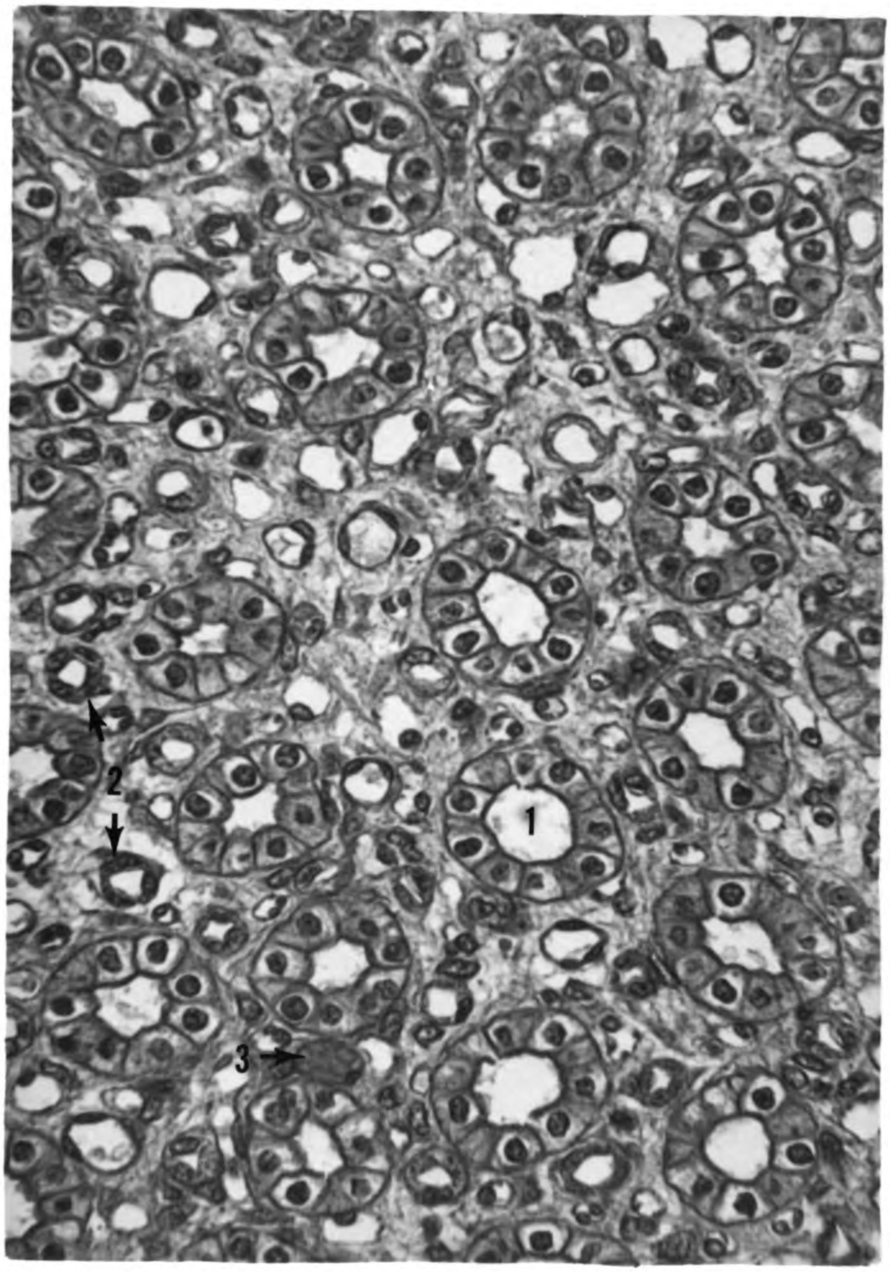
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Figure 23.--Reticular fibers within the medulla of the kidney.

Soule's gold chloride stain x 512

Figure 24.--Papillary ducts emptying into the renal pelvis.

1. Columnar epithelium lining papillary duct
2. Loop of Henle
3. Vasa recta
4. Lumen of renal pelvis
5. Transitional epithelium forming wall of the renal pelvis
6. Smooth muscles fibers within the wall of the renal pelvis

Hematoxylin and eosin x 300

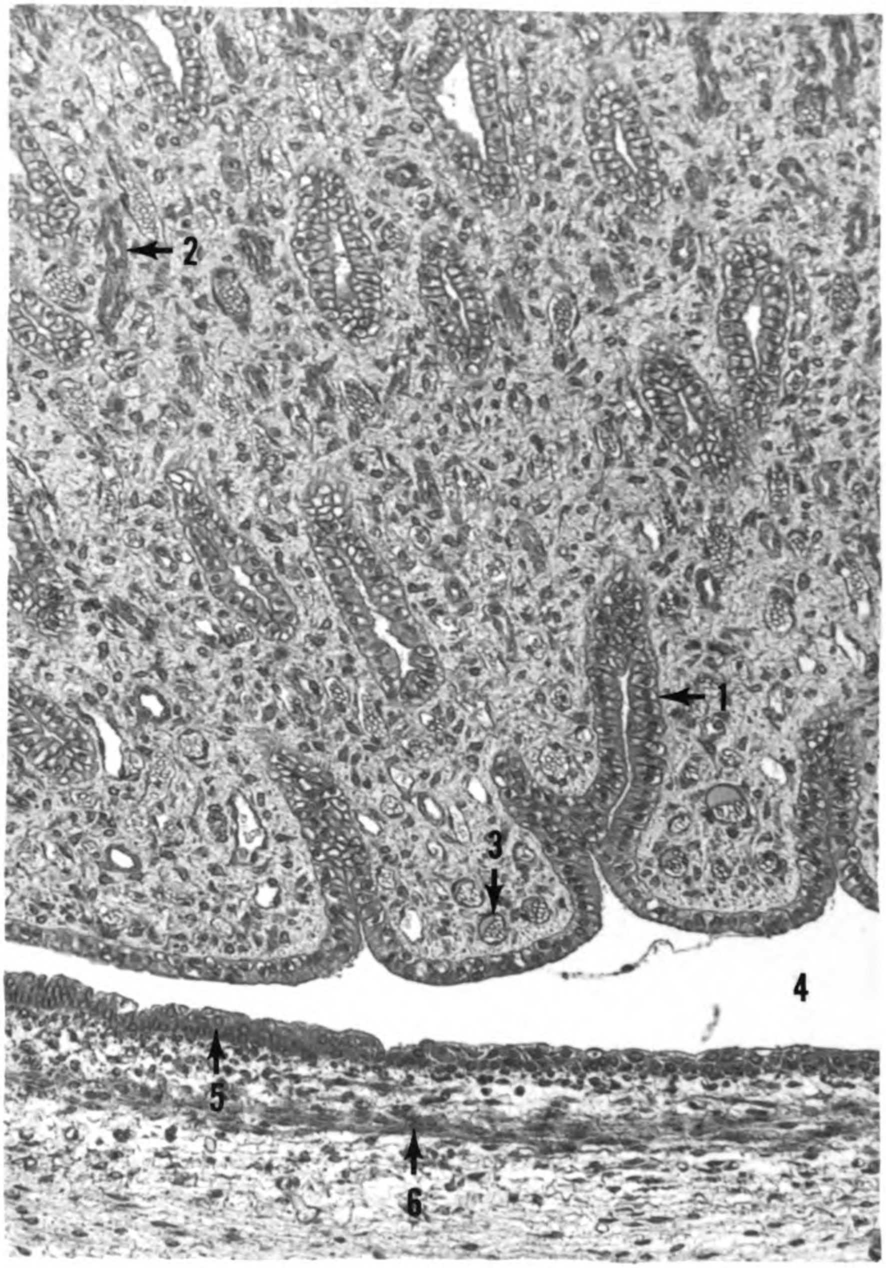
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Figure 25.--Papillary ducts within the medulla.

