THE BOVINE KIDNEYS
IN
HEALTH AND DISEASE

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THESIS

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Contents

Introduction

In the past little has been published on the Bovine kidneys in health or disease. To observe and properly interpret structural alterations requires a clear conception of the normal. Therefore one of the purposes of this investigation is to study and record the findings of the normal Bovine kidneys.

In addition to the above, considerable time has been devoted to the study of the kidneys of animals on variously altered diets and of animals suffering from other diseases. The latter observations are too limited at this time to warrant any discussion. However, some reference is made to the changes observed in calves on a low magnesium diet.

Review of Literature

A review of literature reveals that a great deal has been published on the kidneys of man, and some of the experimental animals, but little has been published on the Bovine kidneys. No available literature could be found on the histological structure of the Bovine kidneys. The same was true for any literature concerning the effects of a low magnesium diet on the kidneys.

In as much as some of the kidneys seen in the low magnesium rations are white spotted; the work of Theobald Smith will be reviewed here (1) He found that a white spotted kidney in calves may be produced with a special strain of Bacillus Coli when the diet has been deficient in colostrum for 36 to 48 hours or longer. The process is in all cases focal and interstitial and limited to the cortex. In the earliest cases (13 to 15 days), the lesion is represented largely by cellular exudates, lymphocytes, and polymorphs. With the increasing age of the calf, the exudative cellular elements tend to give way to plasma-like cells and fibroblasts, and in the oldest animal ($2\frac{1}{2}$ months) the polymorphs and plasma cells have disappeared. The tubules in the main are compressed and without visible lumina. Casts of a homogenous substance are occasionally seen. The capsules of the glomeruli are thickened by several layers of fibroblasts and in the older cases the size of the capsular space may be doubled, and form distorted.

Pfenninger (2) also reached the conclusion that Bacillus Coli is the dominating bacteriological factor.

Materials and Methods

The organs for this study were selected from two types of cases. Those selected for histological study were from apparently normal beef animals of different age groups. Those for pathological study were from animals on variously altered diets from the dairy experimental herd and some animals affected with various diseases.

As soon as possible after the removal of the kidneys, blocks of tissue from the right and left were taken and fixed in Zinkers solution. The kidneys were then preserved in formalin for further use.

The Zinkers fixed material was embedded in paraffin. The sections were cut 8 microns in thickness and stained with eosin and hematoxylin. (Unless otherwise stated references will be made to this method of staining.) In all of the normal cases, serial sections were made. A small piece of tissue about 5 millimeters square was selected from previous paraffin blocks and reembedded. From 60 to 80 consecutive sections were cut 8 microns in thickness and stained with eosin and hematoxylin.

In some of the cases duplicate sections were stained by Verhoeff's technique to bring out the elastic membranes of the vessel walls.

In all of the low magnesium cases formalin fixed tissues were frozen, sectioned 15 microns in thickness, and stained with sudan IV for fat.

Some of the formalin fixed material was embedded in paraffin, sectioned 8 microns in thickness, and stained with a 1% solution of silver nitrate and counter-stained with eosin and hematoxylin to show calcium deposites.

The normal kidneys were also studied by means of the maceration technique. (3) Small blocks of formalin fixed material were placed in concentrated hydrochloric acid for a period of 24 to 48 hours depending on the time it took the connective tissue elements to be digested. The acid was then pipetted off, and the material washed several times with distilled water. The nephrons and their collecting tubules were easily teased apart and ready for study.

The Gross and Microscopic Study of Normal Kidneys

Gross Characteristics

The Bovine kidneys are covered by a fibrous capsule which strips off easily from normal specimens. The left kidney is the more irregular of the two in contour and has a slight twist on its long axis (fig. 1). The right kidney is more uniform and bean shaped (fig. 2). Each kidney is definitely lobated, the number of lobes varying from 16 to 32 (table VIII). The color in most normal specimens is a deep reddish brown. The surface is smooth.

In a sagittal section of a fresh kidney cut through the hilus we see several structures. The outer portion consists of the cortical substance measuring from 3 to 12 millimeters in depth depending on the size of the kidney (table IX). The glomeruli are seen as small spherical dots scattered abundantly in the cortical substance. The striations seen extending up into the cortex from the medulla are due to the straight portions of the tubules and bundles of capillaries (medullary rays).

The medulla consists of from 16 to 32 pyramidal shaped structures, one for each lobule, each measuring from 11 to 23 millimeters in depth (table IX). It is divided into two portions; the outer dark and the inner light portion. The medullary rays show very distinctly because of the large vascular bundles. The apex of the medulla is surrounded by the cup-like calyces of the renal pelvis. It is into the latter structures that the collecting tubules or ducts of Bellini discharge their urinary contents.

The cortical substance on either side of the pyramids

forms the columns of Bertini.

The Microscopic Study of Normal Macerated Kidneys

In the study of the kidney by the use of the maceration method, the nephrons and their collecting tubules were isolated. A few of the principal arteries were also recognized. In order to recognize the various segments of the nephrons and their collecting tubules several things had to be taken into consideration. First, the relative size of each segment measured through their diameters. Secondly, the region in which the different elements were found, whether cortex or medulla. Thirdly, the granularity,because it appeared to vary in different segments of the nephron as well as the collecting tubules.

The average diameters of the renal corpuscles show a variation from 149 to 226 microns for the different age groups. (For variations and averages in the different age groups consult tables I to VII inclusive). The renal corpuscles are round or oval in shape. Each one has two poles; the urinary pole and the vascular pole. At the vascular pole the afferent arteriole enters the glomerulus and the efferent arteriole leaves it (Fig. 3). It is near the vascular pole that the ascending limb of Henle's loop attaches itself to the renal corpuscle. It is at the urinary pole that the neck of the proximal convoluted tubule widens and surrounds the glomerulus as the capsule of Bowman (fig. 4 & 7).

The proximal convoluted tubules are very long and tortuous, and consists of many convolutions (fig. 5 & 6). Collectively they undoubtly occupy as much space as all the other elements of the cortex combined. (4) The neck of the proximal convoluted tubules are relatively short being 113 to 148 microns in length and 35 to 52 microns in diameter. They show a fine granularity at the center with a clear zone at the perphery. The average diameters of the proximal convoluted tubules show a variation from 45 to 62 microns (tables I to VII). The granularity remains about the same for some distance from the corpuscle but before the straight terminal portion is reached a marked change occurs (fig. 6). Here the granules are much courser and no clear zone at the perphery can be seen. The granules appear to be in pairs.

After the proximal convoluted tubules have made a large number of convolutions they finally enter the medullary ray as the straight terminal portions which descend down through the cortex and into the outer medulla (fig. 9). The average diameters of the straight terminal portions show a variation from 27 to 47 microns (tables I to VII). They vary in length depending on the point at which they enter the medullary ray in the cortex. In the outer medulla they taper quickly into Henle's loop (fig. 10 & 11). The granules are dark and about the same size as in the neck region, only not so numerous.

The descending loop of Henle begins in the outer medulla and may reach the apex of the papilla of the inner medulla in some cases. The average diameters of the descending arms of the loop of Henle show a variation from 11 to 14 microns (tables I to VII). The largest diameters generally occurs near the union with the straight terminal portions of the proximal convoluted tubules. The descending limbs appear much lighter in color and very find granules can be seen (fig. 13). In the long loops after the crest is made the thin portions ascend until they change abruptly into the dark portions of the ascending limbs (fig. 12). This abrupt change is characterized by the tubules becoming larger in diameter. The average for these tubules show a variation from 22 to 27 microns (tables I to VII). This portion looks much darker in contrast to the descending limbbecause of the increased number of granules. The ascending limbs follow the medullary rays into the cortical tissue, return to the renal corpuscles and attach themselves to the vascular pole (fig. 8). At this point of attachment the ascending limbs become much larger in diameter. From this point on they become the distal convoluted tubules.

The distal convoluted tubules are more irregular in contour and only extends a short distance before joining a branch of the collecting tubule (fig. 8). The average diameters for these tubules show a variation from 36 to 49

microns (tables I to VII). The granules are much more abundant and darker than in the proximal, but at the margin of the tubule there appears to be a small clear zone.

The small collecting tubules that connect the distal convoluted tubules to the straight collecting tubules of the medullary rays measure from 17 to 30 microns in diameter. They have a mosaic pattern with scattered granules. The average diameters for the straight collecting tubules show a variation from 35 to 42 microns (tables I to VII). The straight collecting tubules are joined by connecting tubules all through the cortex, but in the outer medulla no fusions take place. However, in the inner medulla these tubules fuse at acute angles with similar tubules (fig. 14). From my observations this takes place four or five times. From these central fusions large collecting ducts are formed known as the ducts of Bellini. These ducts open at the area cribrosa on the apex of the papilla. The general characteristics are the same as those of the small collecting tubules.

The renal arteries enter the kidney at the hilus and quickly divide into several secondary branches. From these the interlobar branches arise and follow alongside the major and minor calices and pass upward on either side of the pyramids and finally entering the lobe at the junction of the medulla and the cortex. At this point they become the arciforms which measure around 420 microns in diameter. The arciform soon branches into several interlobular branches measuring from 70 to 131 microns in diameter. Each interlobular gives rise to many smaller

branches, the afferent vessels which measure from 18 to 26 microns in diameter (fig. 3). Each afferent vessel leads to a glomerulus.

The Microscopic Study of Stained Preparations from Normal Kidneys

For convenience of study the lobes of the kidney are divided into various parts. The three main parts are the cortex, outer medulla, and inner medulla. The cortex can be divided into the labyrinths and the medullary rays (fig. 15). In the labyrinths the main structures are the glomeruli, proximal convoluted tubules, distal convoluted tubules, distal portions of the ascending limbs of Henle, connecting segments of the collecting tubules, the interlobular blood vessels and their smaller branches and many capillaries. In the medullary rays are found the straight terminal portions of the proximal convoluted tubules, the distal parts of the ascending limbs, the collecting tubules and the capillaries. The outer medulla consists of the straight terminal portion of the proximal convoluted tubules, the descending limbs of Henle, the straight collecting tubules, and large bundles of capillaries (figs. 26 & 28). In my observations of the outer medulla I have found nothing to warrant a division into outer and inner zone as found in the kidneys of humans (4). The inner medulla consists of: the descending limbs of the loop, the ascending limb of the loop, the collecting tubules, the ducts of Bellini and the capillaries.

The renal corpuscles are numerous in the Bovine kidney although no estimate of the exact number have been given as yet. In human kidneys the estimations of the number of glomeruli vary from 800,000 to 1,000,000 (5). In the cow the average diameters of the renal corpuscles show a variation from 128 to 196 microns for the different age groups (tables I to VII). They consist of the capsule of Bowman and the glomerulus. The capsule of Bowman is lined by a simple squamous epithelium which continues into the neck of the proximal tubule at the urinary pole. The afferent arteriole enters at the vascular pole and breaks up into a large number of capillaries which form the glomerulus. The blood leaves the glomerulus at the vascular pole through the efferent arteriole. The efferent is distinquished from the afferent by being smaller in size and has no internal elastic membrane. The average size of the afferent arteriole is 24 microns with a variation of 15 to 36 microns (table X). The efferent averages 14 microns with a variation of 12 to 18 microns (table X). The glomerulus in many cases does not completely fill Bowman's capsule. In a cross section of a single loop of the glomerulus proceeding from the outside inward we see: the visceral epithelium, basement membrane, reticular fibers, basement membrane, and vascular endothial cells. The visceral cells are larger and more spherical than the endothelial cells and have a nucleolus. The endothelial cells are more elongated, contain more chromatin, and stain darker (fig. 16 & 17). From my observations the visceral cells appear to be more numerous than the endothelial cells although no actual count of the number was made.

In the short neck of the proximal tubule, we find the same characteristics that are found throughout its entire length. It differs from that of the description of the human (4) in having a definite brush border and the cells being higher (fig. 18). The average diameters of the proximal convoluted tubules show a variation from 38 to 59 microns (tables I to VII). The epithelium consists of pyramidal cells with a definite brush border (fig. 19). The nuclei are spherical with fine chromatin particles. The cytoplasm is abundant and quite granular, although it does not stain as deeply with eosin as the distal. The average diameters of the lumina show a variation from 15 to 33 microns (tables I to VII).

The proximal convoluted tubule finally enters the medullary ray as the straight terminal portion and descends into the outer medulla (figs. 24 & 25). The average diameters of the straight terminal portions of the proximal convoluted tubules show a variation from 23 to 37 microns. The lumina of these tubules show a variation from 9 to 20 microns (tables I to VII). The epithelium retains the typical brush border (figs. 26 & 27).

The average diameters of the descending arms of Henle show a variation from 12 to 17 microns (tables I to VII). They have a thin squamous epithelium with a pale staining cytoplasm (fig. 29). Because of the relatively small amount of cytoplasm the spherical nucleus bulges into the lumen. The nucleus has fine chromatin particles and a

nucleolus can be seen in many of the cells. Because of its thinness, it is difficult to differentiate it from blood capillaries (fig. 29).

The average diameters of the ascending arms of Henle show a variation from 17 to 21 microns (tables I to VII). The epithelium varies somewhat in the ascending limb. In many places it is a low cuboidal, but in other places it is almost as low as the descending arm of the loop (fig.23). The cytoplasm is more abundant and stains dark with eosin. The spherical nuclei contain more chromatin which gives the cell a darker appearance. When the ascending limb returns to its renal corpuscle and attaches itself to the vascular pole, the tubule becomes larger in diameter. The epithelium is more cuboidal. The nuclei are rounder, more numerous, and contain large masses of chromatin. From here the ascending limb gradually passes into the distal convoluted tubule.

The average diameters of the distal convoluted tubules show a variation from 34 to 49 microns (tables I to VII). In comparing the distal convoluted tubules with the proximal convoluted tubules several distinctive features can be seen. They have a cuboidal epithelium with no brush border (figs. 20 & 21). The nuclei are more numerous and stain darker due to the greater abundance of chromatin. The cytoplasm is not so abundant and less granular. It takes a deeper stain with eosin. The average diameters of the lumina of these tubules show a variation from 18 to 31 microns (tables I to VII).

The length of the distal convoluted is relatively short in comparison with that of the proximal convoluted tubules. The distal convoluted tubule continues by a short connecting tubule into the initial branches of the collecting tubules.

The straight collecting tubules are joined by connecting tubules all through the cortex but in the outer medulla no fusions take place. However, in the inner medulla they join at acute angles with similar tubules at least four or five times (fig. 30). By making several fusions these tubules form the ducts of Bellini which open at the area cribrosa at the apex of the papilla (fig. 31). The epithelium of these tubules is cuboidal (figs. 21 & 32). The nuclei are round and take a central position in the cell. The chromatin is quite abundant. The cell has a cytoplasm that stains lightly with eosin. The average diameters of the straight collecting tubules show a variation from 27 to 37 microns. The average diameters of the lumina of these tubules show a variation from 13 to 16 microns (tables I to VII). In the ducts of Bellini the epithelium acquires a tall columnar form. The cells retain the other characteristics of the collecting tubules. The surface of the papilla is lined by a transitional epithelium (fig. 34).

The Gross and Microscopic Study of Diseased Kidneys

Case No. 1 (Aut. 3143)

History:

Holstein male age 15 months. The animal has been on a low magnesium diet. The ration consists of whole milk, starch, iron, copper, magnesium, and in addition 16 grams of magnesium oxide daily. The animal died in the afternoon and the kidneys were placed in the refrigerator over night. The kidneys were placed in fixing solution the following day at 9:00 A.M.

Gross appearance:

The kidneys weigh 472 and 515 grams respectively. The heavier kidney shows considerable but not uniform injection of the superficial vessels. Some of the lobes are quite uniformly congested; others show a distinct stippling of the injected foci, with the remaining areas of a pale gray color. A few of the lobes near the hilus show very little injection. The lighter kidney shows considerably less injection of the lobes from the surface, the majority being of a fairly uniform gray color.

On section of one of the most deeply congested lobes the medulla is of a uniform dark red color, the striations of the cortex are fairly distinct but the medullary rays appear more distinct than normal. The outer zone of the medulla shows considerable congestion; the inner zone pale. On section of one of the least congested lobes the stria-

tions are very indistinct, the cortex being almost a uniform gray color with a little evidence here and there of striations. The outer zone of medulla is slightly injected.

Microscopic appearance:

Microscopic examination shows the most extensive alterations in the cortex. They have a patchy distribution. The renal corpuscles show a thickening of Boxman's capsule with connective tissue and a hyaline-like substance. A small number of glomeruli show an increase in cells and a thickening of their basement membranes by a hyaline-like substance. The proximal convoluted tubules, the distal convoluted tubules, the ascending limbs of Henle, and the collecting tubules show varying degrees of atrophy. They are gradually being replaced by proliferating fibroblasts, lymphocytes and mononuclear phagocytes. In some areas, the proliferation of the connective tissue elements have resulted in the formation of concentric rings of collagenous tissue around the atrophic tubules. A hyaline-like substance has surrounded them and increased to such an extent that some of the tubules are nearly obliterated. Some of the nuclei of several proximal, and distal convoluted tubules contain small masses of a homogeneous light brownish red material somewhat resembling bile. The capillaries throughout the cortex are very much congested.

The outer medulla shows little pathology other than a marked capillary congestion. The inner medulla shows congestion and edema. A few of the collecting tubules

are distented and contain casts. The larger ones at the apex of the pyramid show a metaplasia of the epithelium.

Frozen sections of the tissues reveal no fat.

Tissues stained with silver nitrate show a deposition of calcium in a few atrophic tubules.

Case No. 2 (Aut. 3146)

History:

Holstein make age 450 days. The animal has been on a low magnesium diet. The animal was found dead the morning of Oct. 12, 1935. The material was fixed about 11:30 A.M.

Gross Appearance:

The right kidney weights 212 grams and the left 207 grams. The capsule strips with considerable difficulty. On the surface are numerous grayish white foci varying from 1 to 10 millimeters in diameter. In four instances they measure 30 millimeters in diameter. Each lobe shows at least four or five of these lesions.

On section they are limited to the cortex. None are seen in the medullary portion. The lesions appear to be productive but not fibrotic as no evidence of cicatrization can be observed either from the surface or from the depths of the organ. Some of the larger lesions actually project slightly above the surface of the kidney. There is considerable accumulation of fat in the capsule and in the peripelvic tissue.

Microscopic appearance:

The small white areas seen in the gross in some

instances extend through the entire depth of the cortex and into the outer part of the medulla. In the interstitial connective tissue of these areas two conditions are in evidence, one an active productive tissue process in which large numbers of proliferating fibroblasts and a few fibers can be seen; the other an inactive stage that is dominated by a marked increase in collagenous fibers. Numerous lymphocytes and mononuclear phagocytes are found. Several of the renal corpuscles show connective tissue thickening of Bowman's capsule. The glomeruli show no appreciable change in the cellular elements; however, in some instances the basement membranes appear to be thickened with a hyaline-like substance. The tubular epithelium shows varying degrees of atrophy. The fibroblasts have formed concentric rings of collagenous fibers around the tubules as described in the previous case. A few of the collecting tubules are distented and contain casts.

