STUDIES ON THE MICROSCOPIC STRUCTURES OF THE KIDNEY OF INDIAN BUFFALO

A THESIS

Submitted to the Faculty of Veterinary Sciences
Magadh University, in partial fulfilment
of the requirements for the Degree of

MASTER OF SCIENCE (Vet.)

By

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Post-graduate Department of Anatomy
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Dr.R.C.P.Yadava,M.S.,Ph.D.(U.S.A.),
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Department of Anatomy,
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PATNA

Dated 30th Nov.1966.

Certified that the work described in this Thesis entitled "STUDIES ON THE MICROSCOPIC STRUCTURES OF THE KIDNEY OF INDIAN BUFFALO" is the bonafide work of Shri Lalan Prasad Singh, carried out under my guidance and supervision.

R.C.P. Yadava 30/11/66

(R.C.P.YADAVA)

D E D I C A T I O N

Dedicated to my revered Professor Dr. R.C.P.Yadava,M.S.,Ph.D.(Mich.), Professor and Head of the Postgraduate Department of Anatomy, Bihar Veterinary College,Patna,whose unfathomable knowledge and timely inculcations have been the paramount and immense source of inspiration.

V I T A

Lalan Prasad Singh

Candidate for the Degree
of
Master of Veterinary Science

Final examination: December, 1966.
Bihar Veterinary College, Patna.

Thesis: Studies on the Microscopic Structures of the Kidney of Indian Buffalo.

Outlines of Studies

Major subject: Anatomy.

Minor subjects: Surgery (including Radiology) and Gynaecology.

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Birth day : October 2, 1934.

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(i) Member, Research staff, Livestock Research Station, Patna, 18th June to 22nd December, 1958.

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(iii) Member, Bihar Veterinary Association.

A C K N O W L E D G E M E N T S

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A B S T R A C T

Studies on the kidneys of 12 male and 8 female buffaloes were made. Haematoxylin and eosin were used as routine stains and Van Gieson's, Gridley's and Gallego's as special stains. Periodic Acid Schiff technique was also employed to study the special structures of the kidney.

The right kidney is triangular in outline, resembling the heart of a playing card. The hilus is situated almost in the centre of the ventral surface of the right kidney.

The approximate weights of the right and left kidneys are 161 gms. and 172 gms. respectively in the young and 394 gms. & 434 gms. in the adult animals. The length, breadth and thickness of the right kidney in young animals are 11.5 cm., 6.8 cm. and 3.4 cm. but 15.0 cm., 9.7 cm. and 4.3 cm. in adult animals respectively. The dimensions of the left kidney are 10.7 cm., 6.1 cm. and 4.0 cm. respectively in calves, whereas 13.4 cm., 7.6 cm. and 6.8 cm. in adult buffaloes.

The tunica fibrosa of the kidney capsule has a definite layer of smooth muscle cells in its innermost part. The renal fascia which is the first fascial membrane is situated outside the perinephric fat.

The cortical renal corpuscles (139/u in young and 168/u in adult animals) are larger than those of the juxtamedullary region (130/u in young and 156/u in adult animals).

The glomeruli of the cortical region (107/u in young and 138/u in adult animals) are also larger than those of the juxtamedullary zone (95/u in young and 123/u in adult animals).

The capsular space is of greater width in adult kidneys than in young ones.

In the kidneys of calves the typical juxtaglomerular cells with rounded nuclei and PAS positive granules are less numerous than in those of the adult buffaloes.

The proximal tubule has a diameter of 36/u in young and 49/u in adult animals. The lining cells are 9/u and 10/u in height in young and adult animals respectively. PAS positive granules mask the cell boundaries of the lining epithelial cells of the proximal tubule.

The thin segment of the Henle's loop has a diameter of 16/u and 25/u and the epithelial cell height 4/u and 5/u in young and adult animals respectively.

The distal tubule of the kidney of young animals has a diameter of 28/u as against 42/u in adult animals. The epithelial cell height is 6/u in calves but 7/u in adult females.

The macula cells are comparatively taller than those of the rest portion of the distal tubule. The chromatin granules of these cells take deeper stain.

The diameters of the straight collecting tubules in calves and adult buffaloes are 35/u and 50/u respectively.The

heights of the lining cells are 7/u and 8/u in young and adults respectively.