1. Papillary duct
2. Loop of Henle
3. Capillary

Hematoxylin and eosin x 760

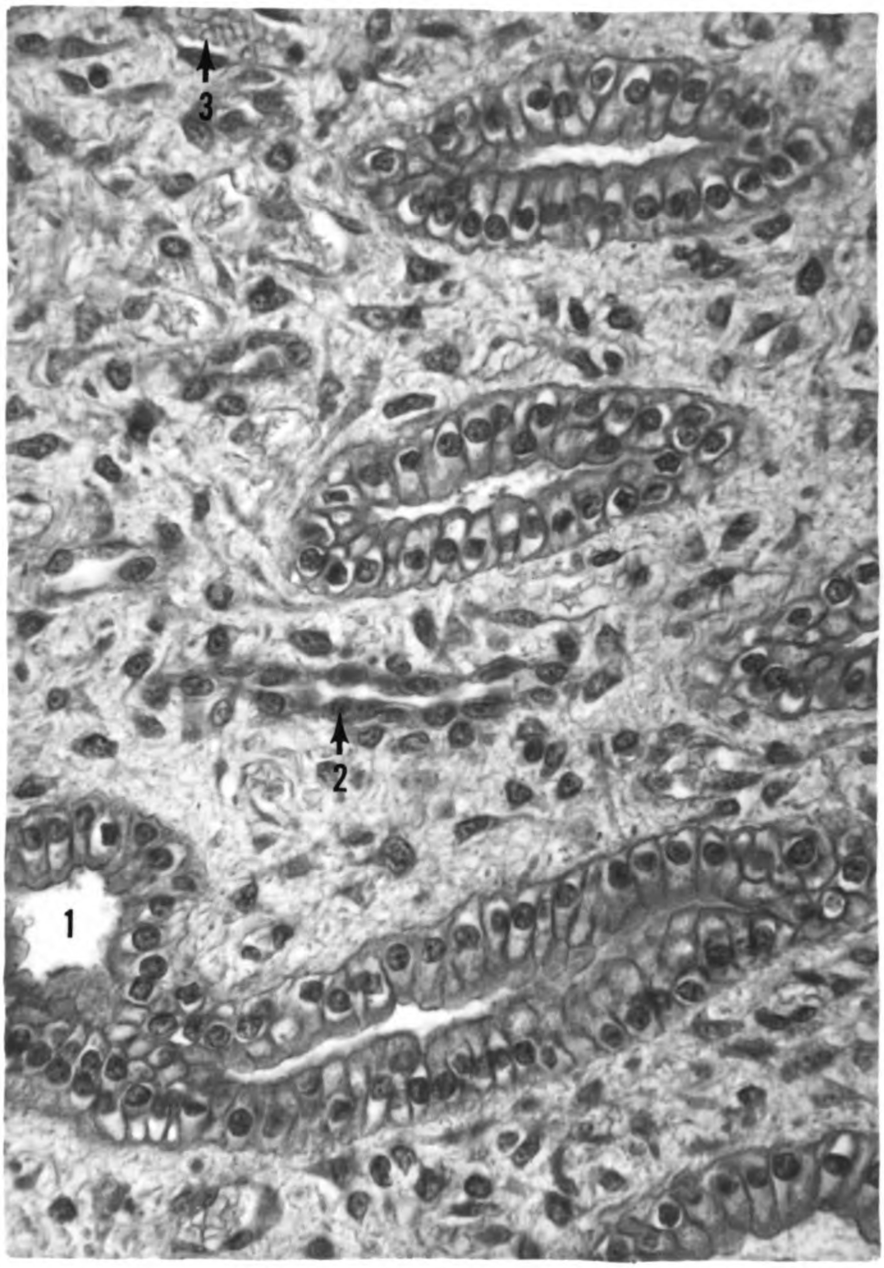
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Figure 26.--PAS positive granules in the papillary ducts and the renal pelvis.

1. PAS positive granules in the papillary duct

2. PAS positive granules in the pelvic epithelium

3. Lumen of renal pelvis

PAS x 307

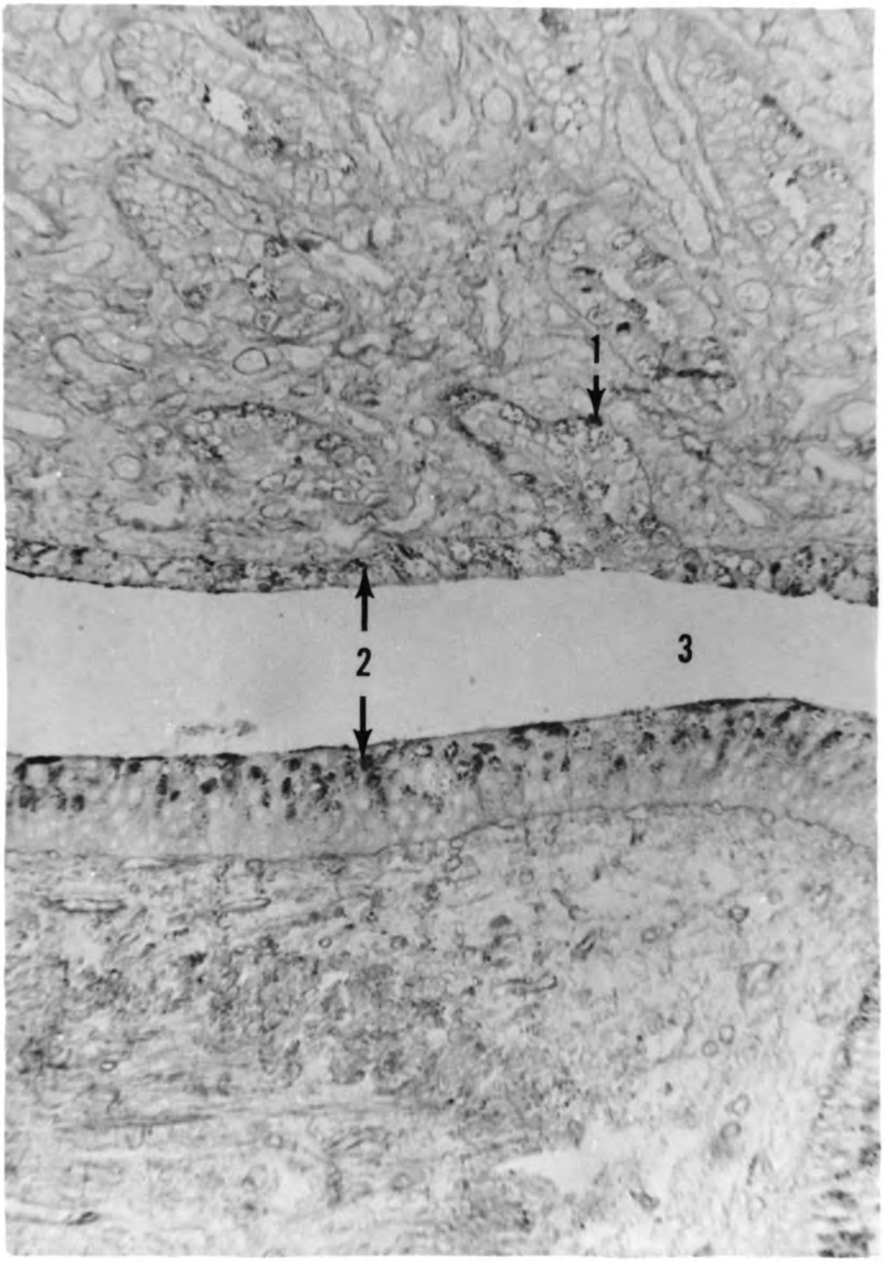
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Figure 27.--Cross-section of the ureter.