In the cortical substance other than the foci described above the tubules show some cloudy swelling and desquamation of the epithelium. The proximal convoluted tubules show this condition more than the other segments.

The medulla does not show the changes seen in the cortical substance. A few of the foci seen in the cortex extends down into the outer medulla and have the same fundamental characteristics as previously described. There is marked capillary congestion.

The blood vessels show several structural alterations.

The interlobular arteries show a proliferation of the subendothelial connective tissue resulting in a thickening and narrowing of the lumen. (Endarteritis obliterans). The media has a vacuolated appearance, but special staining reveals no fat. The intima has thickened and hyalinized in several cases. In the walls of the media of several interlobular arteries there are several small hemorrhages.

Case No. 3 (Aut. 3160)

History

Holstein male age 15 months. The animal has been on a low magnesium diet and was slaughtered. The tissues were fixed in fixing solution one hour after slaughter.

Gross Appearance

The right kidney weighs 324 grams and the left 287 grams. The capsule strips easily from both kidneys. The color of the surface is not normal, but presents somewhat of a stipled gray appearance. The kidneys cut with increased resistance. Striations in the cortex are not distinct, although there appears to be no cicatrization. The condition of indistinct striations is quite uniform throughout both kidneys. The cortex measures from 7 to 10 millimeters in depth. The medulla shows no gross alterations.

Microscopic Appearance:

Microscopic examination shows an extensive nephritis throughout the cortex and the medulla. Nearly all of

the nephrons and their collecting tubules show structural alterations. The renal corpuscles show a marked thickening of Bowman's capsule with connective tissue and a hyaline-like substance. The capsular epithelium has become very irregular in contour. A small number of glomeruli show an increase in cells and a thickening of their basement membranes by a hyaline-like substance. The proximal convoluted tubules, the distal convoluted tubules, the ascending limbs of Henle, and the collecting tubules show varying amounts of atrophy. They are gradually being replaced by proliferating fibroblasts and numerous lymphocytes and mononuclear phagocytes cells. In some areas the proliferation of the connective tissue element has resulted in the formation of concentric rings of collagenous tissue around the atrophic tubules. A hyaline-like substance has surrounded and increased to such an extent that some of the tubules are nearly obliterated by it. The ascending limbs of Henle show the latter condition very extensively. A small number of the distal convoluted tubules and collecting tubules are distended and show numerous casts. The nuclei of several proximal convoluted tubules show the same condition described in cas No. 1. A few of the more normal looking nephrons show some cloudy swelling.

The condition of the medulla is very much like that of the cortex. In the outer medulla, the terminal portions of the proximal convoluted tubules, the ascending limbs of Henle, and the straight collecting tubules show atrophic conditions. Proliferating tissue and small

round cells are gradually replacing the tubules place. As in the cortex, a hyaline-like substance has surrounded the tubules and increased to such an extent that they have almost lost their identity. Several of the collecting tubules are very much distended and filled with a granular debris. The capillaries are congested. In the inner medulla, the conditions are similar to the outer medulla with one exception, the epithelium of the large collecting tubules and that of the papilla show a marked metaplasia.

Examination of the blood vessels show several distinctive features. A few of the interlobular arteries show proliferation of the subendothelial tissues and narrowing of their lumina. The media of the arteries show a vacuolated condition. Frozen sections reveal no fat. The subendothelial tissues in most of the vessels show an infiltration with a hyaline-like substance.

Staining with silver nitrate shows deposition of calcium in scattered atrophic tubules but not in the blood vessels.

Case No. 4 (Aut. 3429)

History:

Holstein male age 10½ months. The animal has been on a low magnesium diet. The tissues were fixed in fixing solution while still warm.

Gross Appearance:

The right kidney weighs 435 grams and the left kidney 391 grams. The capsules strip very easily. The kidneys are very pale and the surface is very irregular. Numerous

small white foci can be seen on each lobe. On section the material was very resistant to the knife. This condition is probably due to a productive tissue change throughout the cortex. The tubules of the medulla appear to be stuffed with a grayish yellow substance.

Microscopic Appearance:

Microscopic examination shows the most extensive alterations in the cortex. The renal corpuscles show a thickening of Bowman's capsule with connective tissue and a hyaline-like substance. The capsule is very irregular in contour. A small number of glomeruli show proliferation of cells and thickening of their basement membranes with hyaline-like substance. In one or two instances the glomeruli have been practically obliterated with this substance. The proximal convoluted tubules, the distal convoluted tubules, the ascending limbs of Henle, and the collecting tubules show varying degrees of atrophy. They are gradually being replaced by proliferating tissue and numerous lymphocytes and mononuclear phagocytes. Throughout the cortex large patches of lymphocytes and mononuclear phagocytes are present with little proliferation of fibroblasts. Nearly all of the tubules in these areas have disappeared; the few that remain are almost obliterated by this hyaline-like substance. In some areas the proliferation of the connective tissue elements have resulted in the formation of concentric rings of collagenous tissue around the atrophic tubules. This hyaline-like substance can be found around most of them.

In scattered parts of the cortex small groups of functioning tubules still remain. Many of them show a condition resembling hypertrophy, but even these tubules show some degenerative conditions.

The condition of the medulla is similar to that of the cortex. Many of the terminal portions of the proximal convoluted tubules, the ascending limbs of Henle, and the straight collecting tubules show atrophy. They are gradually being replaced by small round cells and proliferating tissue. Many of them are surrounded by hyaline-like substance. A few of the tubules show a condition resembling hypertrophy. The capillaries show much congestion. A few of the collecting tubules are distended and contain a granular debris.

The arciform arteries show a vacuolated appearance of the media.

Sections stained with silver nitrate show a deposition of calcium in a few atrophic tubules throughout the kidneys.

Case No. 5 (Aut. 3439)

History:

Jersey male age 11 months. The animal was on a low magnesium diet. The animal was slaughtered and the tissues fixed in fixing solution within a few minutes.

Gross Appearance:

The capsules strip easily. The kidneys are pale in

color. The left is much smaller than the right and appears shrunken. The weights are not recorded.

On section the striations in the cortex are very indistinct. The tubules of the medulla appear to be stuffed with some kind of debris. The intima of the renal artery shows a granular condition that feels like sand paper to the touch.

Microscopic Appearance:

This case shows a very extensive nephritis. The lesions are not confined to any one portion of the nephrons or collecting tubules.

In the cortex scattered areas of normal tissue can be found, but most of the organ shows structural alterations. The renal corpuscles show varying degrees of alterations. In some, Bowman's capsule is greatly thickened by connective tissue and a hyaline-like substance. The capsule has become very irregular in contour. A small number of glomeruli show proliferation of cells and thickening of their basement membranes by a hyaline-like substance. A few of the renal corpuscles have been replaced by connective tissue and a hyaline-like substance.

The ascending limbs of Henle, the proximal convoluted tubules, the distal convoluted tubules, and some of the collecting tubules show varying degrees of atrophy. Their places are gradually being taken by proliferating tissue and large numbers of round cells. In some areas the round cells are very numerous with scattered fibroblasts.

The tubular epithelium has undergone atrophy and the remaining tubules are almost replaced by a hyaline-like substance. In other areas the fibroblasts have proliferated more extensively and a few round cells are found. The tubules are surrounded by concentric rings of connective tissues similar to the condition described in case No. 1. Some of the nuclei of the tubular epithelium shows the inclusions described in case No. 1.

In scattered areas small groups of functioning nephrons are visible. The glomeruli show some congestion and their tubules show some degeneration.

In the medulla, the alterations are not quite so extensive as in the cortex. In the outer medulla some of the terminal portions of the proximal convoluted tubules, the ascending limbs of Henle, and the collecting tubules show varying degrees of atrophy. They are being replaced by proliferating tissue and round cells. In a few instances the more normal terminal portions of the proximal convoluted tubules and ascending limbs of Henle appear to be hypertrophic.

In the inner medulla the collecting tubules in some instances show desquamation of the epithelium. A few of them are distended and filled with a granular debris. The descending limbs of Henle show some atrophy and replacement by proliferating tissue and a hyaline-like substance.

The epithelium of the larger collecting tubules

The epithelium of the larger collecting tubules and that of the papilla shows a metaplastic condition.

Staining the tissues with silver nitrate for calcium show a deposition of calcium in the intima of several arciform arteries. In the cortex a few atrophic tubules show a deposition of calcium.

Discussion

In all of the low magnesium cases a chronic nephritis is present. The amount and distribution of the lesions vary somewhat in the different cases but the pathological conditions are very similar. The kidneys in the gross are usually quite pale and may show numerous white foci. On section many of the striations normally seen are indistinct.

Microscopically, the most extensive alterations are in the cortex and usually patchy in distribution although one case was very much diffuse. A large number of the renal corpuscles show a marked thickening of bowman's capsule with connective tissue and a hyaline-like substance (fig. 35). The capsular epithelium has become irregular in contour. Some of the glomeruli show an increase in cells and a thickening of their basement membranes by a hyaline-like substance. In a few instances the glomeruli have been nearly obliterated by this hyaline-like substance (figs. 36 & 37). In the interstitial connective tissue, two conditions are in evidence, one an active pro-

ductive tissue process in which large numbers of proliferating fibroblasts and few fibers can be seen; the other an inactive stage that is dominated by a marked increase in collagenous fibers. Throughout the cortex large patches of lymphocytes and mononuclear phagocytes are seen (figs. 35 & 39). The proximal and distal convoluted tubules, the ascending limbs of Henle, and the collecting tubules show varying degrees of atrophy (fig. 38). In some areas the proliferation of the connective tissue elements have resulted in the formation of concentric rings of collagenous tissue around the atrophic tubules (fig. 38). A hyaline-like substance has surrounded and increased to such an extent that some of the tubules are nearly obliterated by it (fig. 35). Casts of a homogeneous substance are occasionally seen (fig. 40). Some of the nuclei of several proximal, and distal convoluted tubules contain small masses of a homogeneous light brownish red material resembling bile.

In scattered areas small groups of functioning tubules are visible. A few of the proximal convoluted tubules are greatly distended and the epithelium appears to be of a lower type (fig. 41). Some of them show degeneration. In some cases the capillaries are very much congested.

In the medulla, the alterations are not seen so extensively as in the cortex. One or two cases show no changes at all outside of a little congestion. The others show some pathology similar to that seen in the cortex.

In the outer medulla, some of the terminal portions of the proximal convoluted tubules, the ascending limbs of Henle, and the collecting tubules show varying degrees of atrophy. They are being replaced by proliferating fibroblasts, lymphocytes and mononuclear phagocytes. In the inner medulla a few of the collecting tubules are distended and contain casts. The descending limbs of Henle show some atrophy and replacement by proliferating tissue and a hyaline-like substance. The epithelium of the larger collecting tubules and that of the papilla show a metaplastic condition (fig. 42).

The most conspicuous alterations observed in the arteries are the thickening of the intima with a hyaline-like substance and a vacuolated condition of the media, but special staining reveals no fat (figs. 44 & 45). In a few instances, the interlobular arteries show a proliferation of the subendothelial connective tissue resulting in a thickening and narrowing of the lumina (Endarteritis obliterans) (fig. 43).

Staining with silver nitrate shows deposition of calcium in scattered atrophic tubules in all of the cases (fig. 46). However, only one case shows the deposition of calcium in the intima of the blood vessels, (fig. 47).

In tables I to VII inclusive, data are recorded on the comparative size of the several portions of the nephrons and collecting tubules in fixed and stained specimens and macerated specimens. Numerals indicate diameters in microns.

The following abbreviations will be used in the tables:

Mac. - Macerated
St. - Stained
Max. - Maximun
Min. - Minimun
Ave. - Average
Prox.- Proximal
Convol.-Convoluted

Table I 1 Month Old Calf

	Renal Corpuscles		Proximal Convoluted Tubules		
	Mac.	St.	Mac.	St.	Lumen
	152	140	35	38	13
	152	136	70	51	12
	143	123	48	48	20
	143	127	70	46	8
	160	136	58	47	8
	147	131	53	47	18
	125	124	54	28	12
	143	140	45	44	12
	160	123	44	34	12
	143	131	52	44	25
	170	131	35	38	12
	152	123	58	38	19
	143	128	44	38	19
	143	123	35	35	25
	143	105	39	45	19
	138	135	39	38	16
	143	105	44	32	13
	160	124	39	38	16
	170	140	44	41	-
	160	123	52	49	25
	152	113	52	48	13
	143	140	39	38	16
	160	140	35	37	14
	143	131	44	38	13
	138		35	45	21
Max.	170	140	70	51	25
Min.	125	105	35	28	8
Ave.	149	128	45	38	15

Table I (Continued)

	Diameters of Distal Convoluted Tubules			Diameters of Terminal Portions of Prox. Convol. Tubules		
	Mac.	St.	Lumen	Mac.	St.	Lumen
	33	32	16	27	13	13
	44	33	19	25	25	14
	27	32	19	35	30	14
	36	33	17	30	25	13
	35	33	16	35	22	10
	52	45	24	38	25	10
	44	40	19	35	25	6
	58	38	17	28	25	-
	44	48	32	25	24	6
	30	38	21	16	25	8
	35	41	19	14	22	10
	35	32	19	30	24	8
	35	32	19	35	24	12
	44	40	27	22	22	8
	26	33	19	30	25	12
	30	45	25	26	25	9
	39	33	16	30	25	12
	30	41	19	26	25	12
	26	38	21	18	27	8
	44	38	19	35	22	-
	39	45	24	22	22	12
	26	38	22	35	24	-
	52	37	19	35	25	6
	35	32	19	30	21	12
	39	27	16	35	25	12
Max.	58	48	32	38	30	14
Min.	26	27	16	14	13	6
Ave.	36	36	19	27	23	10

Table I (Continued)

	Diameters of Descending Limb of Henle's Loop		Diameter of Ascending Limb of Henle's Loop		Diameters of Collecting Tubules		
	Mac.	St.	Mac.	St.	Mac.	St.	Lumen
	8	11	30	16	39	25	8
	14	10	27	19	18	27	-
	18	10	21	21	25	32	15
	18	13	28	19	26	37	19
	16	10	22	19	22	25	13
	18	11	27	25	35	25	13
	12	8	18	16	44	19	6
	15	13	18	14	39	24	11
	8	13	26	16	30	25	13
	12	16	22	17	26	32	13
	12	10	18	19	39	27	11
	8	16	22	16	35	24	10
	12	14	22	19	52	32	17
	8	10	26	17	44	35	13
	6	13	18	19	70	25	13
	8	13	18	14	58	22	10
	6	10	18	19	39	29	13
	18	13	18	21	35	32	19
	12	11	22	13	44	25	13
	12	11	26	14	39	35	19
	8	13	30	16	35	27	13
	8	13	26	16	30	30	16
	12	13	26	17	39	32	16
	8	19	18	19	26	27	14
	15	16	26	13	44	25	11
Max.	18	16	30	25	70	37	19
Min.	6	8	18	13	18	19	6
Ave.	11	12	22	17	35	27	13

Table II 1 Year Old Calf

	Renal Corpuscles		Proximal Convoluted Tubules		
	Mac.	St.	Mac.	St.	Lumen
	175	184	52	44	25
	157	175	61	44	25
	149	167	61	51	19
	149	175	52	44	22
	192	175	61	70	19
	192	175	44	54	25
	175	175	70	51	32
	149	157	52	51	-
	157	157	52	51	19
	185	157	52	39	19
	140	175	70	51	33
	175	17 5	35	51	19
	166	166	53	38	-
	184	175	44	44	33
	210	166	52	44	19
	175	149	69	48	25
	175	157	52	44	22
	175	157	44	41	13
	184	148	52	44	-
	157	140	35	38	21
	166	153	44	43	21
	166	140	52	51	19
	183	147	61	32	13
	166	149	52	33	13
	149	175	35	51	25
Max.	210	184	70	70	33
Min.	140	140	35	32	13
Ave.	170	159	53	47	20

Table II (Continued)

	Diameters of Distal Convoluted Tubules			Diameters of Terminal Portions of Prox. Convol. Tubules		
	Mac.	St.	Lumen	Mac.	St.	Lumen
	44	32	17	35	29	6
	44	32	12	39	29	6
	35	38	19	35	25	7
	26	44	25	35	32	8
	44	51	25	44	41	-
	52	29	14	35	30	-
	44	44	25	35	44	19
	26	35	15	44	41	9
	35	38	25	26	38	9
	79	44	29	52	32	13
	35	38	25	26	24	13
	35	44	25	44	35	13
	39	38	19	35	25	8
	44	44	25	52	25	13
	35	44	21	35	38	19
	52	35	19	36	35	11
	35	38	25	35	50	19
	39	43	25	44	25	-
	31	38	19	35	30	6
	44	38	19	35	25	7
	35	38	25	39	25	7
	35	44	22	35	28	16
	35	38	25	44	43	13
	61	32	25	48	35	13
	35	29	13	44	29	12
Max.	79	51	29	52	50	19
Min.	26	29	12	26	24	6
Ave.	41	35	18	38	32	9

Table II (Continued)

	Diameters of Descending Limb of Henle's Loop		Diameter of Ascending Limb of Henle's Loop		Diameters of Collecting Tubules		
	Mac.	St.	Mac.	St.	Mac.	St.	Lumen
	17	16	18	25	35	32	14
	17	10	26	17	44	32	-
	17	14	26	12	35	29	-
	13	13	17	16	31	44	25
	9	13	26	19	37	38	15
	13	16	26	12	44	32	17
	17	14	22	16	44	32	12
	9	16	17	21	35	38	19
	9	13	26	22	26	25	6
	13	11	26	19	31	25	8
	9	17	17	13	17	32	6
	13	13	26	19	39	32	16
	17	16	26	21	26	33	19
	9	14	31	21	31	38	19
	6	14	22	22	26	19	6
	13	13	17	25	52	25	11
	8	12	9	18	52	35	14
	9	17	17	17	17	41	25
	17	14	26	21	52	30	11
	13	14	22	19	35	21	13
	6	21	26	17	70	22	6
	9	19	22	21	70	25	13
	13	11	22	22	35	28	10
	4	9	30	13	39	22	13
	8	14	22	17	35	25	13
Max.	17	21	31	25	70	44	25
Min.	4	9	9	12	17	19	6
Ave.	12	14	23	18	38	30	13