The papillary duct is lined by a single layer of tall columnar cells except at the terminal portion where the epithelium becomes transitional. The transitional epithelium of the papillary duct is seen continued on to the surface of the renal papilla. The duct has a diameter of 48/u in young but 84/u in adult animals. The heights of the lining epithelia in the transitional portion are 17/u and 25/u in the kidneys of calves and adult buffaloes respectively.

The reticular fibres surround the renal tubules. The fibres become more concentrated in the region of the "arteriolae rectae spuriae".

The papillary epithelium is transitional except at the angle of reflexion where hardly two layers of cells are present. The transitional papillary epithelium extends to a varying extent into the papillary duct.

The cell boundaries of Becher's cells are not discernible. The nucleus of the cell has a central deeply stained nucleolus with many such in the periphery.

The cells of Goormaghtigh are indistinctly demarcated from one another. The heaps of Goormaghtigh cells are devoid of blood capillaries.

The above findings on the kidneys of Indian buffaloes are thought to be reported for the first time.

C O N T E N T S

INTRODUCTION

" Practise thyself even in the things which thou despairest of accomplishing. For even the left hand, which is ineffectual for all other things for want of practice, holds the bridle more vigorously than the right hand, for it has been practised in this". This admonition given by Marcus Aurelius Antoninus will indubitably vindicate the reason for Indian buffalo (Bos bubalis) being tipped for the present investigation. Besides this, a few following facts regarding the paramount importance of buffalo, specially in India, will make the reason more elucidative.

The historical importance of buffalo is evident with its existence since the Neolithic era even though its domestication became successful near the Christian times.

Viewing the milk production and the value of meat and hide production in India, one observes that buffaloes play a great role in Indian economy. The total milk production by she buffaloes is 31,71,26,647 mds. per annum as against only 22,87,43,075 mds. by that of the cows. The value of buffalo meat production is Rs.465 lacs and that of its hide is Rs.559 lacs per annum (Singh & Parnerkar, 1966).

Lastly but not the least, the use of Indian buffaloes as laboratory animals in most of the Veterinary colleges and research institutions in India, undoubtedly symbolises the growing importance of this species.

Coming to the topic of selection of the kidney as an organ of study portrayed in this thesis, the following paragraphs are extended in favour of its justification.

Continuous elimination of the waste products, maintaining a proper salt balance, regulating the fluid balance and conservation of fluid and/or dissolved materials necessary for the maintenance of a proper state of affairs in the blood stream are the different important and indispensable functions of the kidney which attract the attention of the anatomists, physiologists and pathologists alike (Ham and Leeson,1961). Viewing the relation of histology to other biological sciences (physiology,pathology,etc.), the indispensibility of a sound back ground of the histology of the kidney as preliminary to the study of this organ in other subjects in the veterinary and medical curricula can hardly be over emphasized.

Save and except the english translation of Trautmann and Fiebiger's German text-book,"Fundamentals of the Histology of the Domestic Animals"(1957) and "Comparative Histology of the Kidney of the Domestic Animals" (Yadava's thesis,1955), there is scanty information regarding the histology of the kidney of domestic animals.

Ellenberger's text-book, "Hand-buch der vergleichende Mikroskopischen Anatomie der Haustiere", though contain a chapter on the kidney of domestic animals (Tereg,1911), but this book is deprived of many things, as so many structures have been discovered since then by different scientists in the kidney of man and animals.

The comprehensive studies on the microscopic structure of the bovine kidney by Langham and Hallman (1939) and Langham et al. (1942) did not embrace the maculadensa, the juxtaglomerular apparatus and Becher's cells of the kidney.

Valuable descriptions extended by Bloom (1954) in his book, "Pathology of the dog and cat", is confined to the structures of the kidney of dog and cat.

The studies on the kidney during pregnancy in the cow by Pellegrini and Pellegrini (1960) are much more of pathological than of anatomical importance.

Summing up the works of different scientists enlisted above, one observes that the study on the microscopic structures of the buffalo kidney remained absolutely untouched till now. Under the circumstances, it is imperative to visualise the microscopic structures of the kidney of buffalo, for which this investigation was undertaken.

The present research embraces the realm of both microscopic and gross structures of the kidney of Indian buffalo. The microscopic structures have been depicted in detail, whereas only a brief account of its gross structures has been made.