1. Transitional epithelium
2. Plasma cells within the lamina propria and submucosa
3. Smooth muscle fibers arranged in a circular manner
4. Blood vessels coursing through the adventitia
5. Submucosa

Hematoxylin and eosin x 300

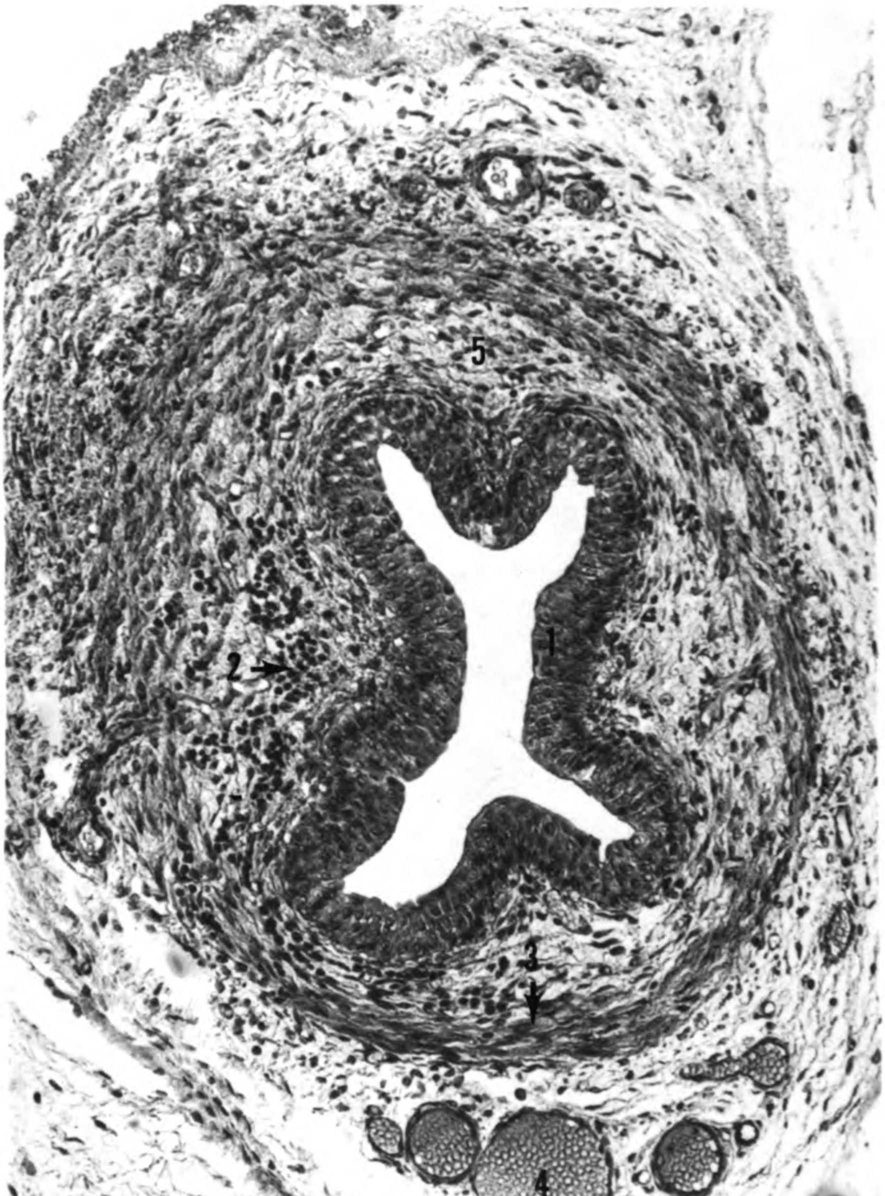
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Figure 28.--Transitional epithelium lining the ureter.

1. Lumen of the ureter

2. Transitional epithelium

3. Plasma cells located in the lamina propria

4. Capillary beneath the epithelium

Hematoxylin and eosin x 960

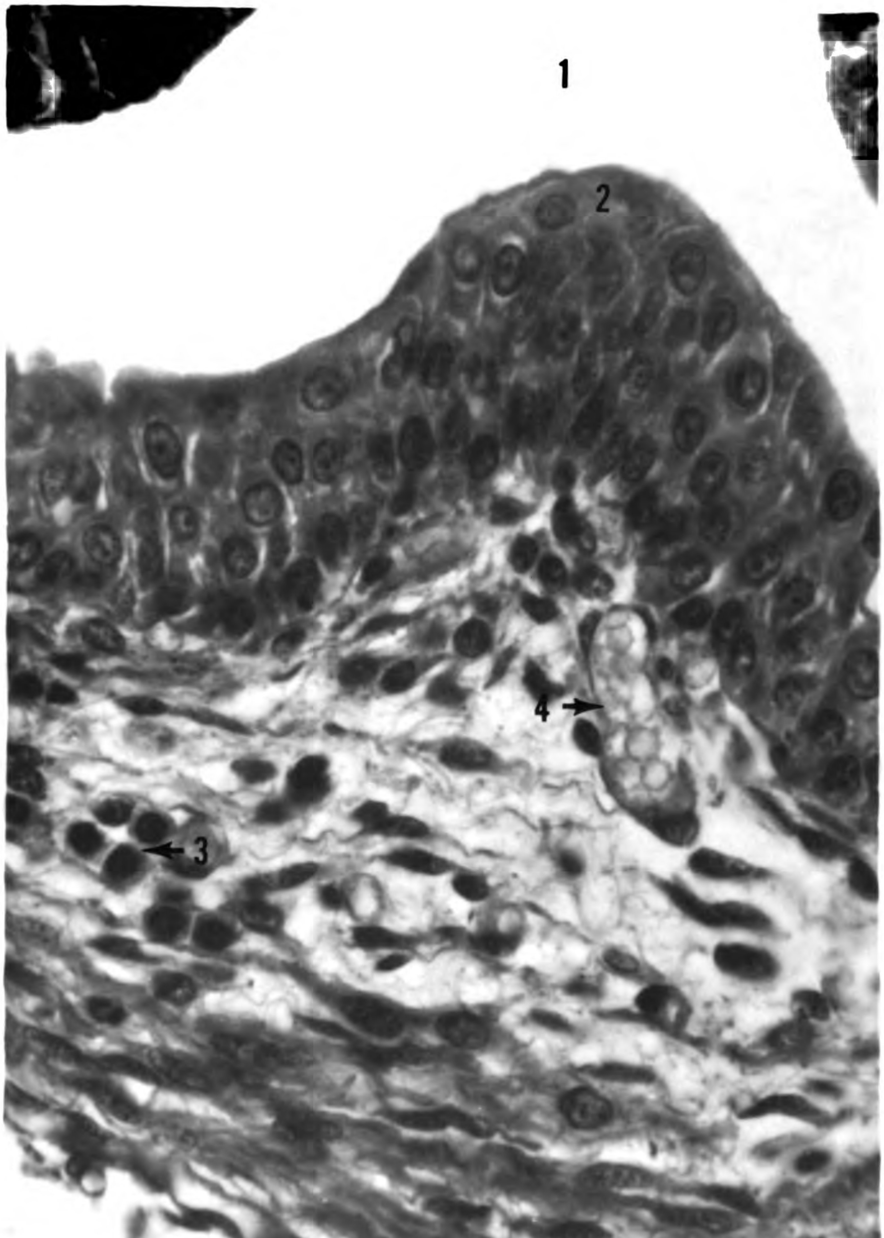
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Figure 29.--Transitional epithelium lining the urinary bladder.