Table III 1 Year Old Calf

	Renal Corpuscles		Proximal Convoluted Tubules		
	Mac.	St.	Mac.	St.	Lumen
	210	175	26	57	29
	201	175	61	57	29
	175	201	52	35	22
	192	192	44	48	30
	184	175	52	51	19
	188	210	61	49	33
	175	201	52	62	32
	179	210	52	57	35
	184	201	35	51	25
	192	201	39	48	19
	175	192	44	52	25
	205	210	52	51	25
	179	218	79	52	32
	201	192	44	49	25
	184	192	52	54	32
	184	218	70	57	25
	157	218	52	51	25
	184	192	48	51	25
	175	201	39	70	29
	179	183	61	45	25
	188	183	70	51	25
	219	201	58	37	13
	219	183	52	57	25
	175	201	87	60	27
	201	183	7 9	57	22
Max.	219	218	87	70	35
Min.	157	175	26	37	13
Ave.	180	189	54	52	26

Table III (Continued)

	Diameters of Distal Convoluted Tubules			Diameters of Terminal Portions of Prox. Convol. Tubules		
	Mac.	St.	Lumen	Mac.	St.	Lumen
	35	32	13	44	30	13
	79	41	25	44	29	13
	48	29	16	30	32	16
	52	38	21	48	32	16
	52	38	24	26	44	19
	30	45	25	35	40	22
	44	29	19	26	32	14
	35	25	13	35	32	14
	44	29	17	39	34	13
	30	38	17	30	32	16
	35	37	19	35	32	13
	30	29	14	30	27	13
	52	37	14	35	25	13
	61	49	24	39	24	11
	44	32	14	35	24	13
	39	25	10	35	22	10
	52	59	45	44	29	13
	70	32	13	48	27	8
	52	38	13	35	25	13
	61	35	14	44	19	-
	70	32	13	44	30	13
	44	37	19	48	36	14
	44	57	32	35	38	17
	52	45	22	44	35	14
	30	33	23	44	25	6
Max.	79	59	45	48	44	22
Min.	30	25	10	26	19	6
Ave.	47	36	19	40	32	14

Table III (Continued)

	Diameters of Descending Limb of Henle's Loop		Diameter of Ascending Limb of Henle's Loop		Diameters of Collecting Tubules		
	Mac.	St.	Mac.	St.	Mac.	St.	Lumen
	18	19	18	19	61	29	6
	18	14	26	19	26	38	10
	16	19	26	17	22	29	17
	18	16	30	21	44	25	11
	12	19	26	14	44	38	19
	12	16	35	21	35	36	16
	8	14	26	22	61	25	13
	16	14	26	17	26	38	19
	8	13	22	19	35	32	14
	18	14	26	17	22	32	19
	12	18	30	25	26	37	19
	12	20	30	19	35	38	25
	8	16	26	24	52	27	19
	12	19	22	25	18	38	14
	12	14	30	24	35	38	20
	22	18	26	25	30	32	17
	8	18	30	17	58	25	9
	12	9	26	20	35	38	15
	12	9	30	25	35	32	15
	12	11	22	22	39	32	13
	8	13	30	13	61	25	6
	18	13	35	19	58	38	19
	12	14	35	19	52	29	8
	6	19	26	17	44	33	13
	12	18	30	17	44	35	11
Max.	22	20	35	25	61	38	25
Min.	6	9	18	13	18	25	6
Ave.	13	16	28	21	40	37	14

Table IV 2 Year Old Calf

	Renal Corpuscles		Proximal Convoluted Tubules		
	Mac.	St.	Mac.	St.	Lumen
	175	140	35	57	44
	192	157	61	45	16
	218	175	44	70	19
	17 5	166	35	45	-
	192	157	52	59	32
	184	183	44	57	32
	188	175	58	76	46
	184	157	52	50	25
	175	187	52	52	25
	205	157	70	50	25
	175	157	35	69	44
	184	157	39	60	36
	166	166	52	57	38
	175	175	61	57	33
	149	183	52	44	19
	175	175	65	57	32
	192	175	44	57	-
	166	192	52	82	57
	201	183	44	57	25
	175	183	52	57	32
	184	166	70	69	44
	201	201	52	60	25
	210	192	70	57	31
	166	183	39	63	-
	205	192	35	76	50
Max.	218	201	70	76	57
Min.	149	140	35	44	16
Ave.	172	167	51	59	33

Table IV (Continued)

	Diameters of Distal Convoluted Tubules			Diameters of Terminal Portions of Prox. Convol. Tubules		
	Mac.	St.	Lumen	Mac.	St.	Lumen
	35	32	17	26	32	13
	44	30	19	35	30	14
	35	32	19	35	38	17
	35	32	19	22	38	24
	30	43	22	26	32	14
	26	41	25	35	30	13
	44	32	22	26	25	13
	52	32	19	35	32	13
	30	38	20	30	28	14
	35	38	25	35	25	10
	35	29	13	35	25	6
	52	30	14	30	32	13
	52	40	25	35	30	13
	39	32	19	26	32	14
	30	24	13	30	25	13
	44	38	25	18	30	14
	35	32	19	35	25	8
	35	38	27	30	25	13
	52	33	19	35	37	17
	66	38	21	41	24	10
	105	32	19	35	29	13
	44	38	19	35	29	14
	35	33	19	30	30	-
	44	26	17	35	33	16
	66	45	30	35	25	13
Max.	105	45	30	41	38	24
Min.	26	24	13	18	24	6
Ave.	44	34	20	32	30	13

Table IV (Continued)

	Diameters of Descending Limb of Henle's Loop		Diameter of Ascending Limb of Henle's Loop		Diameters of Collecting Tubules		
	Mac.	St.	Mac.	St.	Mac.	St.	Lumen
	18	12	22	13	39	25	13
	18	14	30	24	35	36	17
	15	13	22	22	44	25	10
	12	14	22	25	30	25	6
	8	13	22	18	44	33	14
	12	16	26	16	35	32	16
	6	11	18	17	35	32	13
	12	13	18	21	44	33	13
	18	11	30	22	39	25	8
	12	13	26	25	35	19	6
	12	16	26	19	70	25	13
	18	8	22	17	35	32	17
	8	13	30	30	52	37	19
	8	16	18	22	39	38	1 9
	12	17	22	30	56	38	19
	12	8	26	20	30	33	16
	8	11	26	27	35	45	25
	12	13	18	24	62	21	5
	15	17	15	20	44	25	13
	8	9	30	17	35	41	19
	18	16	22	13	39	35	18
	12	22	30	21	44	27	10
	30	16	22	16	26	51	32
	26	13	22	25	44	45	25
	12	8	26	19	44	43	25
Max.	30	22	30	30	70	51	32
Min.	6	8	15	15	26	19	5
Ave.	14	13	27	21	41	35	16

Table V 2 Year Old Calf

	Renal Corpuscles		Proximal Convoluted Tubules		
	Mac.	St.	Mac.	St.	Lumen
	218	183	52	49	25
	192	187	44	57	38
	236	245	52	49	19
	210	210	44	45	22
	245	201	58	38	13
	227	210	87	51	19
	245	210	44	59	19
	245	210	52	46	25
	210	227	70	60	24
	280	192	7 0	51	22
	245	210	44	68	32
	183	183	66	57	22
	245	175	39	57	25
	236	183	44	38	19
	201	201	35	49	25
	192	201	35	38	14
	201	210	44	51	25
	245	166	66	45	13
	210	240	52	38	19
	183	201	44	33	19
	175	183	39	45	22
	227	201	58	51	22
	210	183	39	64	25
	245	227	70	51	24
	201	218	44	46	16
Max.	280	245	87	68	38
Min.	175	166	35	33	13
Ave.	212	190	51	49	22

Table V (Continued)

	Diameters of Distal Convoluted Tubules			Diameters of Terminal Portions of Prox. Convol. Tubules		
	Mac.	St.	Lumen	Mac.	St.	Lumen
	39	51	20	44	45	25
	35	43	20	12	32	16
	44	57	32	26	46	19
	52	49	25	35	26	13
	70	51	25	39	32	19
	44	43	25	35	38	21
	30	38	21	26	33	11
	52	37	19	35	27	13
	35	32	17	44	46	19
	39	35	19	35	35	19
	35	38	17	35	33	19
	44	40	25	35	33	19
	70	45	21	26	45	24
	52	25	17	35	30	13
	44	29	13	35	40	19
	35	52	25	30	33	17
	44	45	32	39	35	17
	26	38	16	35	32	13
	66	45	25	35	27	15
	66	51	32	44	35	10
	35	64	38	39	40	25
	39	65	40	48	44	13
	39	51	32	26	25	13
	52	38	25	44	17	6
	35	38	22	35	14	6
Max.	70	65	40	48	46	25
Min.	26	25	13	12	17	6
Ave.	45	46	29	36	34	20

Table V (Continued)

	Diameters of Descending Limb of Henle's Loop		Diameters of Ascending Limb of Henle's Loop		Diameters of Collecting Tubules		
	Mac.	St.	Mac.	St.	Mac.	St.	Lumen
	18	16	22	19	48	27	9
	18	14	18	16	35	51	27
	12	13	22	18	39	38	17
	6	11	30	19	26	25	8
	12	6	26	19	66	45	22
	18	8	30	13	39	32	6
	12	13	30	16	35	35	12
	22	13	26	24	39	25	9
	12	17	26	19	35	25	13
	6	11	30	19	35	27	13
	18	13	26	20	35	24	6
	8	8	26	18	52	32	13
	15	11	22	22	70	33	14
	18	9	15	19	30	38	13
	12	11	18	25	66	25	13
	15	9	30	22	44	33	19
	22	13	22	22	39	38	16
	8	13	26	24	35	32	13
	12	8	30	31	39	38	13
	8	6	22	28	35	32	8
	8	13	30	25	30	25	8
	18	11	18	21	39	38	19
	18	8	26	18	35	35	14
	8	13	22	29	35	29	13
	12	13	26	25	52	33	14
Max.	22	17	30	31	66	51	27
Min.	6	6	15	13	26	24	6
Ave.	13	11	25	21	41	33	13

Table VI 2 Year Old Calf

	Renal Corpuscles		Proximal Convoluted Tubules		
	Mac.	St.	Mac.	St.	Lumen
	245	175	52	51	25
	210	192	61	51	25
	245	218	44	44	25
	227	184	74	64	25
	236	184	44	49	19
	210	218	70	52	32
	254	201	79	51	19
	227	201	44	44	20
	245	227	70	48	19
	289	184	61	52	20
	271	192	52	60	25
	245	192	70	51	25
	227	218	61	54	32
	236	192	70	52	32
	175	218	61	48	25
	227	192	79	38	22
	210	192	52	57	-
	175	192	61	40	14
	236	210	79	44	19
	218	184	35	54	19
	192	192	52	52	19
	245	192	61	51	19
	183	183	70	57	25
	253	175	70	57	25
	184	183	52	38	19
Max.	271	227	79	64	32
Min.	175	175	35	38	14
Ave.	226	196	62	50	22

Table VI (Continued)

	Diameters of Distal Convoluted Tubules			Diameters of Terminal Portions of Prox. Convol. Tubules		
	Mac.	St.	Lumen	Mac.	St.	Lumen
	61	46	32	44	32	12
	52	37	19	35	39	14
	61	29	13	52	33	16
	52	44	25	30	36	19
	35	44	25	35	32	13
	35	36	16	44	32	13
	52	36	19	44	35	16
	61	32	16	57	35	17
	35	41	19	48	40	21
	79	38	22	44	38	19
	44	38	19	52	29	8
	61	35	19	52	25	8
	52	51	32	48	35	13
	44	45	25	35	30	27
	44	31	19	39	32	9
	35	32	13	44	38	14
	38	51	32	35	30	13
	44	50	35	52	33	13
	70	44	29	35	41	21
	52	35	24	44	32	9
	44	56	36	44	38	14
	44	32	19	35	19	6
	70	30	12	39	17	6
	35	32	19	44	29	13
	35	44	32	52	25	6
Max.	79	51	36	57	41	21
Min.	35	29	12	30	17	6
Ave.	49	39	2 3	43	32	13

Table VI (Continued)

	Diameters of Descending Limb of Henle's Loop		Diameter of Ascending Limb of Henle's Loop		Diameters of Collecting Tubules		
	Mac.	St.	Mac.	St.	Mac.	St.	Lumen
	18	22	44	19	61	38	19
	18	12	35	22	52	44	19
	14	19	26	19	52	34	13
	9	11	39	25	61	46	25
	6	14	30	17	44	32	13
	9	14	26	19	22	38	20
	12	13	35	21	35	40	19
	18	13	22	13	44	33	13
	12	16	30	21	35	44	13
	12	8	14	25	44	19	6
	12	13	26	13	44	25	9
	9	14	26	19	39	36	12
	6	13	30	17	35	44	25
	18	11	26	24	39	32	16
	9	16	30	25	39	32	13
	12	13	18	24	44	25	13
	18	8	30	25	44	38	6
	6	13	18	27	35	48	25
	9	17	26	19	52	38	19
	12	14	30	20	35	38	19
	12	10	30	17	35	44	21
	6	13	18	25	39	38	19
	12	11	22	16	44	35	19
	18	15	22	16	44	25	6
	12	15	26	27	30	40	21
Max.	18	22	44	27	61	48	25
Min.	6	8	14	13	22	19	6
Ave.	12	14	27	21	42	36	16

Table VII 9 Year Old Cow

	Renal Corpuscles		Proximal Convoluted Tubules		
	Mac.	St.	Mac.	St.	Lumen
	227	201	44	60	44
	219	201	79	51	25
	245	175	52	57	25
	192	210	61	57	32
	183	175	70	51	25
	192	210	61	51	19
	210	175	44	57	28
	236	192	87	57	19
	218	166	70	57	32
	192	166	44	63	32
	210	175	48	57	32
	201	157	7 0	49	24
	219	175	44	60	38
	201	166	70	50	19
	175	192	7 0	51	44
	210	184	52	64	-
	227	175	70	57	-
	227	157	52	70	41
	210	157	35	54	-
	183	166	52	44	15
	219	183	48	43	19
	245	157	66	43	19
	236	170	70	44	-
	184	175	52	47	-
	210	175	52	47	-
Max.	245	210	87	64	44
Min.	175	157	35	43	15
Ave.	211	174	59	54	28

Table VII (Continued)

	Diameters of Distal Convoluted Tubules			Diameters of Terminal Portions of Prox. Convol. Tubules		
	Mac.	St.	Lumen	Mac.	St.	Lumen
	35	32	19	22	36	17
	44	44	32	26	25	8
	52	57	25	44	33	12
	61	57	36	35	40	19
	61	51	30	52	32	13
	44	56	32	35	44	19
	52	51	38	44	40	19
	52	60	44	44	32	13
	44	48	29	52	25	-
	44	63	44	44	43	17
	52	45	32	39	49	25
	35	51	39	39	44	17
	52	56	38	44	44	25
	35	65	44	52	54	25
	44	32	19	44	43	19
	35	57	35	61	25	12
	44	35	25	35	35	19
	70	57	28	52	32	12
	61	38	21	35	24	8
	44	38	19	48	32	13
	35	56	32	52	38	19
	44	32	13	52	32	-
	44	48	29	44	38	22
	35	46	25	44	35	19
	52	57	41	35	44	32
Max.	70	60	44	52	54	32
Min.	35	32	19	22	25	8
Ave.	47	49	31	47	37	18

	Diameters of Descending Limb of Henle's Loop		Diameter of Ascending Limb of Henle's Loop		Diameters of Collecting Tubules		
	Mac.	St.	Mac.	St.	Mac.	St.	Lumen
	26	19	26	17	87	44	19
	18	19	22	25	35	38	19
	18	22	18	19	44	25	9
	8	24	52	21	35	44	24
	12	19	26	25	52	38	19
	12	17	35	17	48	44	16
	22	11	44	19	35	32	13
	18	14	22	17	35	19	6
	8	11	26	19	44	25	13
	22	19	26	17	22	27	13
	8	14	26	11	30	32	14
	18	14	22	22	70	25	17
	18	14	26	17	78	32	13
	12	13	26	24	48	44	25
	15	17	22	19	35	38	16
	12	19	30	19	39	36	10
	22	13	30	14	26	54	25
	18	13	26	19	22	38	10
	12	17	26	19	18	38	13
	8	19	18	17	39	44	13
	8	13	22	17	30	38	10
	12	22	30	25	26	44	25
	18	17	18	22	30	38	16
	8	19	30	23	61	40	19
	6	16	35	22	44	49	32
Max.	26	24	52	25	87	49	32
Min.	6	11	18	11	18	19	6
Ave.	14	17	27	19	41	37	16

Table VIII

Comparison of the weights and the number of lobes of the kidneys according to age.

Age	Weights (in gms.)		Lobes	
	Right Kidney	Left Kidney	Right Kidney	Left Kidney
Fetus, 9 months	52	57	32	31
1 month	153	157	-	-
1 "	137	140	22	22
1¼ "	157	145	24	19
1½ "	141	152	18	18
1½ "	194	182	29	30
2½ "	107	106	22	23
3 "	122	122	27	24
4 "	195	202	20	20
6½ "	314	27 0	-	-
11 "	393	412	24	24
11 "	314	332	21	24
11 "	360	340	27	31
1 year	345	357	24	27
1 "	304	324	25	32
2 "	252	236	27	28
2 "	250	276	27	26
1½ "	456	444	26	21
2 "	418	385	24	24
2 "	406	385	20	20
2 "	251	268	16	16
7 "	548	640	-	-
9 "	535	550	19	19

Table IX

Comparative depths of the Cortex and Medulla according to Age

Age	Cortex and Medulla	Cortex
Fetus, 9 months	14 - 19 mm.	3 - 6 mm.
11 months	20 - 25 mm.	8 - 10 mm.
11 "	25 - 29 mm.	7 - 10 mm.
11 "	30 - 35 mm.	10 - 11 mm.
12 "	24 - 29 mm.	7 - 12 mm.
12 "	22 - 30 mm.	9 - 12 mm.
12 "	19 - 23 mm.	6 - 9 mm.
2 years	25 - 33 mm.	8 - 10 mm.
2 "	21 - 28 mm.	9 - 12 mm.
2 "	25 - 31 mm.	9 - 11 mm.
7 "	24 - 32 mm.	9 - 12 mm.
9 "	29 - 31 mm.	11 - 12 mm.

Table X

Comparison of the afferent and efferent glomerular blood vessels. Measurements of diameters taken in microns.

	Afferent	Efferent
	24	15
	15	15
	21	18
	18	14
	23	18
	21	12
	19	12
	19	14
	21	12
	24	15
	24	12
	24	15
	19	12
	25	12
	18	15
	16	12
	18	
	30	
	30	
	30	
	36	
	32	
	24	
	36	
	30	
Max.	36	18
Min.	15	12
Ave.	24	14

Fig. 1. Photograph of right and left kidney of six weeks old calf. Note the lobated condition.

Fig. 1. Photograph of right and left kidney of six weeks old calf. Note the lobated condition.

Fig. 1

Fig. 2 Photograph of the right kidney of four months old calf.

Fig. 2 Photograph of the right kidney of four months old calf.