Microscopic studies were made under light microscope and as such ultramicroscopic structures can not be expected in this work. Moreover, the field of light microscopy is also left open for further investigation to be carried on especially for the reversal of Golgi material in the maculadensa, the granules of the juxtaglomerular cells, the nerve terminations and the pattern of blood and lymph vessels in detail.

Inspite of the above omissions, this investigation will certainly contribute towards an up-to-date study of the anatomy of the kidney of Indian buffalo with special reference to its microscopic structures.

Over and above, the present work carried on the kidney of Indian buffalo in such an entity is thought to be reported for the first time.

HISTORICAL BACKGROUND

The urgency of the historical review can be best elicited by the Cicero's dictum,"Not to know what has been transacted in former times is to be always a child. If no use is made of the labours of past ages, the world must remain always in the infancy of knowledge".

Aristotle (384-322 B.C.), a great thinker and philosopher was the first to elucidate the comparative study on the uro-genital system of mammals. He mentioned the terms "the nephros", "the cavity of the nephros",and "duct from nephros to cystis" for the kidney, its pelvis and the ureter respectively in his book entitled "Historia Animalium".

It were the early decades of second century A.D.when Aretaeus considered the kidneys to be true glands. He compared them with testes, probably due to the superficial similarity between the shapes of the two organs. His illustrious description of the kidney has led many scientists of the field to suspect that Aretaeus was knowing the existence of the papillary ducts.

An explanatory outline of the urino-genital system was sketched by Leonardo davinci (1452-1519).

Berenger (1470-1530) injected the renal blood vessels.

Vesalius (1543) in his monograph "On the fabric of the human body" dealt with the male and female urino-genital system.

Eustachius (1520-1574) criticised Vesalius for representing dog kidney in place of that of the human. Cortical

substance of the kidneys was described for the first time by Eustachius.

Ruini (1599) extended "Anatomia del Cavallo" in which he made an illustrious description of the kidney of horse.

Due to elaborate study made on the renal glomerulus by Rnysch (1638-1731), the term "glomerulus Rnyschiana" was employed for the renal glomerulus in the honour of the scientist.

The celebrated histologist Malpighi (1659) discovered that the kidney was made up of pyramidal masses and as such these pyramids are called the "pyramids of Malpighi". With the help of injected specimens, he noted that the convoluted tubules started as capsules containing a cluster of small blood vessels which in turn hang on the little arteries like "apples on a tree". Hence these structures are called as "Malpighian corpuscles".

The credit for the discovery of the straight collecting tubules and the papillary ducts goes to the renowned anatomist Bellini (1662). The papillary ducts are also termed as the "ducts of Bellini" after him.

Ferrein (1693-1769) described the medullary rays and hence these medullary rays were also once called as "Ferrein's pyramids". He further described the convoluted uriniferous tubules of the kidney.

Bertini (1772-1845) discovered the renal columns and as such these columns are termed as "columns of Bertini".

Henle (1841) in his "Allgemeine Anatomie" described in detail the loops of uriniferous tubules which are termed as "loops of Henle" after him.

Heidenhain (1834-1897) developed a method of staining the cells of the kidney by injecting indigo-caramine into the blood.

Bowman (1842) was the first who drew a picture of the single nephron which is the renal functional unit.

The foregoing statement is based upon the work of Singer (1925), Castiglioni (1947) and Mettler (1947).

Referring the historical background of the kidneys of Indian buffalo, it is presumed that no scientist has come up as yet with any remarkable investigation.

REVIEW OF LITERATURE

Gross Anatomy

Chauveau (1891), presenting a comparative description of the kidney of ox, stated that each kidney was a multipyramidal agglomeration containing fifteen to twenty secondary kidneys.

Chauveau (1891), Bremer (1944), Patten (1953) and Arey (1954) described many lobes with well defined external lobation in the kidneys of mammalian foetuses.

Dixon (1931) described superficial lobation in the kidney of young child and adult both but the lobes were found sometimes and less distinctly in the latter.

Straus (1934) referred the kidney of man to be multipyramidal and that of apes unipyramidal.

Langham and Hallman (1939) pointed out sixteen to thirtytwo lobes in each kidney of the ox.

Grahame (1944a) and Smith (1958) studied the kidney of elephant and found it to be multipyramidal with clear superficial lobation. The latter citing Sperber,described that in many mammals (cow,elephant,hippopotamus, seal, whale etc.), kidney was divided into a number of lobes so nearly independent that they were virtually separate kidneys.