1. Lumen of urinary bladder

2. Transitional epithelium

3. Dense collagenous fibers within the lamina propria

Hematoxylin and eosin x 960

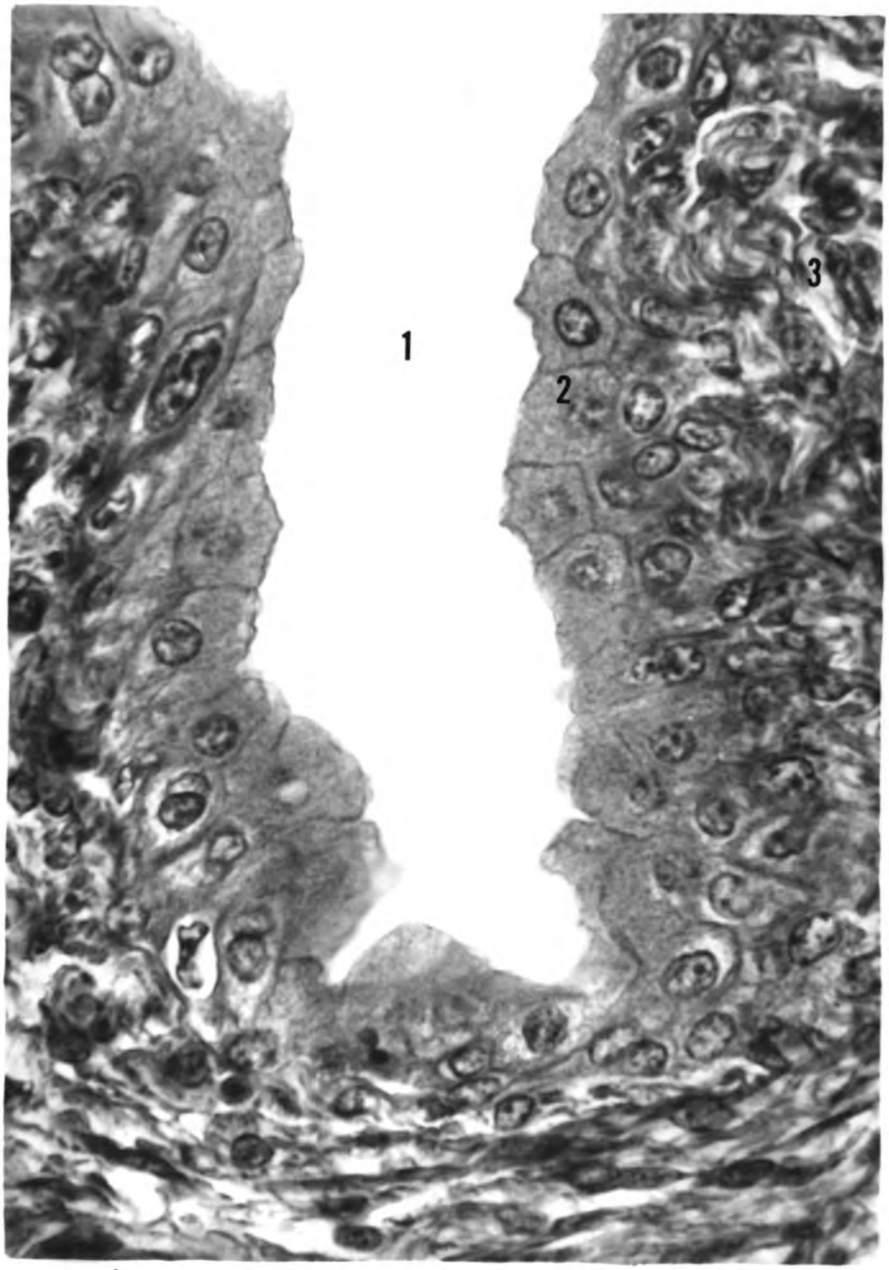
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Figure 30.--Three layers of smooth muscle composing the muscularis of the urinary bladder.