Fig. 2

Fig. 3. Macerated specimen showing some of the blood vessels. A. Glomerulus. B. Afferent arteriole. C. Interlobular artery. (X145)

Fig. 4. Macerated specimen showing glomerulus with a portion of its proximal convoluted tubule. A. Glomerulus. B. Proximal convoluted tubule. C. Afferent arteriole. (X130)

Fig. 3. Macerated specimen showing some of the blood vessels. A. Glomerulus. B. Afferent arteriole. C. Interlobular artery. (X145)

Fig. 4. Macerated specimen showing glomerulus with a portion of its proximal convoluted tubule. A. Glomerulus. B. Proximal convoluted tubule. C. Afferent arteriole. (X130)

Fig. 3

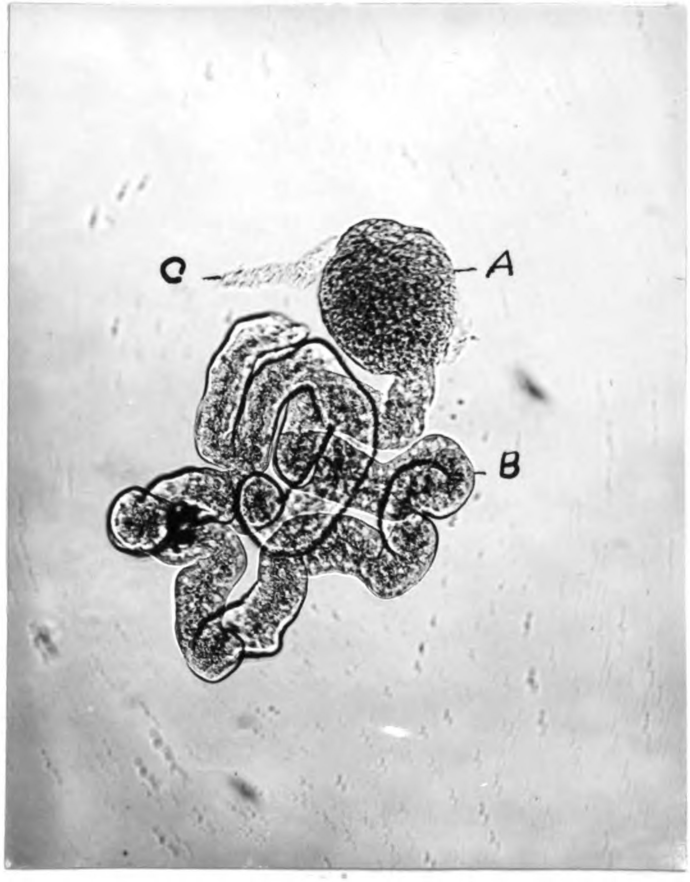

Fig. 4

Fig. 5. Macerated specimen showing the glomerulus, A. and a portion of the proximal convoluted tubule, B. (X90)

Fig. 6. Same specimen as Fig. 5. Note the difference in granularity at A and B. (X145)

Fig. 5. Macerated specimen showing the glomerulus, A. and a portion of the proximal convoluted tubule, B. (X90)

Fig. 6. Same specimen as fig. 5. Note the difference in granularity at A and B. (X145)

Fig. 5

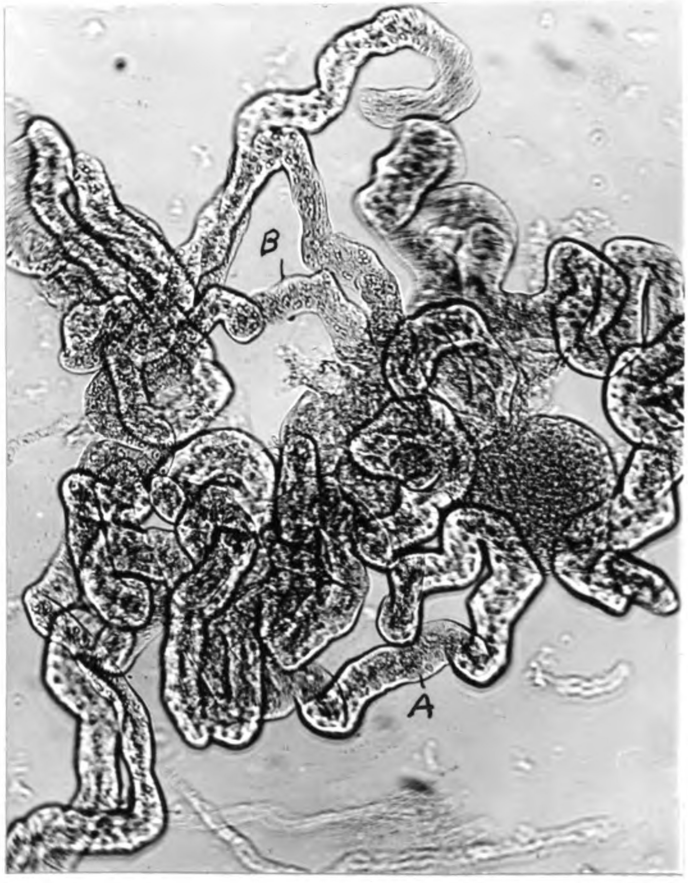

Fig. 6

Fig. 7. Injected specimen showing small part of the nephron. A. Glomerulus. B. Proximal convoluted tubule. C. Ascending limb of Henle's loop. D. Distal convoluted tubule. (X150)

Fig. 8. Injected specimen showing small part of the nephron and collecting tubule. A. Ascending limb of Henle's loop. B. Glomerulus. C. Distal convoluted tubule. D. Connecting portion of collecting tubule. (X150)

Fig. 7. Macerated specimen showing small part of the nephron. A. Glomerulus. B. Proximal convoluted tubule. C. Ascending limb of Henle's loop. D. Distal convoluted tubule. (X125)

Fig. 8. Macerated specimen showing small part of the nephron and collecting tubule. A. Ascending limb of Henle's loop. B. Glomerulus. C. Distal convoluted tubule. D. Connecting portion of collecting tubule. (X135)

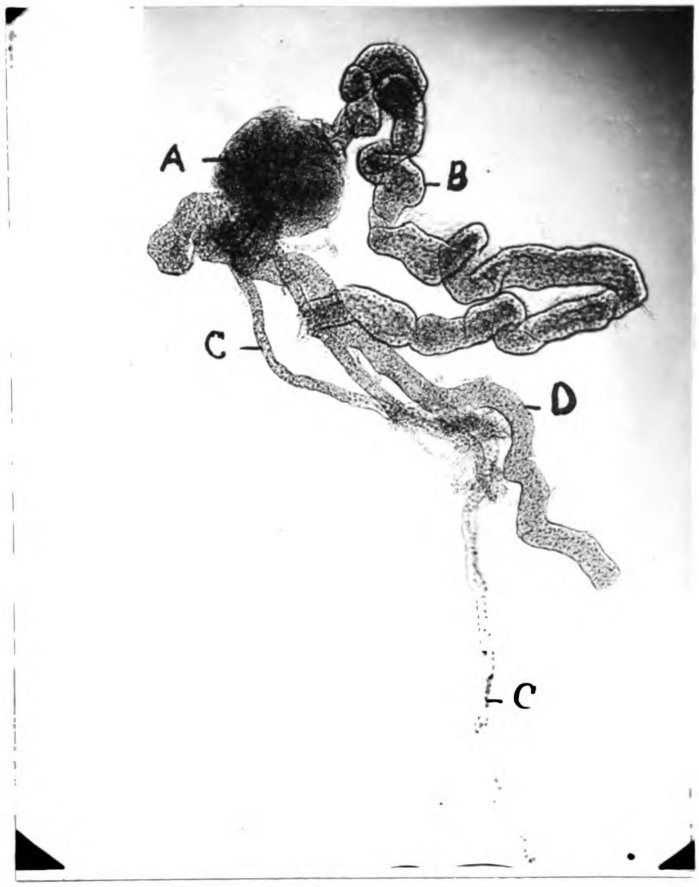

Fig. 7

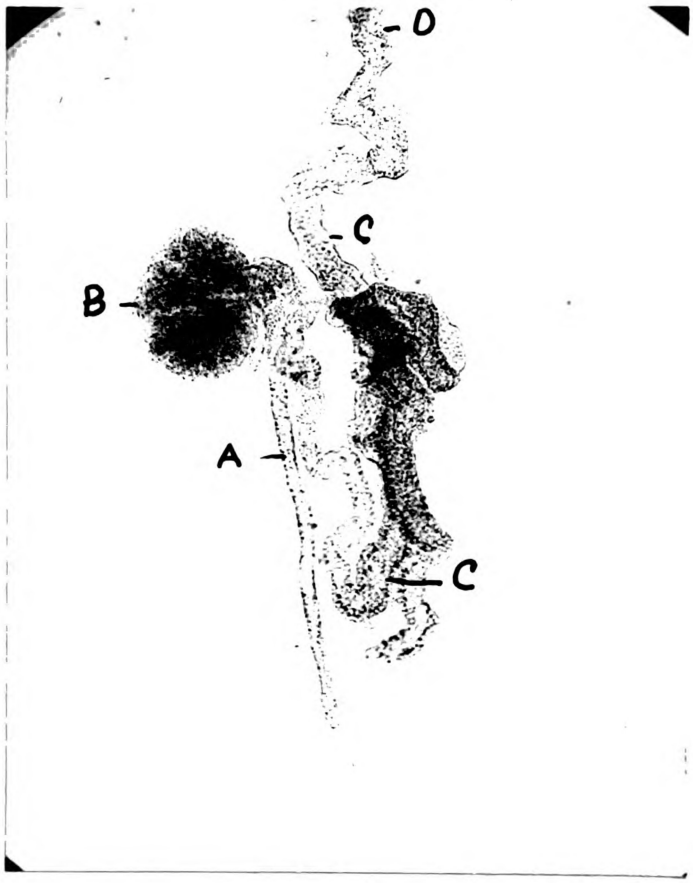

Fig. 8

Fig. 4. Suggested specimen showing small part of the proximal convoluted tubule. (X25)

A. Glomerulus. B. Proximal convoluted tubule. C. Part of the terminal portion of the

Fig. 9. Macerated specimen showing small part of the nephron. A. Glomerulus. B. Proximal convoluted tubule. C. Part of the terminal portion of the proximal convoluted tubule. (X98)

Fig. 9

Fig. 10. Macerated specimen showing the abrupt change of the terminal portion of the proximal convoluted tubule into the descending limb of Henle's loop. A. Terminal portion of proximal convoluted tubule. B. Descending limb of the loop. (XIOI)

Fig. 11. Macerated specimen showing similar portions as Fig. 10. (XIOI)

Fig. 10. Macerated specimen showing the abrupt change of the terminal portion of the proximal convoluted tubule into the descending limb of Henle's loop. A. Terminal portion of proximal convoluted tubule. B. Descending limb of the loop. (X101)

Fig. 11. Macerated specimen showing similar portions as fig. 10. (X101)

Fig. 10

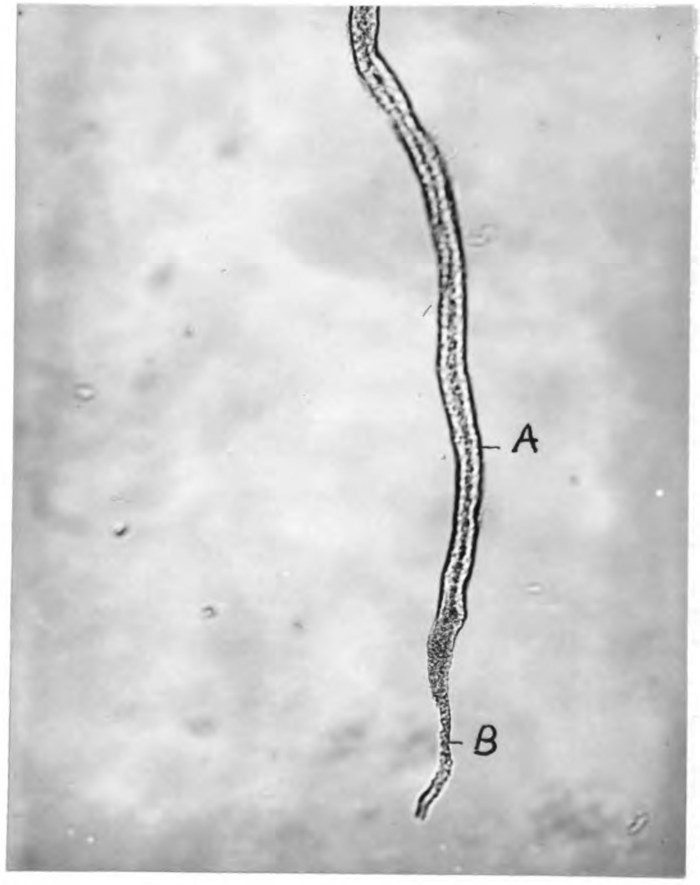

Fig. 11

Fig. 12. Macerated specimen showing descending limb of a long loop of Henle. (X101)

Fig. 13. Macerated specimen showing part of the descending and ascending limb of the loop of Henle. A. Descending limb. B. Ascending limb. (X101)

Fig. 12. Macerated specimen showing descending limb of a long loop of Henle. (X101)

Fig. 13. Macerated specimen showing part of the descending and ascending limb of the loop of Henle. A. Descending limb. B. Ascending limb. (X101)

Fig. 12

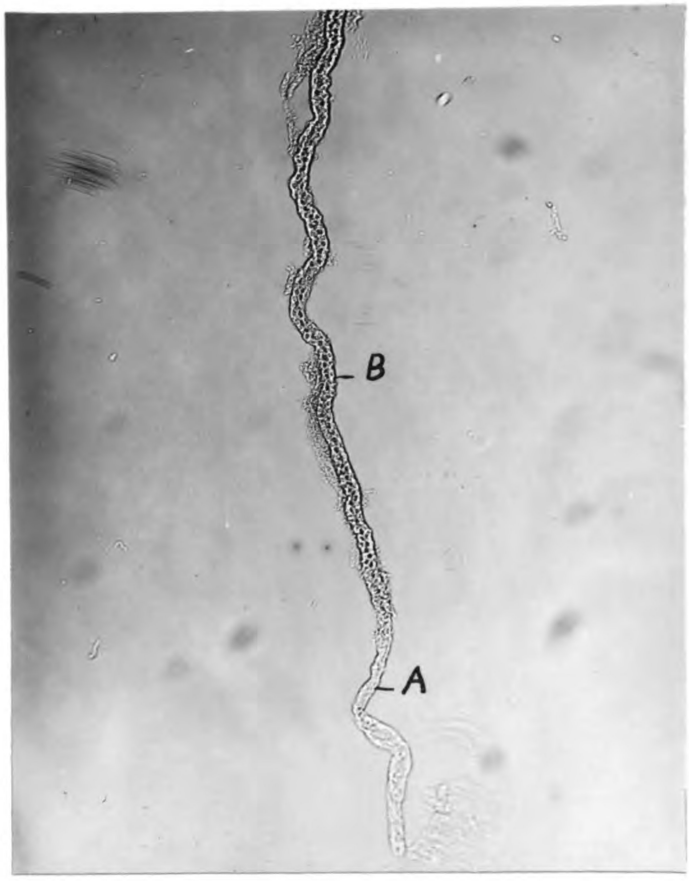

Fig. 13

Fig. 14. Macerated specimen showing a branching collecting tubule. (X146)

Fig. 15. Parallin section of cortex. A. Glomerulus. B. Medullary ray. C. Labyrinth. (X15)

Fig. 14. Macerated specimen showing a branching collecting tubule. (X146)

Fig. 15. Paraffin section of cortex. A. Glomerulus. B. Medullary ray. C. Labyrinth. (X85)

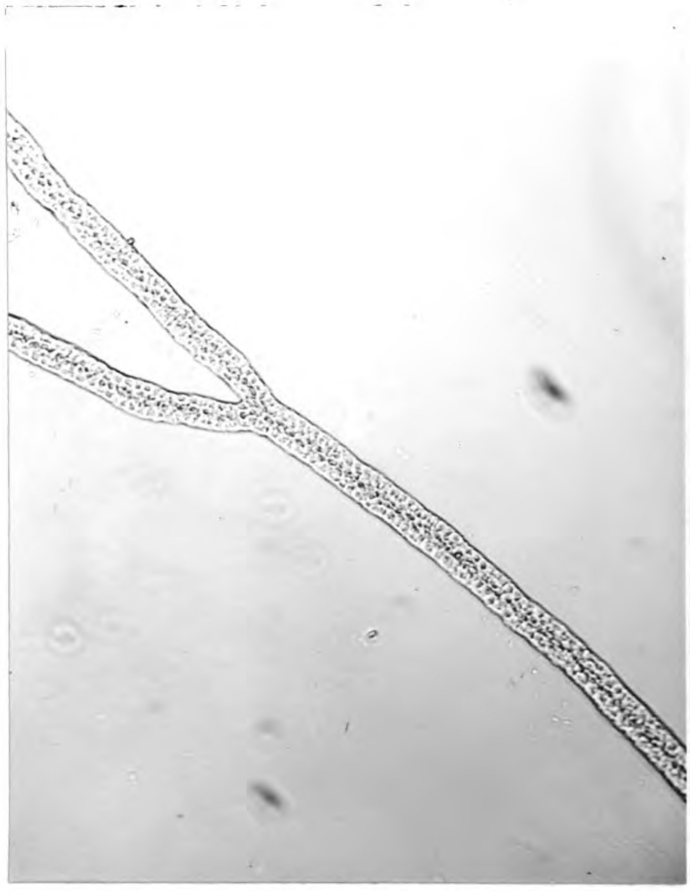

Fig. 14

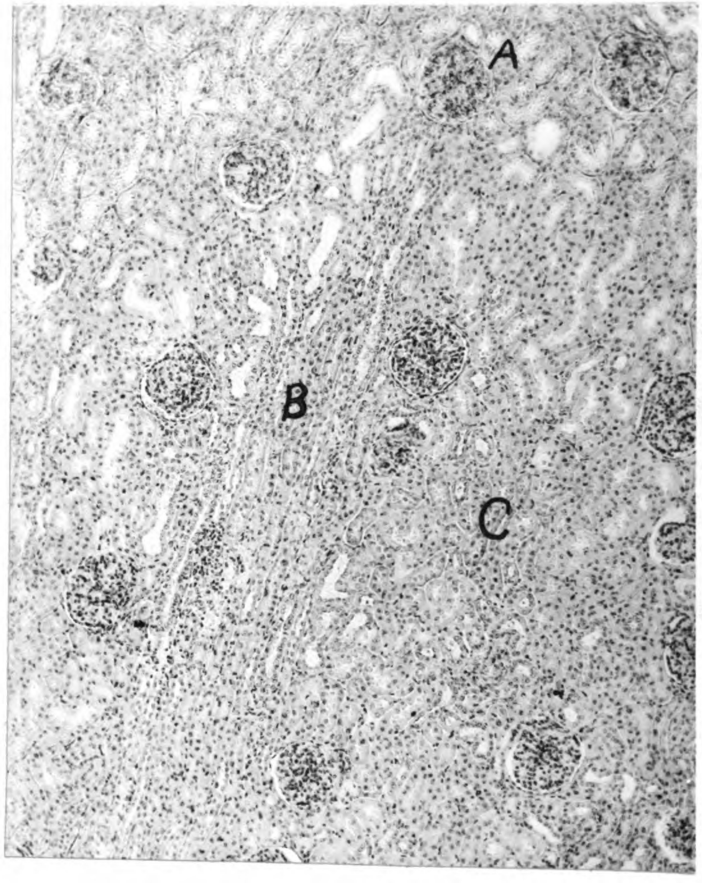

Fig. 15

Fig. 16. Paraffin section of glomerulus. A. Visceral glomerular epithelial cell. B. Endothelial cell. (X820)