Elias (1944) and Sisson & Grossman (1962) described the kidney of pig. They observed distinct pyramids in the pig kidney but found quite smooth external surface like that of unipyramidal kidneys.

Elias (1944) made an invaluable contribution towards the gross structures of mammalian kidneys. He found unilobar kidneys in horse, sheep and goat as in the case of rodents. He observed certain resemblances between the pyramids of the kidney of German shephered dog and those of the pig. The pyramids were seen to be closely united in the great-dane dog. In the case of cat he found unilobar kidney with a simple pyramid.

Bradley and Grahame (1960) described distinct superficial lobation in the kidney of fowl, the number of lobes varying from three to four.

Pfeiffer et al. (1960) found a short crest on the lateral wall of the small, simple pelvis in non-lobed kidney of Aplodontia rufa.

Sisson and Grossman (1962) gave an elaborate description of the kidneys of horse, ox, sheep, pig and dog. According to them the longitudinal section of the kidney of horse presented a non-papillated appearance. A concave projection called renal crest located in the inner central part of the medulla presented many small openings of the papillary ducts. The name "area cribrosa" was attributed to this congregation of the small openings which was seen projecting into the renal pelvis of horse. These anatomists stated that distinct pyramids with their papillae projecting into the calyces minores were noticed in the kidney of ox. Renal crest in the kidney of sheep was the resultant of the fusion of twelve to sixteen pyramids. In the pig also they found distinct papillae. Further, they observed curved ridges proceeding dorsally and ventrally from the renal crest in the frontal section of the kidney of dog.

Wrobel (1963) described 377 lobes in the kidney of sea-lion (Zalophus californianus).

Microscopic Anatomy

Capsule

Chauveau (1891) stated that the capsule of the kidney of horse was a fibrous membrane, closely attached to the parenchyma of the organ.

Tereg (1911) described two easily separable layers in the capsule of the mammalian kidney. The outer layer comprised of blood and lymph vessels and nerves whereas the inner one was devoid of blood vessels.

Tereg (1911) and Trautmann and Fiebiger (1957) pointed out the presence of smooth muscle fibres in the capsule of the kidney of ox and sheep. The location of smooth muscle fibres were said to be in the innermost part of the capsule.

Maximow and Bloom (1952) and Copenhaver (1964) gave an account of the capsule of the kidney of man. According to them the capsule of human kidney contained collagenous and elastic fibres.

Greep (1954) went to the extent of describing the presence of a few smooth muscle cells in the delicate tunica-fibrosa besides, the collagenous and elastic fibres in the human kidney. He indicated the easy removal of the capsule from the kidney to be a sign of normal kidney. He further described a fatty layer, the capsula adiposa outside the tunicafibrosa.

Yadava (1955) discovered smooth muscle cells in the inner layer of the capsule of the kidney of ox,horse,pig,sheep, goat and dog. Further, he reported the absence of smooth muscle cells in the capsule of the cat kidney.

Hayner (1956) described the basic pattern of the renal fascia in the kidney of dog,cat,rhesus-monkey and man. He explained that the first fascial membrane (renal fascia) was devoid of any lateral alar stem of its own. The second fascial membrane i.e. tunica fibrosa, being partially or entirely surrounded by perinephric fat, closely and completely covered the kidney and formed an in between septum of the kidney and the adrenal gland.

Hammersen and Staubesand (1961) described a stratum fibro-vasculare between the fibrous and adipose capsules of the kidney of man but a simple fibro-lipo-vascular capsule in the dog.

Uriniferous Tubule

Greep (1954) presented a systematic classification of uriniferous tubules into two segments, a secretory tubule and a collecting tubule. He maintained the term 'nephron' which was given to the secretory or terminal tubule by Braus as cited by Copenhaver (1964). According to Greep uriniferous tubule, secretory tubule and collecting tubule of human kidney,measured 50-60 mm.,30-40 mm. and 20-22 mm. in length respectively.

Nephron

Huber (1932) studied the nephron of rabbit kidney and termed it,"the renal tubule", which comprised of the renal corpuscle, the proximal convoluted portion with the medullary loop, the distal convoluted portion and the junctional tubule.

Smith (1958) divided the tubular portion of the dog and cat nephron on the basis of both cytological structures and

function into three segments.