1. Outer longitudinal layer

2. Middle circular layer

3. Inner longitudinal layer

4. Blood vessel coursing between muscle layers

Hematoxylin and eosin x 300

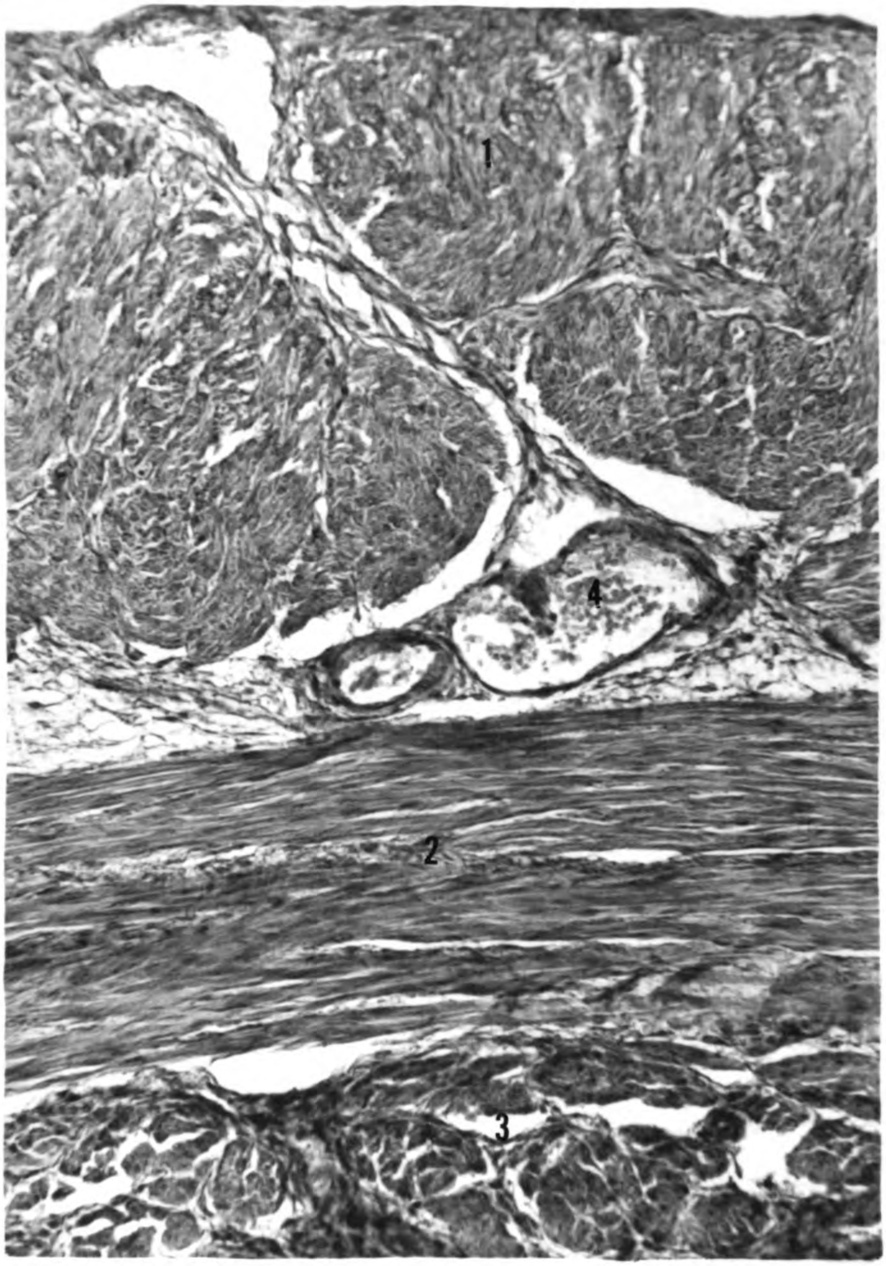
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Figure 31.--Cross-section of the prostatic urethra.

1. Lumen of prostatic urethra
2. Multilobular mucous acini of the prostrate gland
3. Ductus deferens
4. Blood vessel coursing through the submucosa

Hematoxylin and eosin x 75

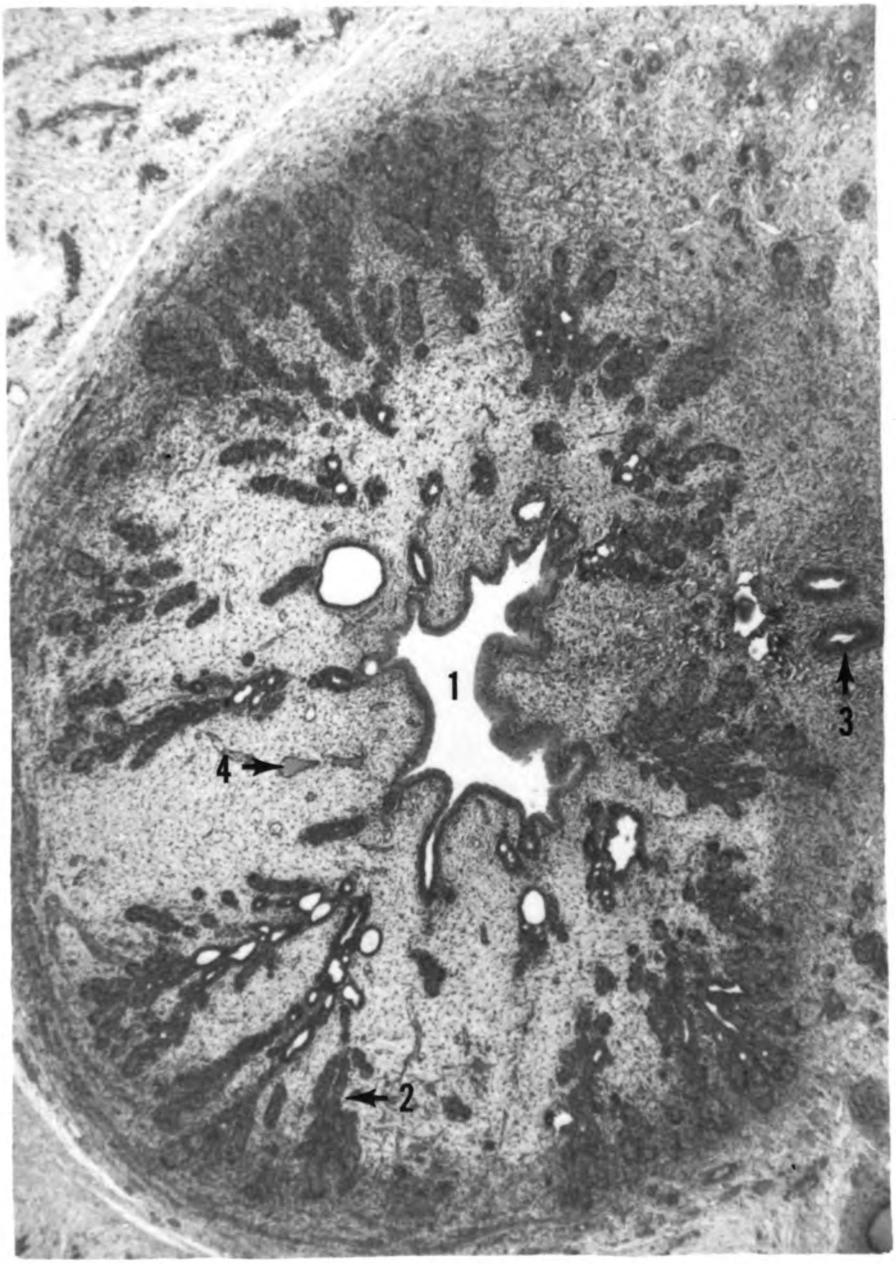
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Figure 32.--Developing multilobular mucous acinus in the prostrate gland.