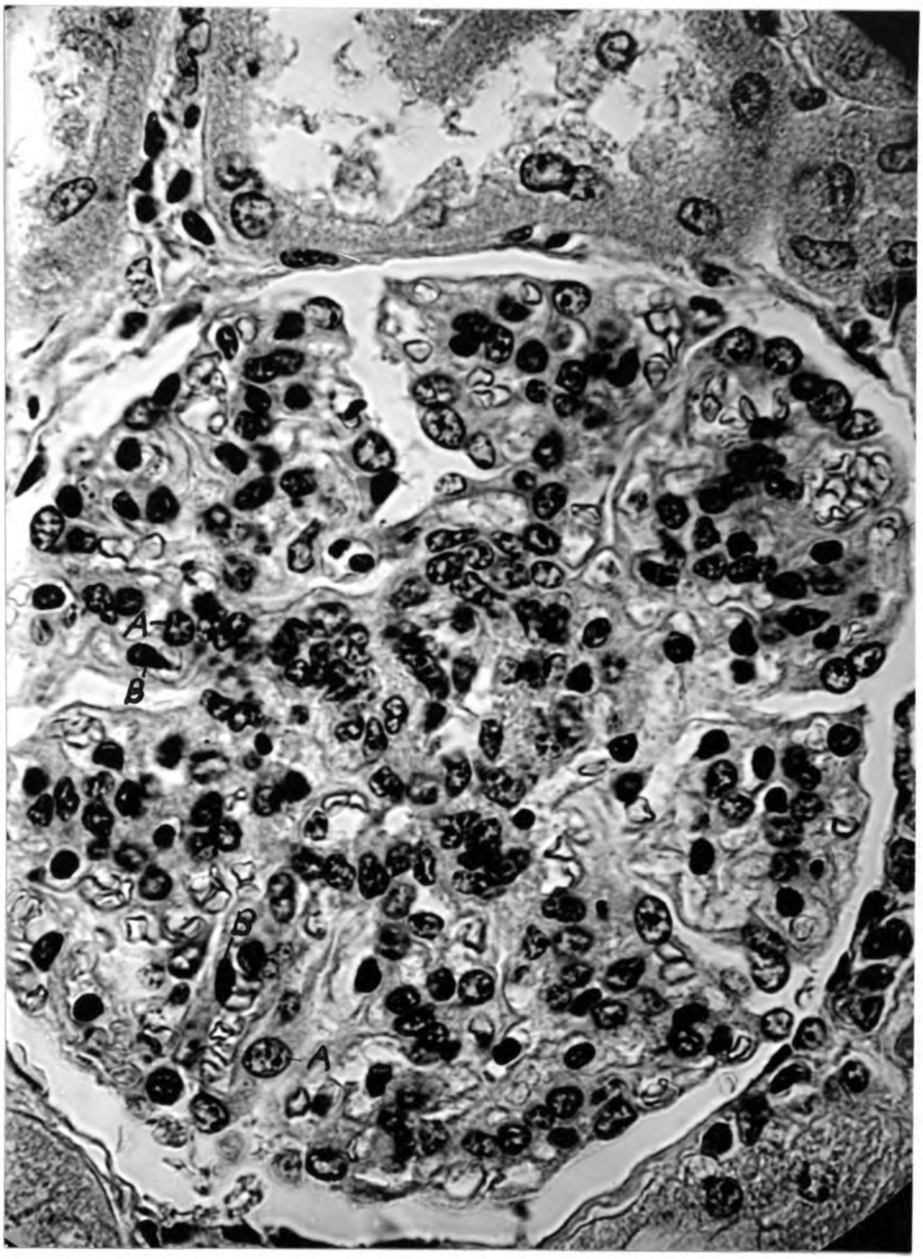

Fig. 16

Fig. 14. Transverse section of glomerulus. A. Visceral glomerular epithelial cell. B. Endothelial cell. (X870)

Fig. 17. Paraffin section of glomerulus. A. Visceral glomerular epithelial cell. B. Endothelial cell. (X870)

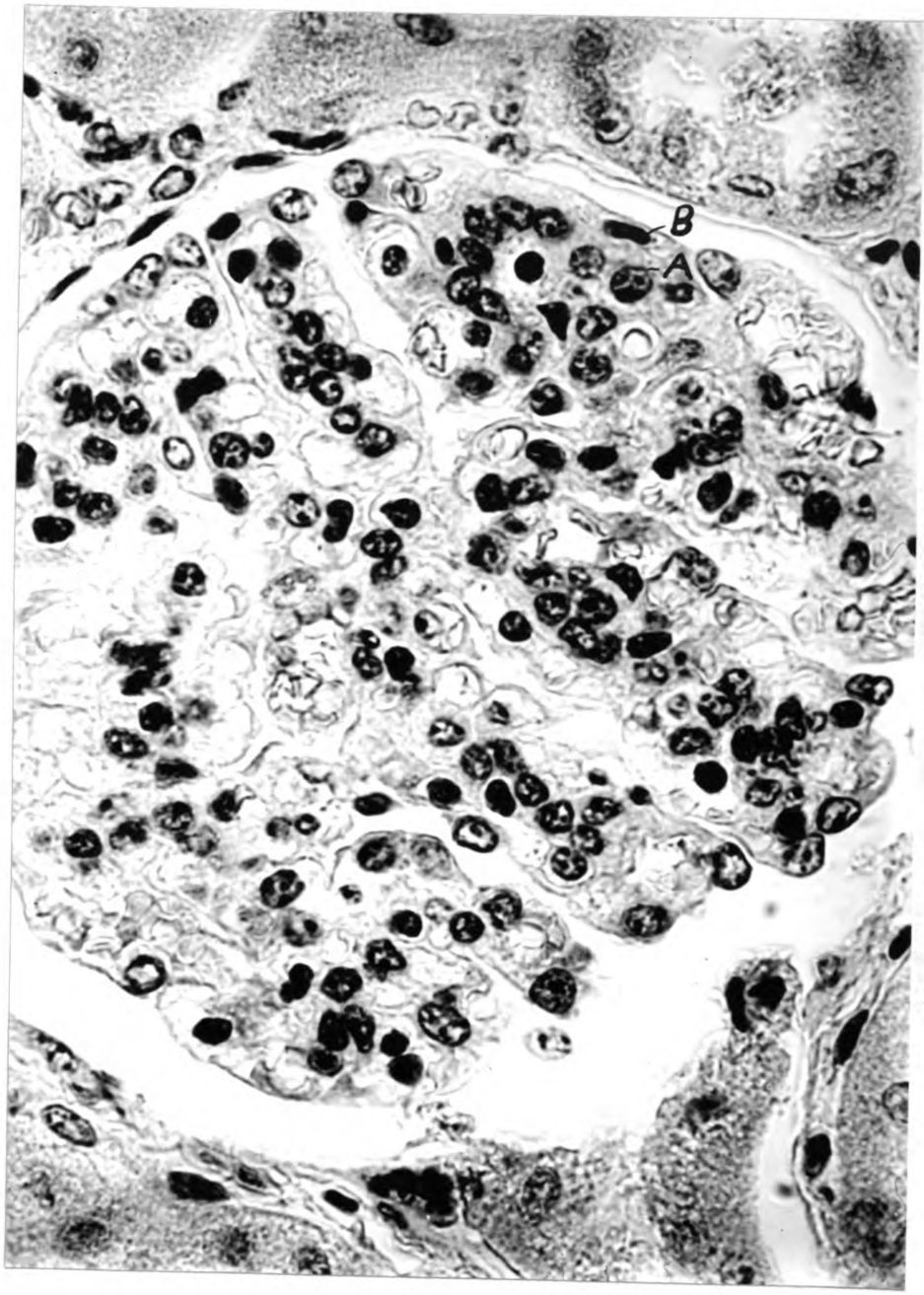

Fig. 17

Fig. 10. Longitudinal section showing filaments and rack
of proximal convoluted tubule. M. filaments.
P. Rack of proximal convoluted tubule. C.
Basal border. (X500)

Fig. 18. Paraffin section showing glomerulus and neck of proximal convoluted tubule. A. Glomerulus. B. Neck of proximal convoluted tubule. C. Brush border. (X830)

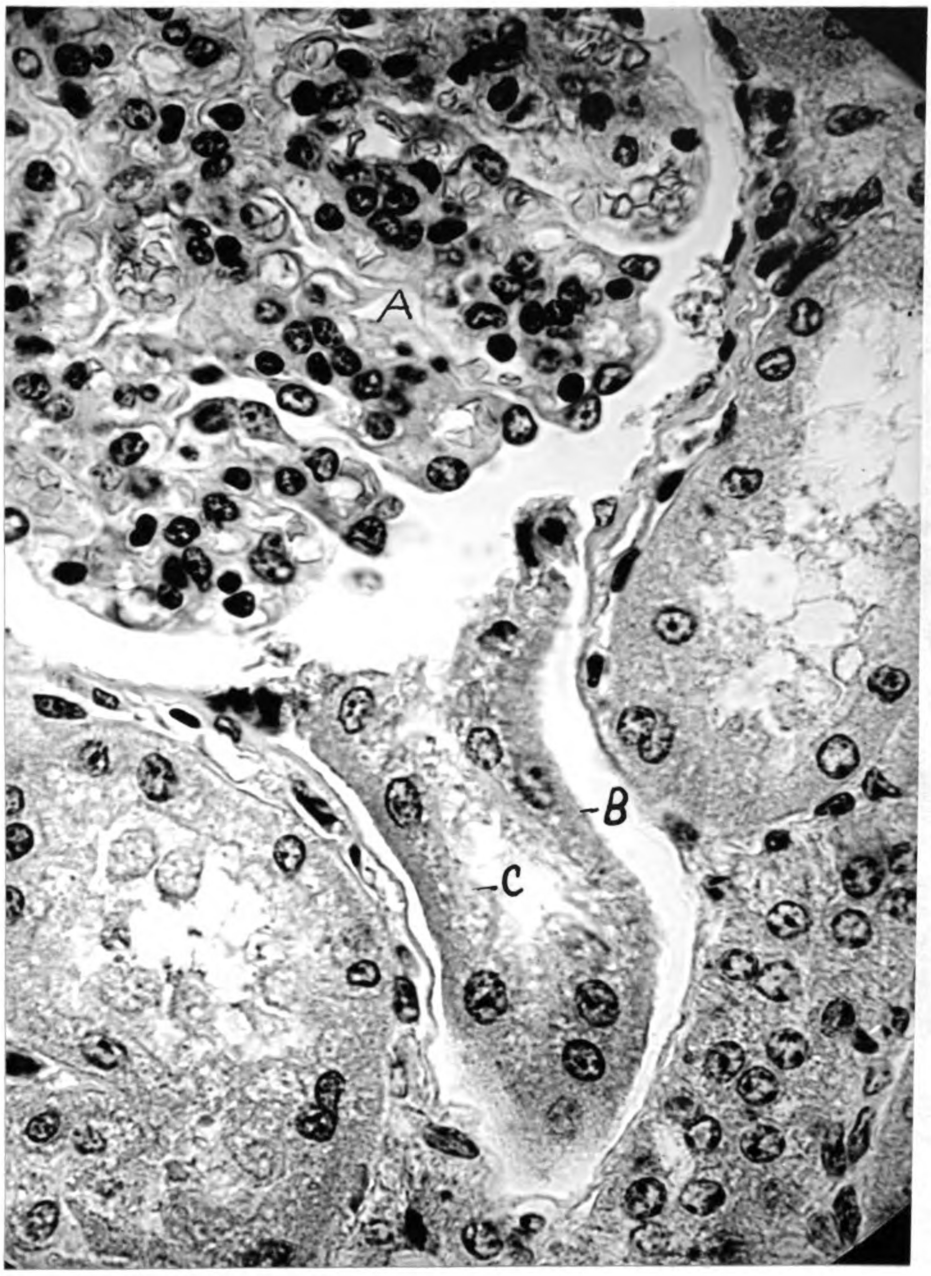

Fig. 18

Fig. 19. Parietin section showing several proximal convoluted tubules. N. Brush border of parenchymatous cell. (X863)

Fig. 19. Paraffin section showing several proximal convoluted tubules. A. Brush border of parenchymatous cell. (X823)

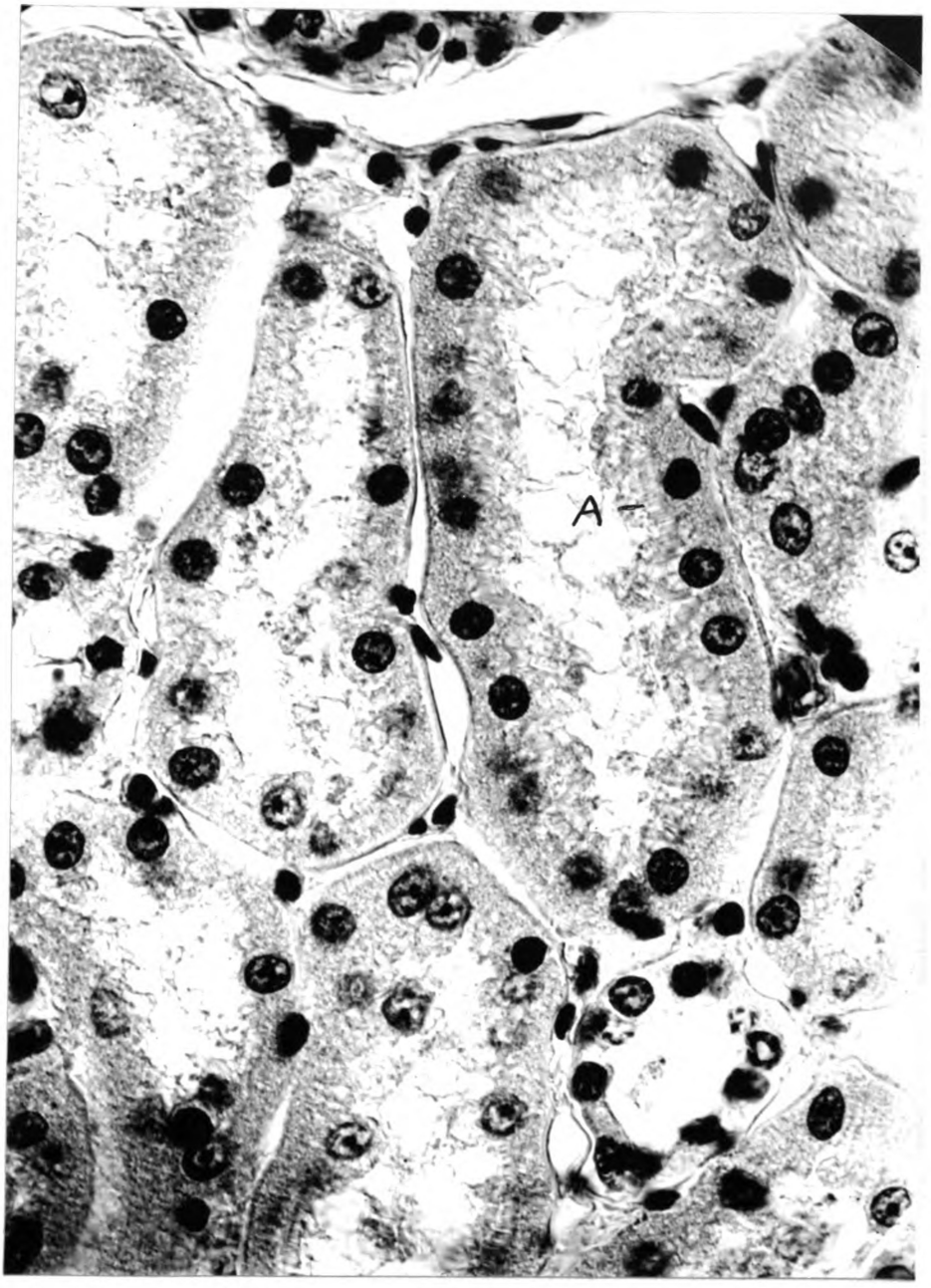

Fig. 19

Fig. 10. Intestine section showing proximal convoluted tubule, M; distal convoluted tubule, B. (X272)

Fig. 20. Paraffin section showing proximal convoluted tubule, A; distal convoluted tubule, B. (X875)