(1) Proximal tubule (Pars convoluta and Pars recta)

(2) Thin segment

(3) Distal tubule (Pars recta and Pars convoluta).

Desmet (1960) distinguished the following segments in the Polypherus nephron, viz: Malpighian corpuscle, a neck-segment, a proximal convoluted segment (with four more or less different portions), a ciliated intermediate segment, an initial collecting segment and a general collecting segment.

Desmet et al. (1963) described the highly differentiated nephron of Amia calva which was comprised of Malpighian corpuscle, two parts in the proximal segment, the intermediate segment and six parts in the distal segment.,

The renal corpuscle. Huber (1932,1935) found spherical shape of the mammalian renal corpuscle with a diameter varying between 100 μ to 200 μ.

Langham and Hallman (1939) measured the diameter of bovine (adult) renal corpuscles. He found that each renal corpuscle had a diameter of 216 μ in fixed stained preparation.

Greep (1954) and Copenhaver (1964) mentioned that renal corpuscle of human kidney had the diameter of 200 μ.

Yadava (1955) discovered that the cortical renal corpuscles were larger than those of the juxtamedullary zone in ox, sheep and goat.

Yokoi (1959) observed that the renal corpuscles of mice, guineapigs and rabbits were larger in the internal part of the cortex than those of the external part.

The glomerulus. Yadava (1955) found that the cortical glomeruli were larger than the juxtamedullary in ox but the reverse was true in case of horse, pig and cat. However, in the sheep and goat kidneys, the cortical glomeruli were equal or slightly larger than those of the juxtamedullary zone.

Elias (1957) called the renal glomerulus, "Lamina vasculosa glomeruli" due to its appearance like a branched flat sheet. He applied the term "Endencyma" to the mass of cells, possibly syncytial, belonging to the endothelial system which is contained in it. He advocated that the blood channels course in the endenchymal mass of the glomerulus of the mammalian kidney.

Dolezel (1962) observed marked indivisual differences between the glomeruli of different regions and in the same region in the kidney of rat.

Abrams et al. (1963) described that essentially a truncated prolate spheroid glomerulus bore a selective spatial orientation with respect to the afferent arteriole in human kidney.

Moffat and Fourman (1964) found ectopic glomeruli in the renal pelvis of rat, cat, dog, rabbit and ferret and in the human full term foetus. The glomeruli were found to be embedded in the connective tissue around the main intra renal vessels and deep to the pelvic mucosa and thus they did not form a part of the renal parenchyma.

Munkacsi and Palkovits (1965) did not find any exact relationship between the glomerular volumes, kidneys weight and body weight in different mammals when compared to each other. They noted that the desert living animals had a much bigger difference in volume between the cortical and the juxtamedullary

glomeruli than those animals of water rich environment. The large size of the juxtamedullary glomeruli and deep nephrons in relation to dehydration was considered as an adaptation to life in an arid environment.

Afferent arteriole. Bensley (1929), Schloss (1946) and Dorello (1948) noticed dilatation in the afferent arteriole of the guineapig, human and pig kidneys respectively after its entrance into the renal corpuscle. Schloss termed such expansion as "Becher's glomerular sinus".

Codden (1949) however, did not observe any such dilatation but he saw a ramification of the afferent arteriole in the human kidney just after its entrance into the renal corpuscle.

The glomerular capillary tuft: Wilmer (1941) observed in human kidney that there were no shunts within the glomerulus, and the capillaries did not anastomose with each other,but coalesce into an efferent arteriole which in turn breaks up again into a second capillary system i.e. peritubular capillaries.

Hall (1955) described direct channels between the afferent and efferent sides of the glomerulus, besides the usual tuft of capillaries in the glomeruli of rat,cat,dog,rabbit and man kidneys.

Boyer (1956) held that the capillary network of the glomerulus of animals and human kidneys was comparable to all other capillary beds in the body but for its adaptation to the spatial arrangement of its unique location. He further condemned the classical concept of capillary loops without anastomoses between loops or between limbs of the same loop.

Smith (1958) described that the capillary tuft in the human kidney was formed by abrupt division of the afferent arteriole into 2 or 4, rarely upto 10, primary branches which had as many as 50 capillary loops.

Bonhomme et al. (1960) observed two types of capillaries in the glomerulus of dog, cat, and guineapig kidneys, the ramification of the afferent arteriole at the periphery of the glomerulus and a capillary net at the centre of the glomerulus.