1. Lumen of the prostatic urethra

2. Transitional epithelium

3. Multilobular mucous acinus

4. Lamina propria

5. Submucosa

Hematoxylin and eosin x 307

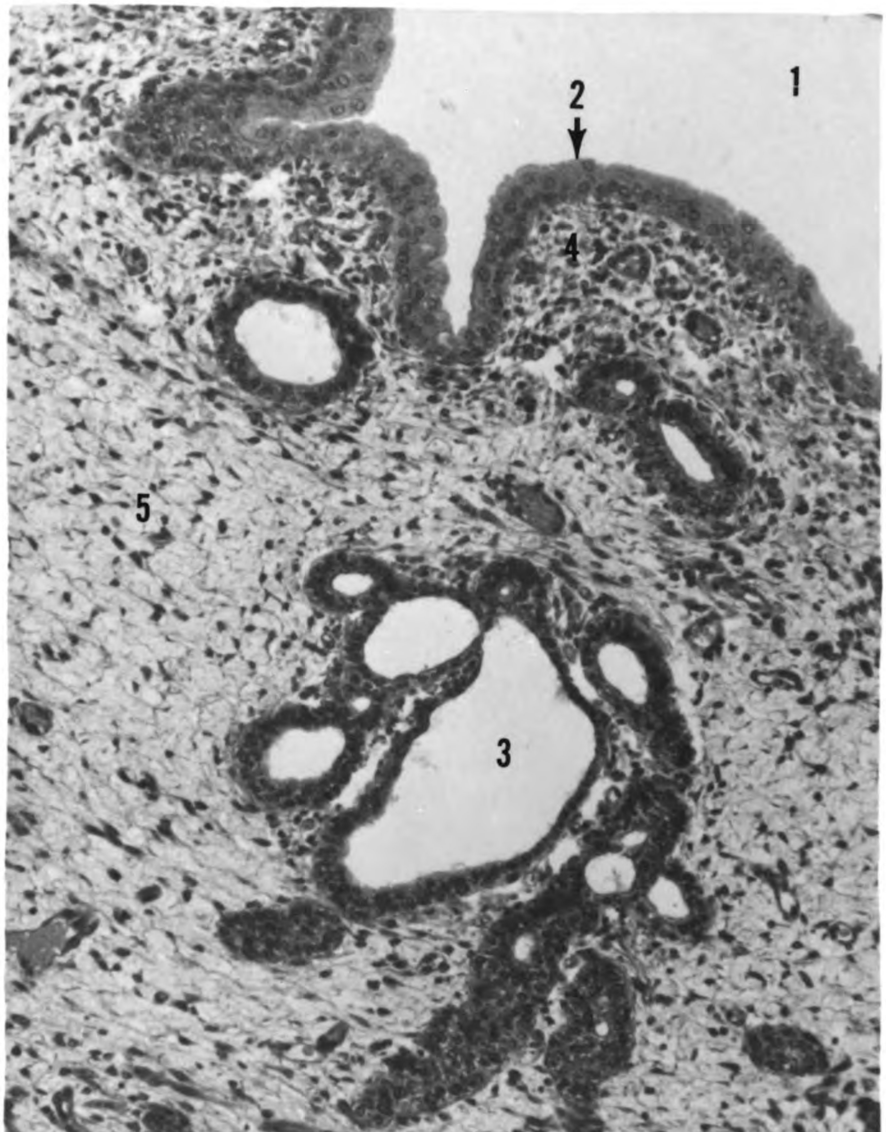
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Figure 33.--Epithelial lining of the membranous urethra.

1. Urethral lumen

2. Venous plexus within the submucosa

Hematoxylin and eosin x 384

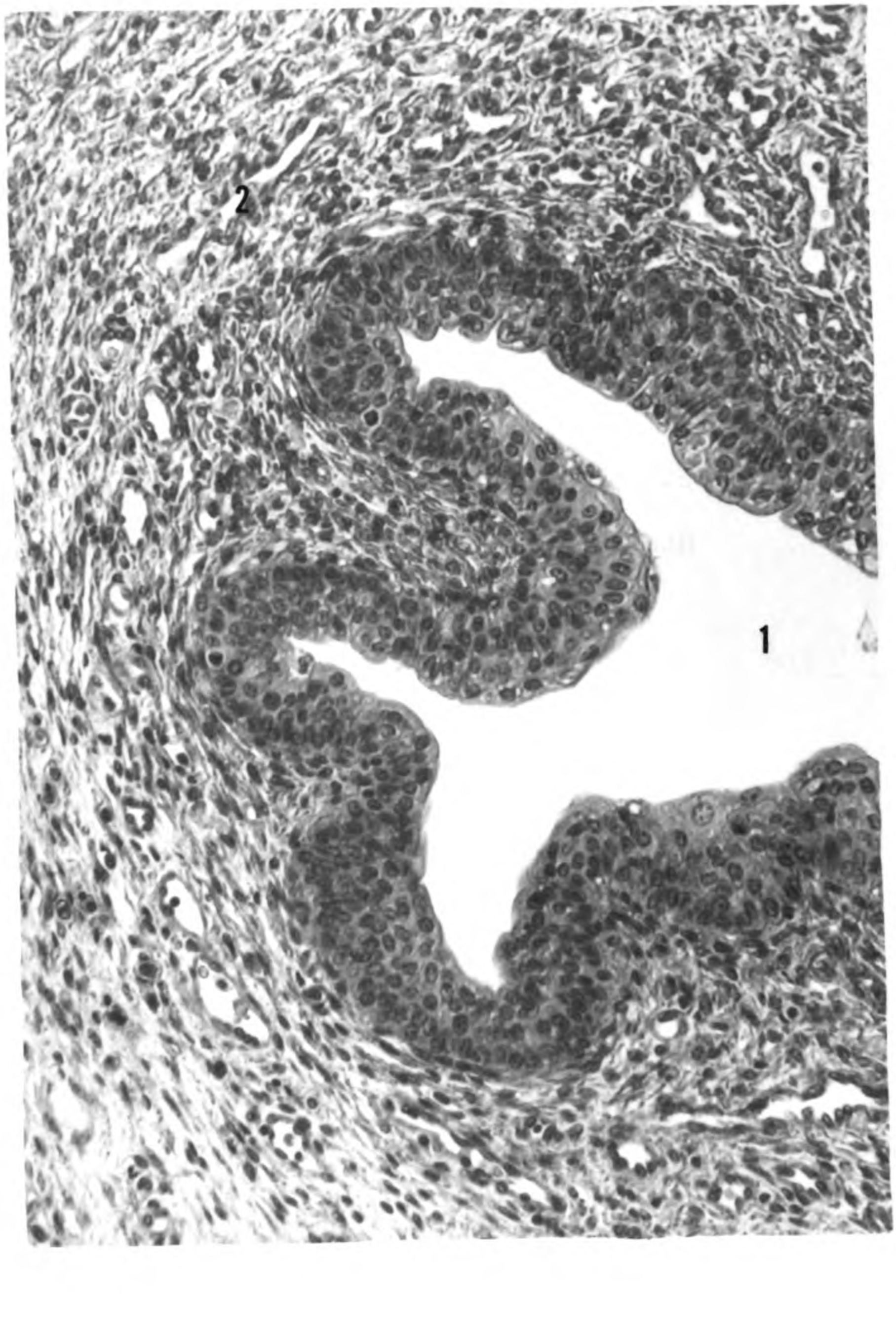
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Figure 34.--Cross-section of the proximal portion of the penile urethra.