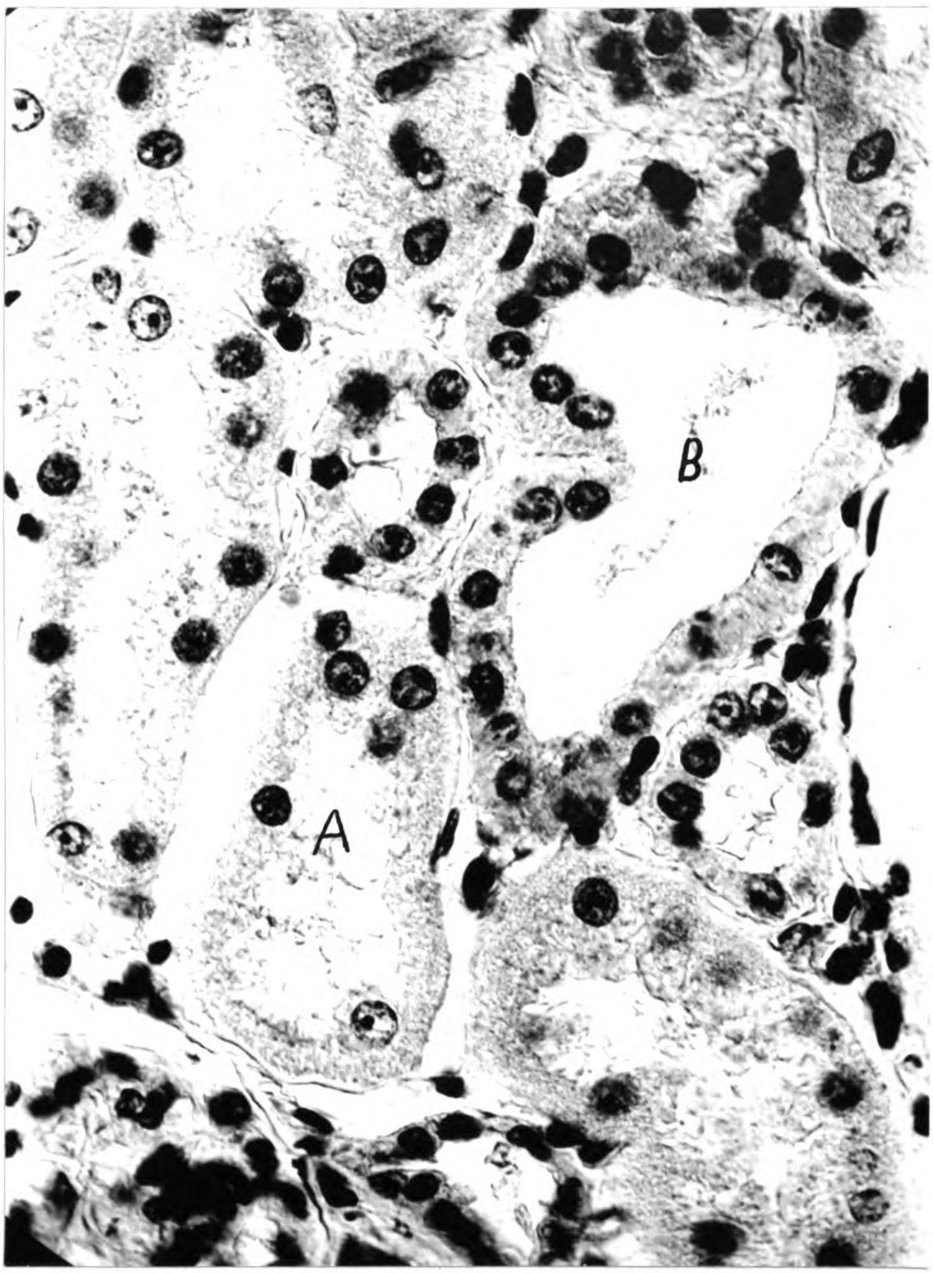

Fig. 20

Fig. 21. Torsion section through corner. a. stiffening
corner. b. first convoluted nipple. c.
second convoluted nipple. d. inner
convoluted cupple. e. diaphragm. (1940)

Fig. 21. Paraffin section through cortex. A. collecting tubule. B. Distal convoluted tubule. C. Ascending limb of Henle's loop. D. Proximal convoluted tubule. E. Glomerulus. (X810)

Fig. 21

Fig. 20. Interlobular section through medullary ray. a. Capillary abutting endothelial cell. b. Ascending limb of Henle's loop. c. Straight terminal portion of the proximal convoluted tubule. (X850)

Fig. 22. Paraffin section through medullary ray. A. Capillary showing endothelial cell. B. Ascending limb of Henle's loop. C. Straight terminal portion of the proximal convoluted tubule. (X820)

Fig. 22

Fig. 23. Paraffin section through medullary ray. A. Ascending limb of Henle's loop. B. Terminal portion of the proximal convoluted tubule. (X290)

Fig. 24. Paraffin section showing division between cortex and outer medulla. A. Glomerulus. B. Terminal portion of the proximal convoluted tubule. C. Interlobular artery. (X149)

Fig. 23. Paraffin section through medullary ray. A. Ascending limb of Henle's loop. B. Terminal portion of the proximal convoluted tubule. (X790)

Fig. 24. Paraffin section showing division between cortex and outer medulla. A. Glomerulus. B. Terminal portion of the proximal convoluted tubule. C. Interlobular artery. (X149)

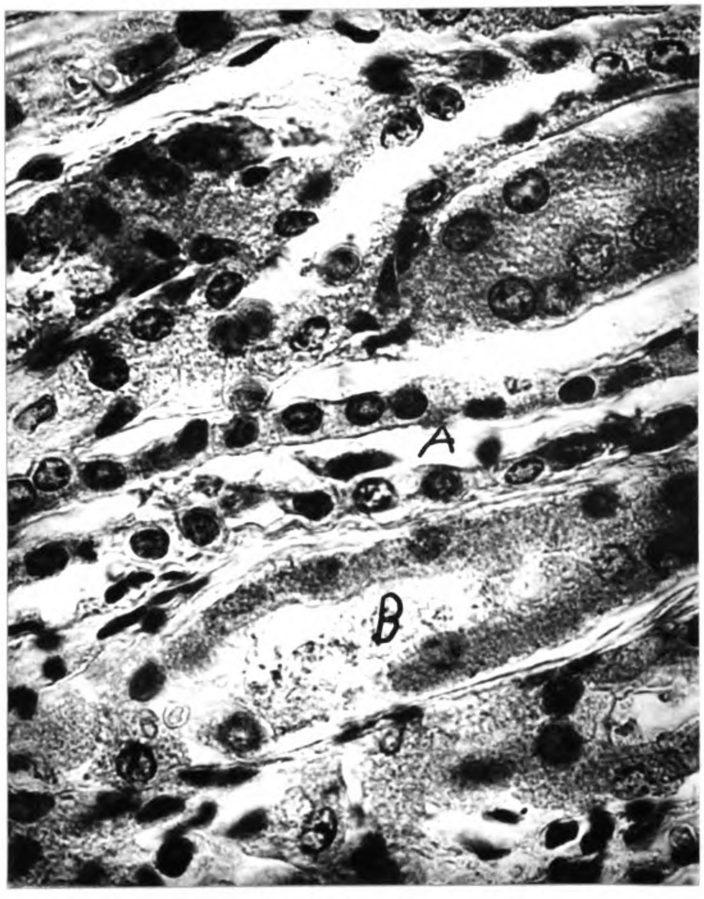

Fig. 23

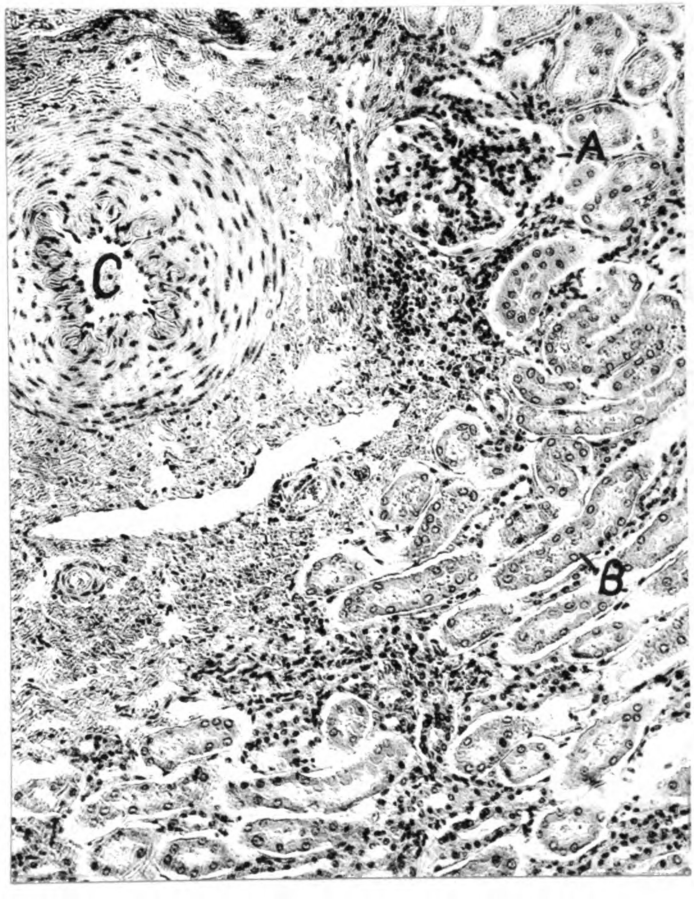

Fig. 24

Fig. 25. Paraffin section of outer medulla. A. Terminal portions of the proximal convoluted tubules. (X86)

Fig. 26. Paraffin section of outer medulla. A. Bundle of capillaries. B. Terminal portions of the proximal convoluted tubules. C. Ascending limb of Henle's loop. D. Collecting tubule. (X69)

Fig. 25. Paraffin section of outer medulla. A. Terminal portions of the proximal convoluted tubules. (X86)

Fig. 26. Paraffin section of outer medulla. A. Bundle of capillaries. B. Terminal portions of the proximal convoluted tubules. C. Ascending limb of Henle's loop. D. Collecting tubule. (X169)

Fig. 25

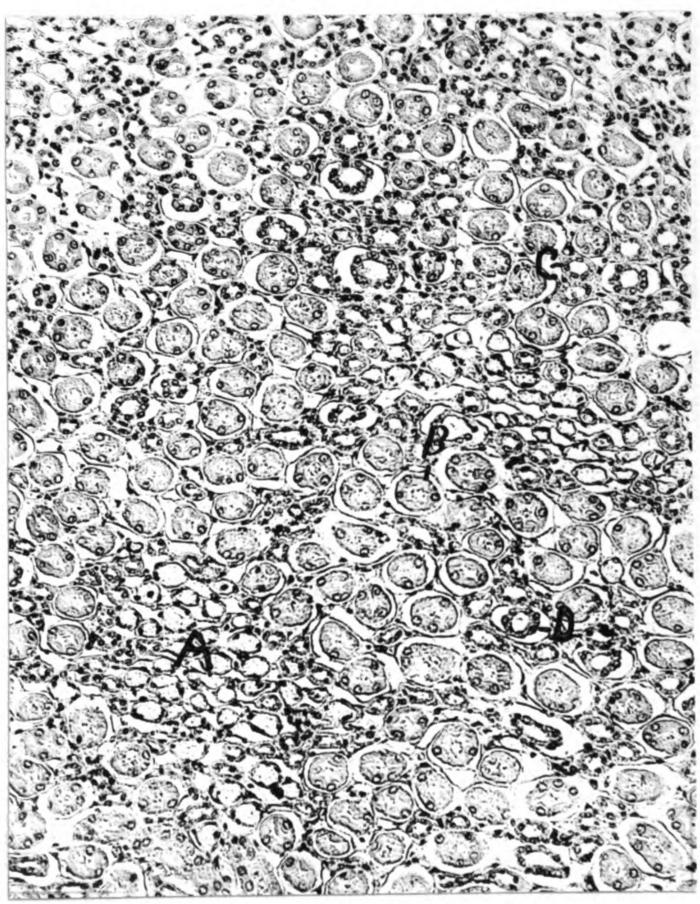

Fig. 26

Fig. 27. Higher magnification of fig. 26. A. Terminal portion of proximal convoluted tubule. B. Ascending limb of Henle's loop. C. Collecting tubule. (X870)

Fig. 28. Higher magnification of fig. 26 showing bundle of capillaries. (X870)

Fig. 27. Higher magnification of fig. 26. A. Terminal portion of proximal convoluted tubule. B. Ascending limb of Henle's loop. C. Collecting tubule. (X870)

Fig. 28. Higher magnification of fig. 26 showing bundle of capillaries. (X870)

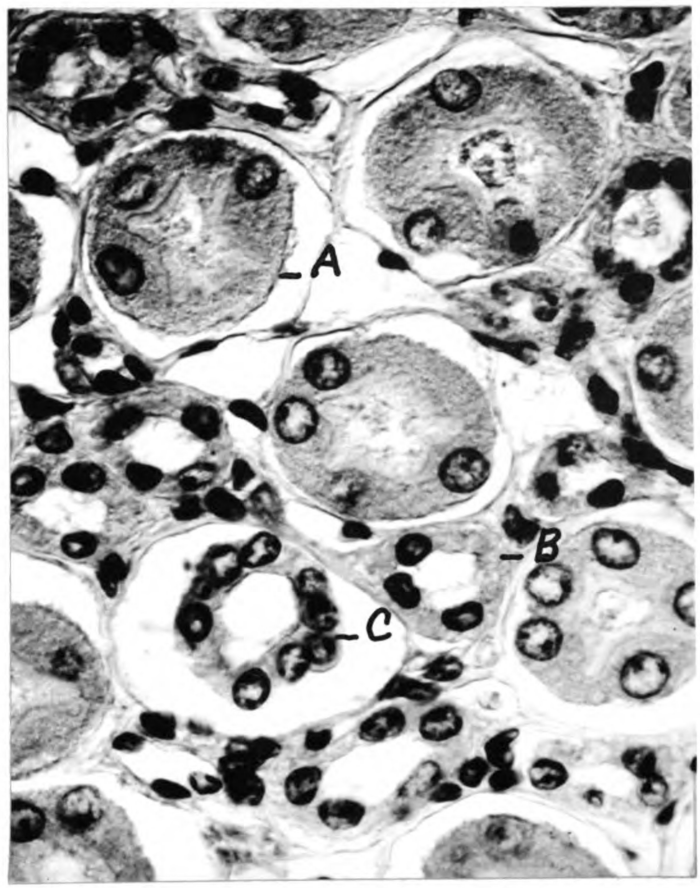

Fig. 27

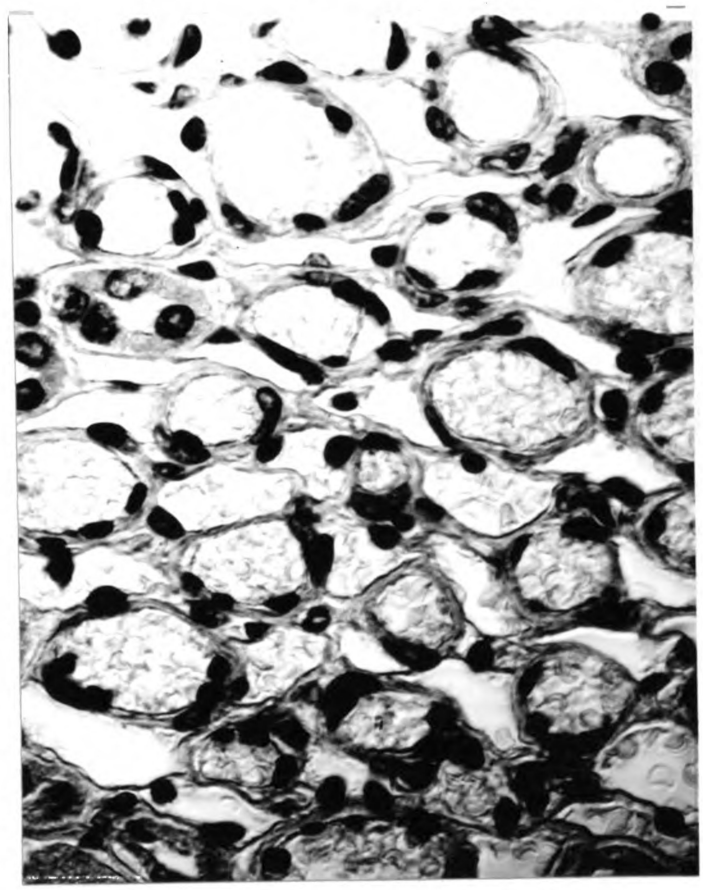

Fig. 28

Fig. 10. Tangential section of inner medulla. A.
Collecting tubule. B. Ascending limb of Henle's loop.
Capillary. (X750)

Fig. 11. Tangential section of inner medulla. A.
Collecting tubule. B. Ascending limb of Henle's loop.

Fig. 29. Paraffin section of inner medulla. A. Descending limb of Henle's loop. B. Capillary. (X769)

Fig. 30. Paraffin section of inner medulla. A. Collecting tubule. B. Branching of collecting tubule. (X160)

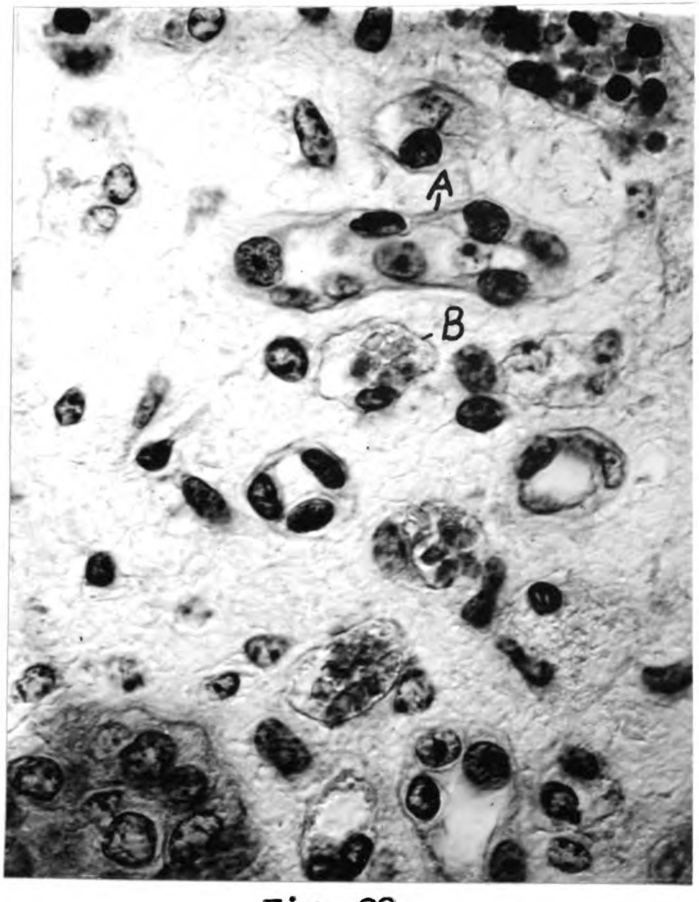

Fig. 29

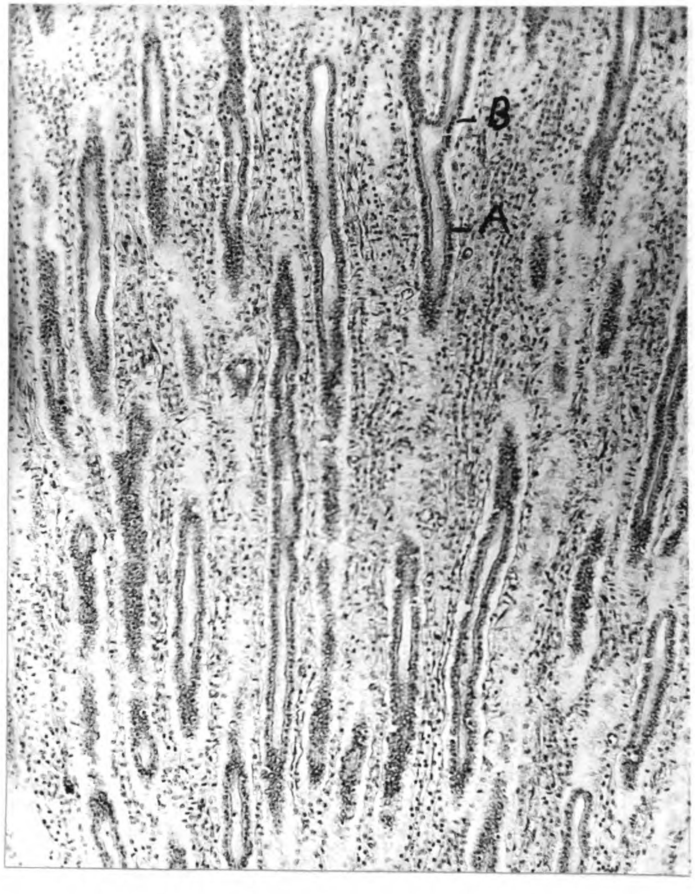

Fig. 30

Fig. 31. Paraffin section of inner medulla. A. Collecting tubules fusing to form duct of Bellini. B. Duct of Bellini. (X160)