Tardini (1961) confirmed the existence of a vast anastomotic network which originated from the 4 or 5 branches of afferent artery.

Kinoshita and Fujisaki (1963) described that the human and other mammalian glomerular capillary loops were composed of epithelium, a basement membrane, endothelium and mesengial cells. They did not observe any basic difference between human subjects and other mammalian species.

The efferent arteriole. Bensley (1929) described that the efferent arteriole of guineapig varies in structure from an endothelial vessel to a typical arteriole, invested by smooth muscle cells. He found much longer efferent vessels in the juxtamedullary region which entered into the formation of the arteriolae rectae of the medulla.

Schloss (1946) found a dilatation in the efferent arteriole of human kidney just at the point of its emergence from the glomerulus.

Edwards (1953) discovered that only 20 to 25% of the efferent arterioles of the juxtamedullary region in the human kidney were short, thin walled and gave rise to a network of

capillaries. The rest efferent arterioles were long which were found to descend into the medulla. Edwards (1956) further demonstrated that the volume of muscle in the walls of the medullary arterioles was greater than that in those of the cortex.

Adebahr (1963) observed that epetheloid and muscle cells form a small funnel at the commencement of the efferent arteriole in the rat kidney and a similar structure at the dividing point of the efferent arteriole in the rabbit.

The intercapillary or axial space. Bensley and Bensley (1930) observed a small amount of connective tissue in the axial space of human and mammalian glomerulus.

McManus et al. (1951) found carbohydrate material in the intercapillary space of the human glomerulus.

Jones (1953) noticed connective tissue cells in the human glomerulus with their number increasing with the age, approximating the number of endothelial and epithelial cells at the age of thirty.

Yadava (1955) found fibroblasts and histiocytes in the axial space and collagenous and reticular fibres surrounding the capillary tuft in the glomerulus of domestic animals (ox, horse, sheep, goat, pig, dog and cat).

Dunihue (1957) mentioned that most electron microscopists either denied or ignored the existence of mesangial or intercapillary cells and maintained that the only cellular elements in the glomerulus, other than blood cells, were endothelium and epithelium. He noted fuchsinophilic granular cells in

the glomerulus of rat, cat, duck and rabbit, whose size and number were seen to increase in response to a mineralocorticoid deficiency like the granular juxtaglomerular cells.

Smith (1958) described the axial space of the human glomerulus and stated that there was infrequent presence of a third type of cell (neither endothelial nor epithelial), possibly a connective tissue cell, already described by Zimmermann as the mesangium.

Latta et al.(1960) studied the intercapillary cells within the centrolobular regions of rat kidney glomeruli, which had many branched processes in contrast to endothelial cells. They further observed an amorphous inter-cellular substance filling much but not all of the centrolobular space between the intercapillary cells and their processes.

Tardini (1961) believed that the formerly so called mesangium, was represented by endothelial cells which were probably not exposed to the blood stream.

Latta and Cook (1961) with the aid of electron microscope demonstrated collagen fibres adjacent to the intercapillary cells in centrolobular regions on the capillary side of the glomerular basement membrane in the normal rat kidney. They considered the presence of collagen, next to normal intercapillary cells as an additional evidence to regard them as special cell type and not just as endothelial cells.

Huhn et al.(1962) stressed on the intercapillary location of mesangial cells which were always separated by endothelial cells from capillary lumina in the glomerulus of dog and mouse.

Farquhar & Palade (1962) were of the opinion that there was a distinctive "Third" cell in the rat glomerulus.

Jones et al. (1962) suggested that in rat kidney, the sponge fibres which were arborisations from the glomerular hilus, with their enmeshed stalk cells (Third cell type) actually form the structure, upon which the capillaries were hung as they wound their way into and out of the glomerular space. They emphasised that the Zimmermann's "Mesangium" was actually constituted by the stalk cells and sponge fibres.

Takaki et al. (1962a) viewing the structure of the mouse glomerulus concluded that mesangium was a part of the wall of the blood vessel, retaining the multipotency of differentiation.

Foster & Riad (1963) demonstrated three types of cells in the rabbit glomeruli.

(1) Cells - epithelial in nature.

(2) Cells - P.A.S. positive.

(3) Cells - containing acid phosphatase.