1. Venous plexus within the submucosa

2. Developing cartilage which will become the os penis

Hematoxylin and eosin x 307

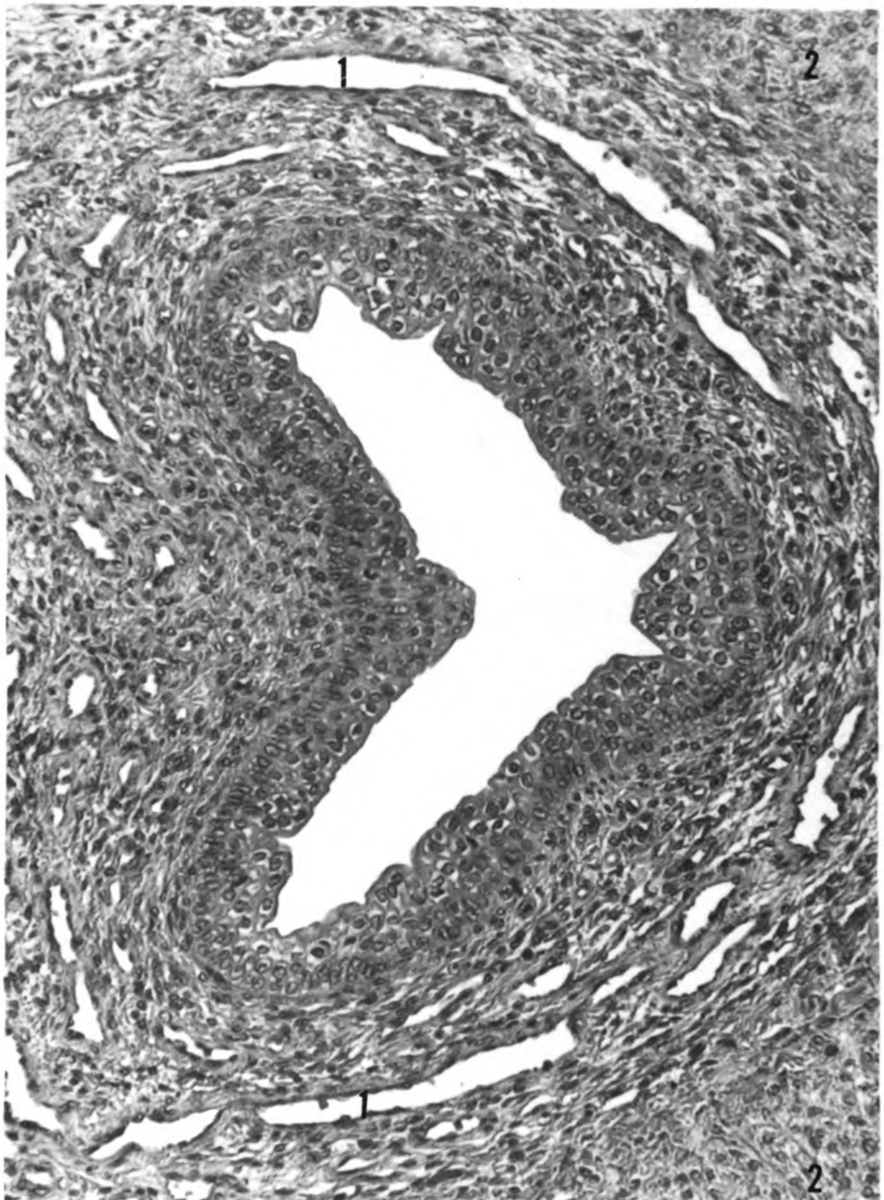
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Figure 35.--Cross-section of the distal portion of the penile urethra.

1. Capillary plexus within the lamina propria

2. Venous plexus within the submucosa

Hematoxylin and eosin x 307

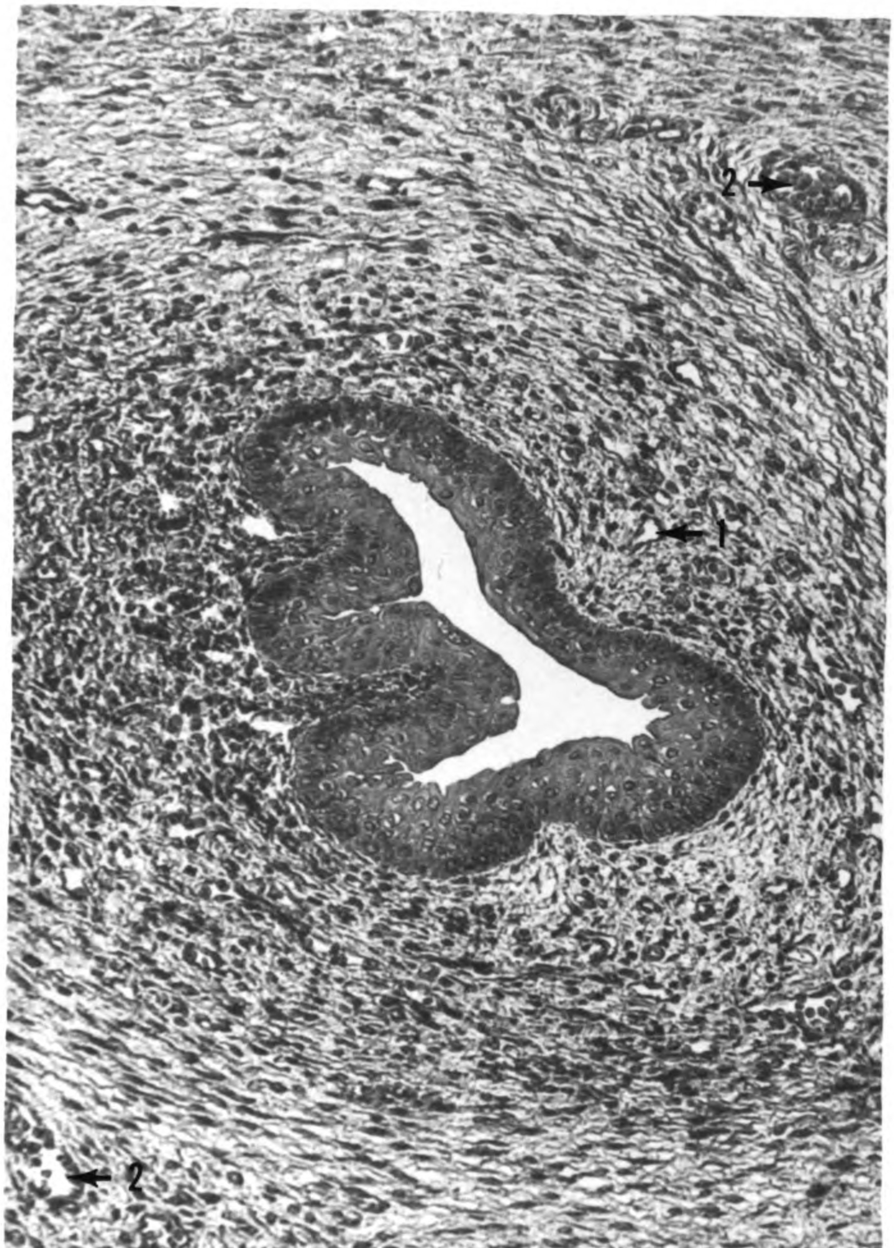
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Figure 36.--Epithelial lining of the penile urethra near the external urethral orifice.