Fig. 32. Paraffin section of collecting tubule. (X1030)

Fig. 31. Paraffin section of inner medulla. A. Collecting tubules fusing to form duct of Bellini. B. Duct of Bellini. (X160)

Fig. 32. Paraffin section of collecting tubule. (X1030)

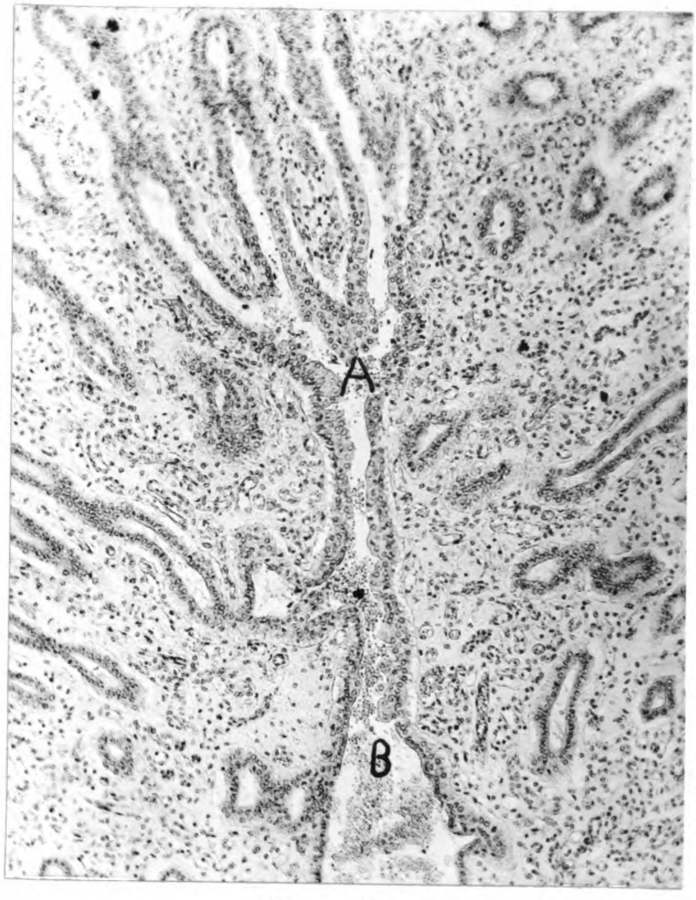

Fig. 31

Fig. 32

Fig. 33. Paraffin section showing collecting tubule.
(X200)

Fig. 34. Paraffin section of inner medulla. A.
Collecting tubule. B. Epithelium of
papilla. (X160)

Fig. 33. Paraffin section showing collecting tubule. (X200)

Fig. 34. Paraffin section of inner medulla. A. Collecting tubule. B. Epithelium of papilla. (X160)

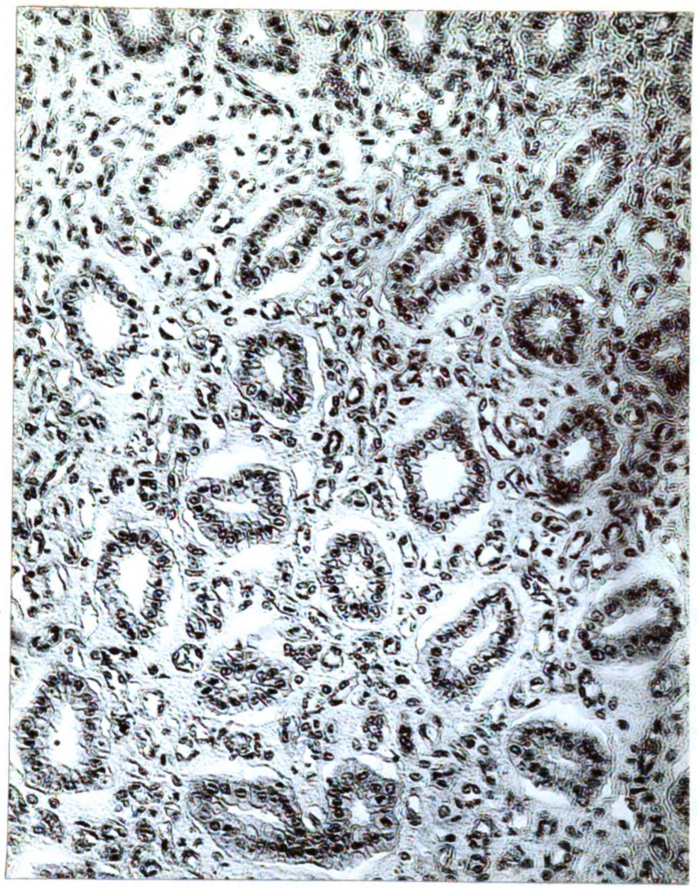

Fig. 33

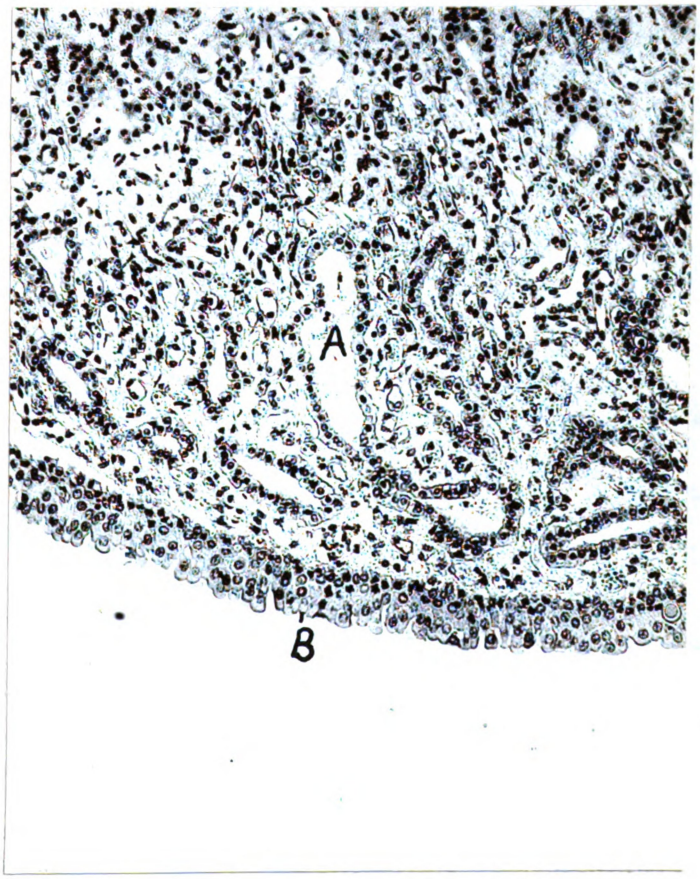

Fig. 34

Fig. 35. Paraffin section showing pathological conditions of cortex. A. Renal corpuscle showing a marked thickening of Bowman's capsule with connective tissue and a hyaline-like substance. B. Group of lymphocytes and mononuclear phagocytes. C. Tubule nearly obliterated by hyaline-like substance. (X140)

Fig. 36. Paraffin section showing a glomerulus nearly obliterated by hyaline-like substance. (X180)

Fig. 35. Paraffin section showing pathological conditions of cortex. A. Renal corpuscle showing a marked thickening of Bowman's capsule with connective tissue and a hyaline-like substance. B. Group of lymphocytes and mononuclear phagocytes. C. Tubule nearly obliterated by hyaline-like substance. (X140)

Fig. 36. Paraffin section showing a glomerulus nearly obliterated by hyaline-like substance. (X180)

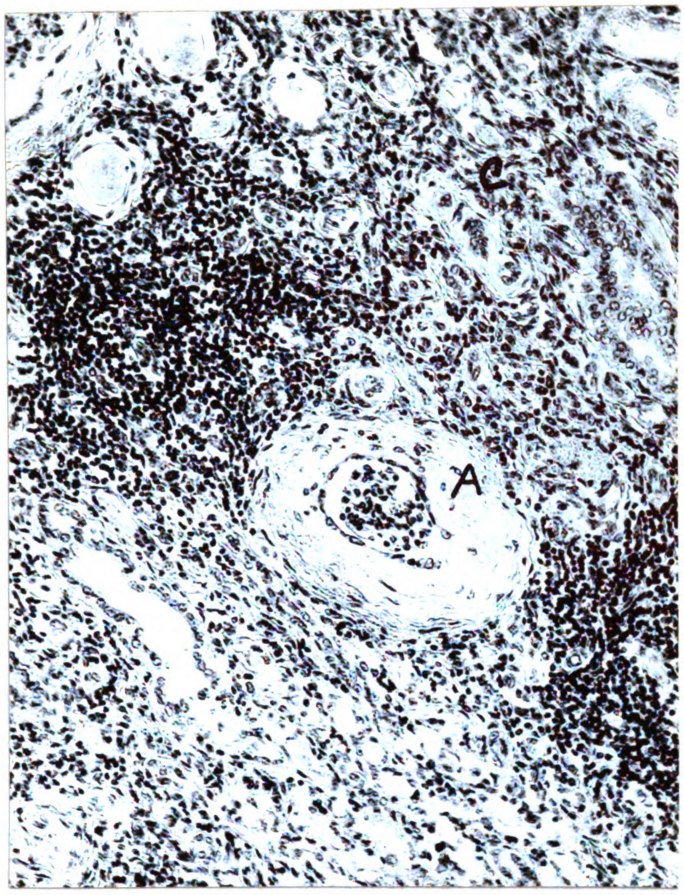

Fig. 35

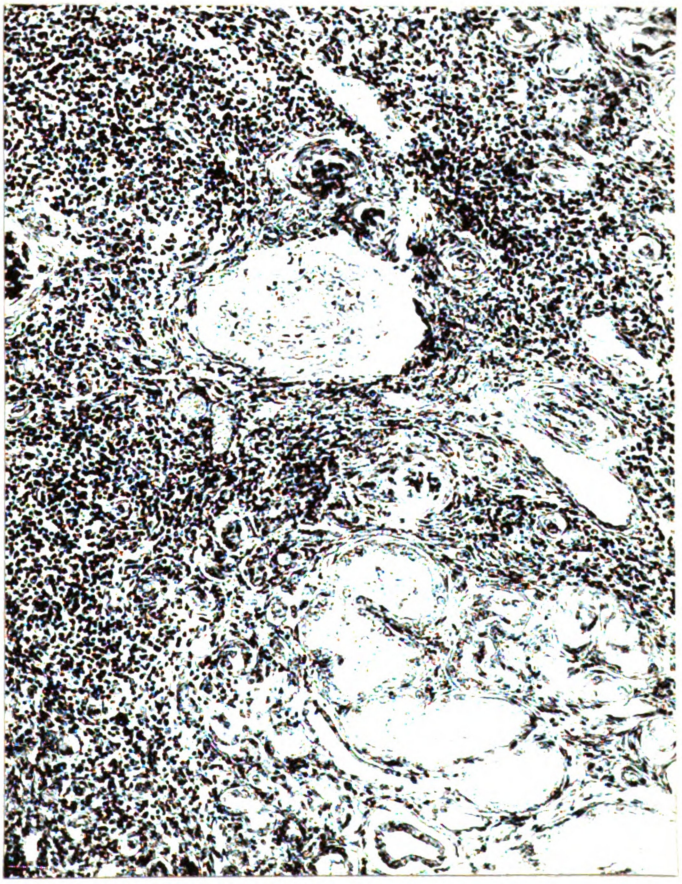

Fig. 36

Fig. 37. The same glomerulus shown in Fig. 36, but
of a greater magnification. (X866)

Fig. 37. The same glomerulus shown in fig. 36, but of a greater magnification. (X866)

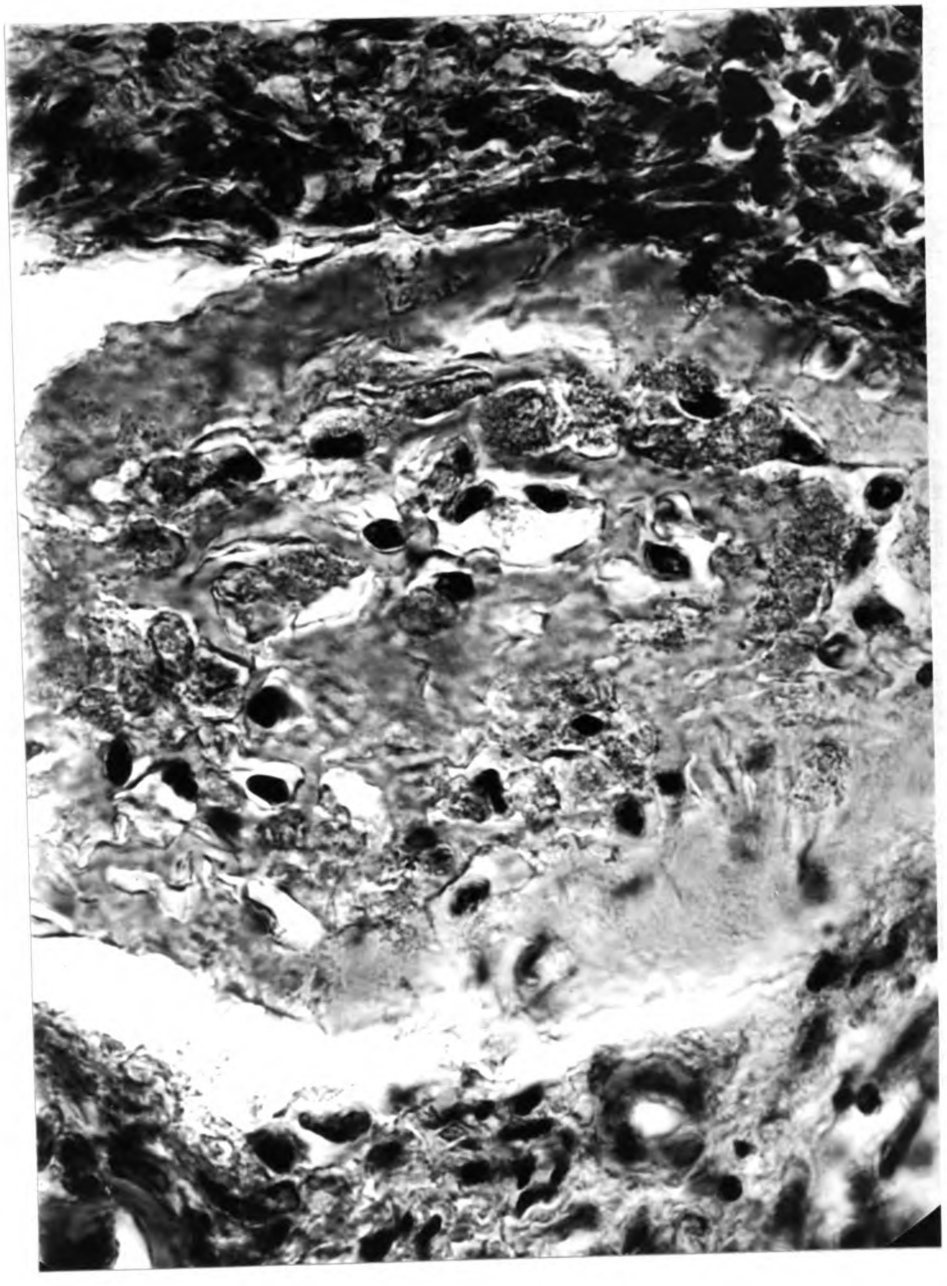

Fig. 37

Fig. 38. Paraffin section showing the concentric rings of collagenous tissue around the atrophic tubules. (X175)

Fig. 39. Paraffin section showing a large patch of lymphocytes and mononuclear phagocytes in the cortex.