1. Urethral lumen

2. Capillary plexus within the lamina propria

Hematoxylin and eosin x 1228

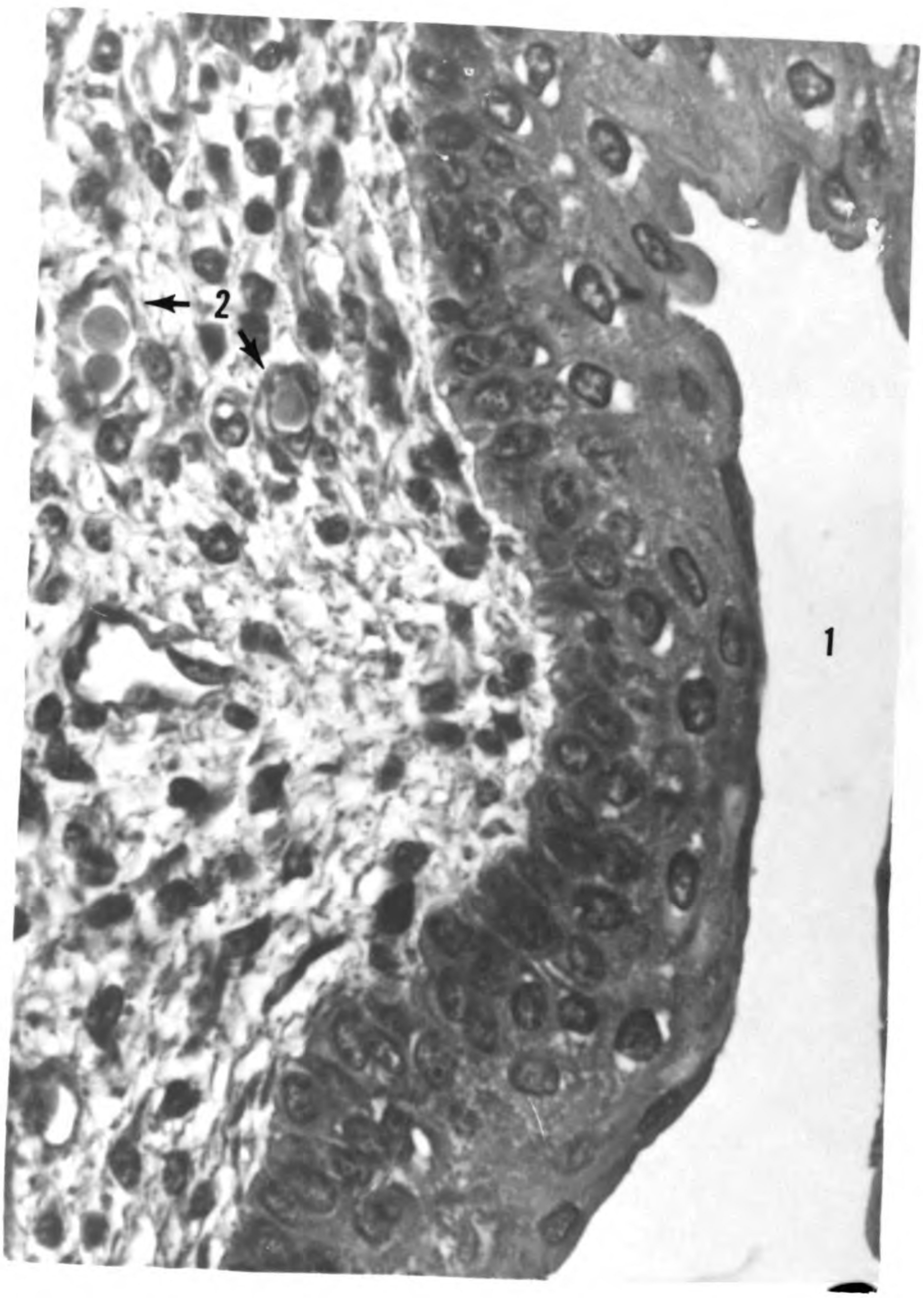
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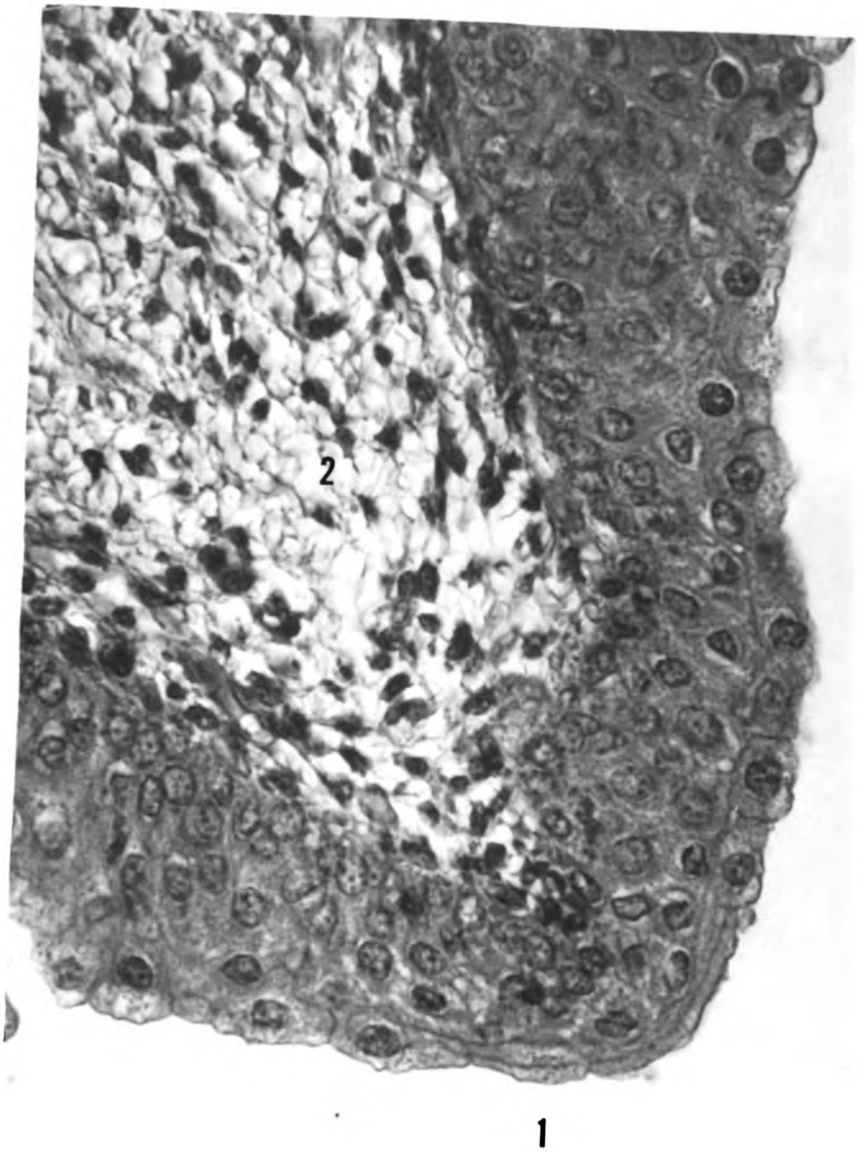
Figure 37.--Epithelial lining of the female urethra.

1. Urethral lumen

2. Submucosa

Hematoxylin and eosin x 768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