(X140)

Fig. 38. Paraffin section showing the concentric rings of collagenous tissue around the atrophic tubules. (X175)

Fig. 39. Paraffin section showing a large patch of lymphocytes and mononuclear phagocytes in the cortex. (X140)

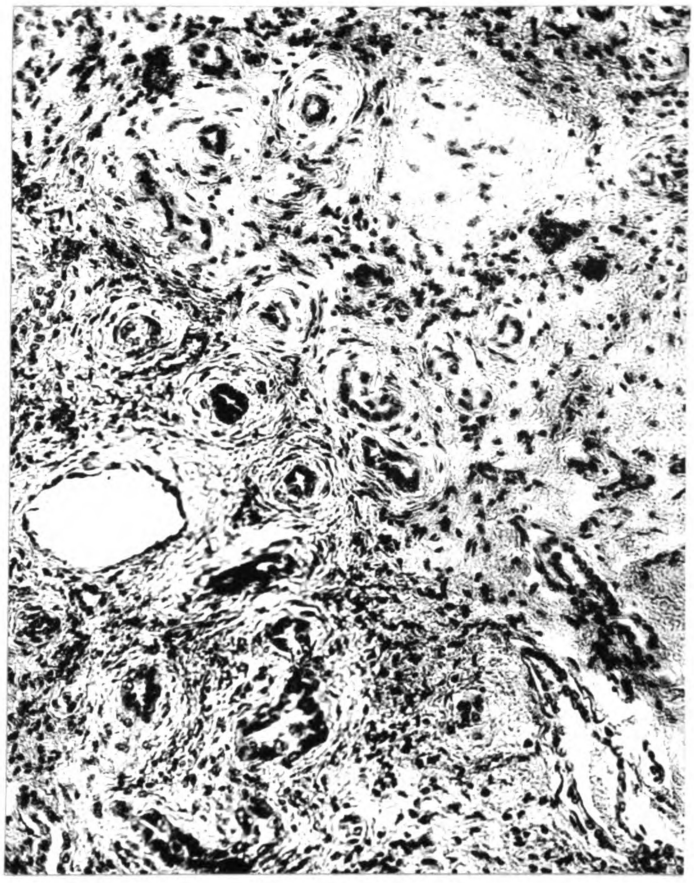

Fig. 38

Fig. 39

Fig. 40. Paraffin section showing a cast. (X150)

Fig. 41. Paraffin section showing dilatended tubules with low epithelium. (X150)

Fig. 40. Paraffin section showing a cast. (X150)

Fig. 41. Paraffin section showing distended tubules with low epithelium. (X169)

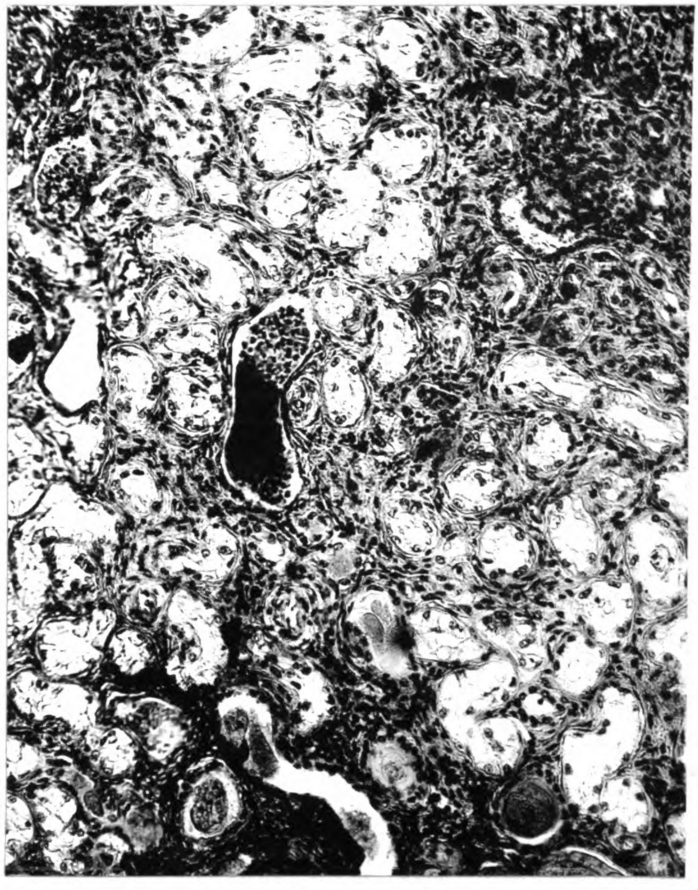

Fig. 40

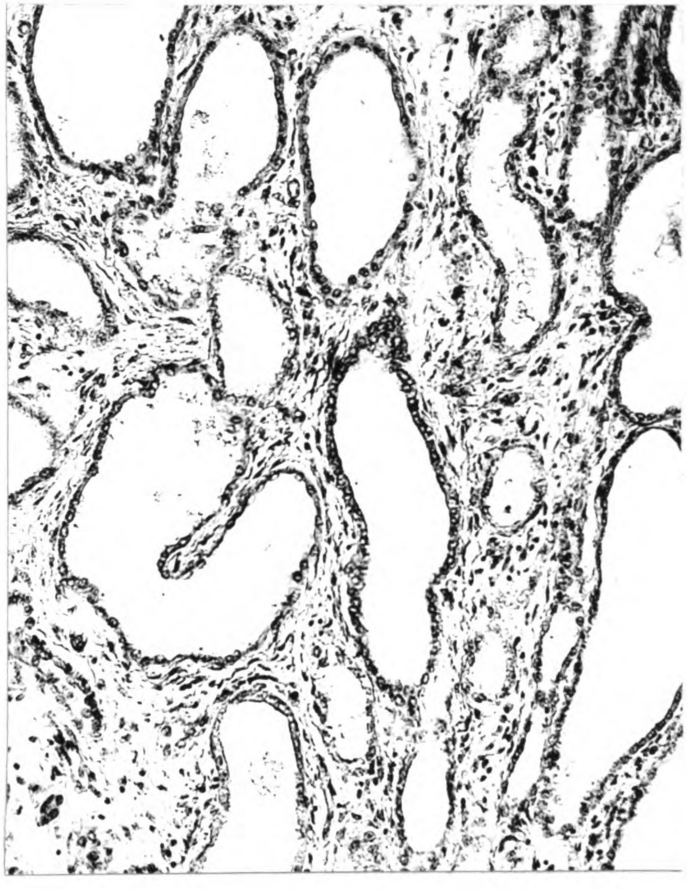

Fig. 41

Fig. 42. Paraffin section showing metaplasia of the epithelium of the large collecting tubules and the papilla. (X180)

Fig. 43. Paraffin section showing proliferation of the subendothelial connective tissue of an artery resulting in a thickening and narrowing of the lumen (Endarteritis obliterans), and hemorrhage into media. (X180)

Fig. 42. Paraffin section showing metaplasia of the epithelium of the large collecting tubules and the papilla. (X180)

Fig. 43. Paraffin section showing proliferation of the subendothelial connective tissue of an artery resulting in a thickening and narrowing of the lumen (Endarteritis obliterans), and hemorrhage into media. (X150)

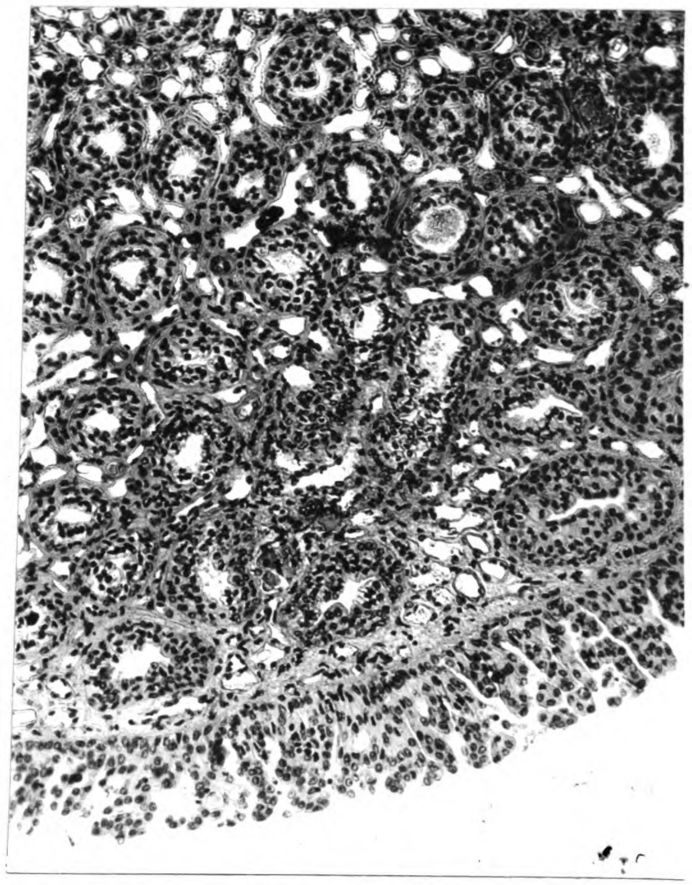

Fig. 42

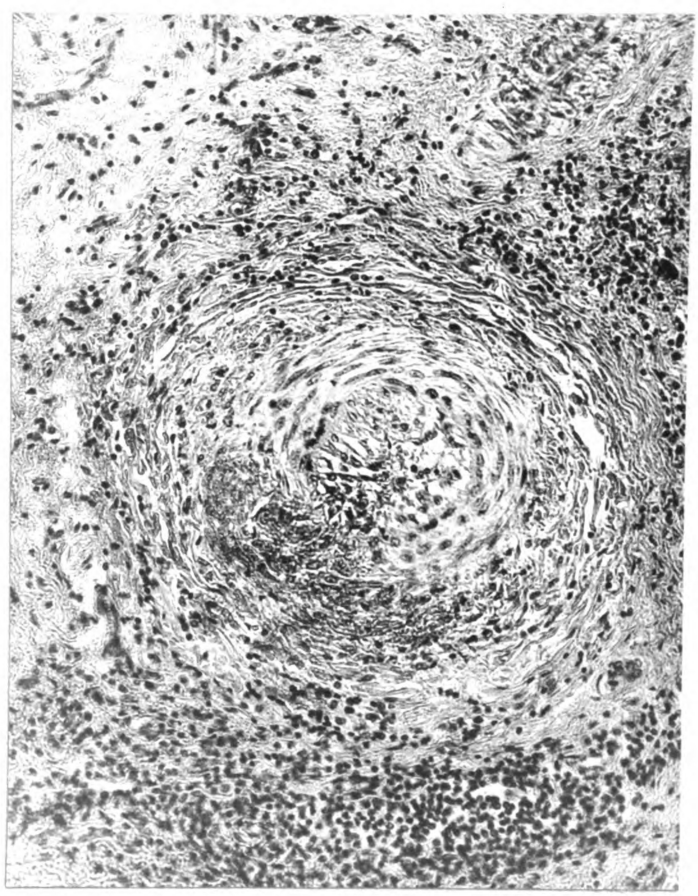

Fig. 43

Fig. 4. Fluorite section showing the recognized

[illegible] of the media in an [illegible]. (XMC)

Fig. 44. Paraffin section showing the vacuolated appearance of the media in an artery. (X140)

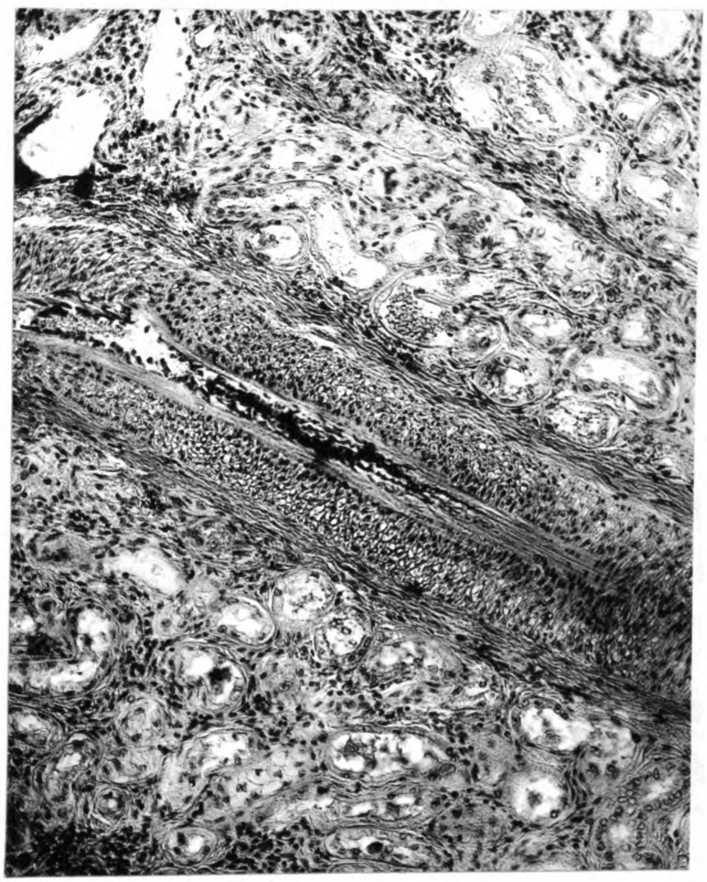

Fig. 44

Fig. 45. Same as fig. 44, but of a greater magnification. (980X)

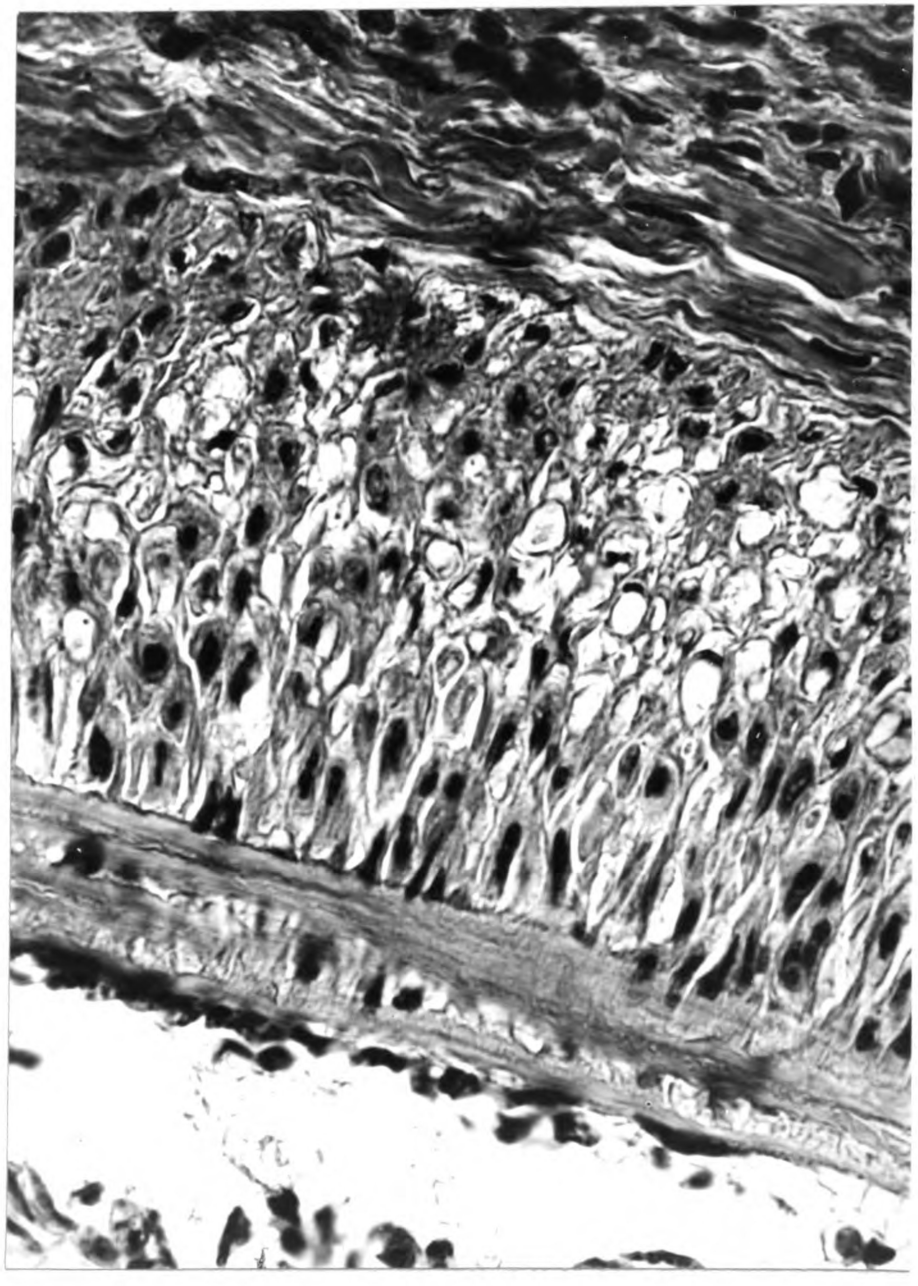

Fig. 45

Fig. 46. Paraffin section stained with silver nitrate to show deposits of calcium in scattered atrophic tubules. (X175)

Fig. 47. Paraffin section stained with silver nitrate to show deposits of calcium in the intima of a small artery. (X185)

Fig. 46. Paraffin section stained with silver nitrate to show deposits of calcium in scattered atrophic tubules. (X175)

Fig. 47. Paraffin section stained with silver nitrate to show deposits of calcium in the intima of a small artery. (X135)

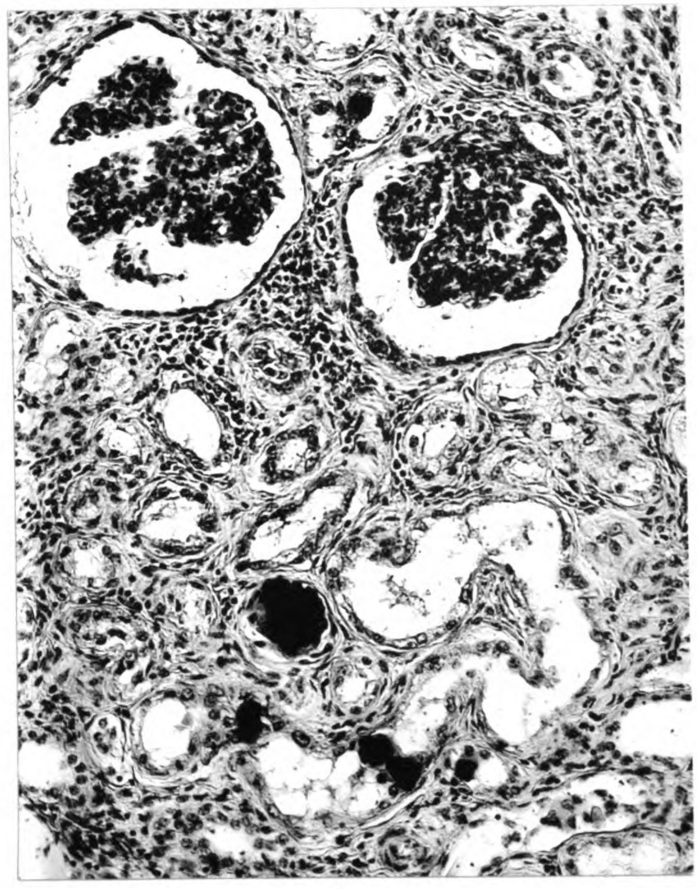

Fig. 46

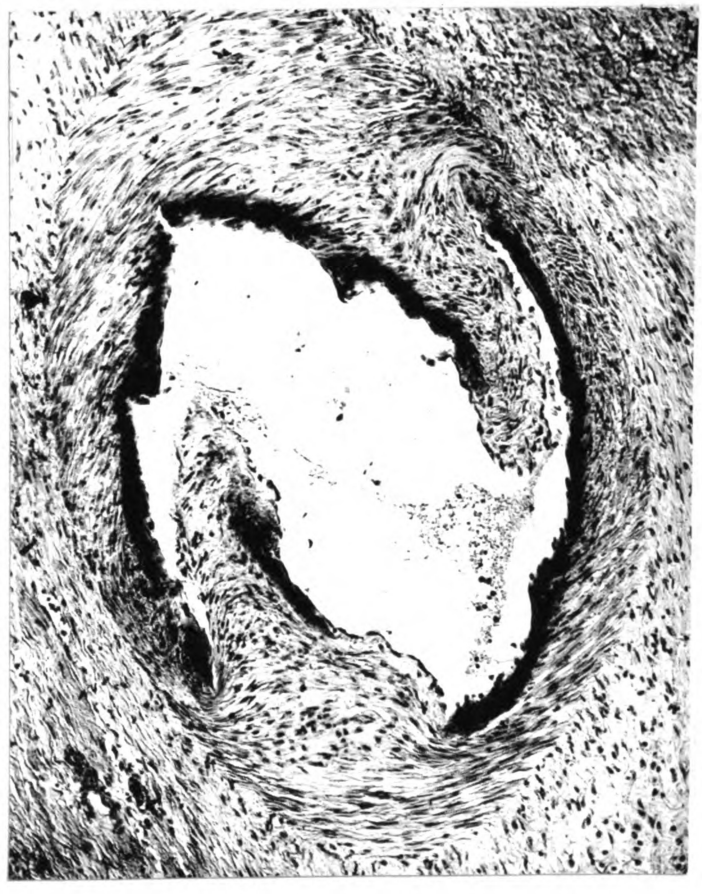

Fig. 47

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