Dunihue & Boldosser (1963) with the aid of light and electron microscopy, supported the hypothesis that some mesangial cells were similar to the cells of the juxtaglomerular apparatus in the cat kidney.

Yasuta et al. (1963) argued that the relatively thick capillary wall of the toad glomeruli in comparision to that of mammals, was due to the presence of mesangial layer between the epithelium and endothelium.

Linss & Gayer (1964) with the aid of electron microscope showed the presence of intercapillary cells not only in

the hilar region but also in the peripheral parts of the capillary loops of the glomerulus of Rana esculenta.

The three primary membranes of the glomerulus. McGregor (1929) and Bensley & Bensley (1930) described the three primary membranes of the glomerulus - capillary endothelium, basement membrane and capsular epithelium, which were usually considered continuous. However, they contended that the visceral epithelium was discontinuous and the individual cells were highly irregular in shape and exhibited delicate discrete processes, which invested the glomerular capillaries in the manner of the pericytes applied to the capillaries elsewhere in the body of human beings and small mammals.

Pease & Baker (1950) observed a continuous epithelium, a discontinuous endothelium and a basement membrane covered externally by a system of interdigitating ridges.

Oberling et al. (1951) and Dalton (1951), in mouse, saw the glomerular epithelium carrying many branched villi-like processes.

Hall et al. (1953a) found a highly porous but continuous endothelium, a finely porous basement membrane, and an epithelium with cells having interdigitating processes.

Simer et al. (1953) noted incomplete visceral epithelial and endothelial layers in mice, although every capillary had a fibrillar basement membrane.

Pease (1955a) with the help of electron microscope found that in rat kidney, the epithelial cells had long primary and secondary branches. The basement membrane was seen to be continuous and made up of three layers, the middle layer being

of high electron density. The endothelial cytoplasm was found extremely attenuated in most parts of the capillaries.

Yadava (1955) observed the three primary membranes of the glomerulus in domestic animals, viz: visceral layer of Bowman's capsule, basement membrane and endothelium.

Latta et al.(1960) observed that the central dense layer of the basement membrane followed the epithelium over the centrolobular region without splitting and entering it or sending a layer beneath the central portion of endothelial cells in the rat kidney.

Kurtz (1961) noted that the lamina densa was a permanent and of definite texture, with absolutely no replacement occurring normally.

Willis et al.(1964) observed glomerular epithelial cells in human kidney containing nuclei and free cytoplasmic processes which formed direct or indirect annular branches on the outer capillary walls.

Osawa et al.(1966) revealed that the width of the basement membrane was not related to age and sex. They calculated the mean width of the basement membrane, which was 3146Å.

Bowman's capsule. Crabtree (1941) described that both the layers and particularly the parietal layer of Bowman's capsule of mouse kidney comprised cuboidal cells similar in structure to those of the proximal tubule.

Oleynik (1952) advocated the term,Shymlansky's capsule" for Bowman's capsule, because he believed that this structure was studied by Shymlansky sixty years before Bowman.

Pease (1955b) with the aid of electron microscope, demonstrated cytoplasmic processes in the parietal cells of Bowman's capsule.

Yadava (1955) observed flattened squamous cells in both the layers of Bowman's capsule in the kidney of ox, horse, sheep, goat, dog, cat and pig.

Suzuki et al. (1962) noted that the basement membrane of Bowman's capsule was lamellar and fibrous in rat kidney.

Takaki et al. (1962b) studied the glomerulus of the mouse kidney with the aid of electron microscope. They saw one or two cuboidal or flat cells with foot processes in between epithelial cells of the glomerular capillary and those of Bowman's capsule. Further, they also noticed one or two intermediate cells between the epithelium of the proximal tubule and that of Bowman's capsule. These cells also showed transitional characters i.e. basal intussusceptions, brush border and cell orgenelles.

The juxtaglomerular apparatus or polkissen. Goormaghtigh (1940,1945a,1945b,1947), Kaufmann (1942), Graef (1943),Oberling (1944) and Graef and Proskauer (1945) believed that in man and dog atleast, the "polkissen" was only a modification of medial cells associated with random, poorly differentiated smooth muscle cells; even though the term "juxtaglomerular apparatus", was employed by Goormaghtigh to the modified arteriolar wall and its associated extravascular cells.

McManus (1942) preferably used the term "juxtaglomerular complex" to include the juxtaglomerular apparatus and the macula densa.

Schloss (1946) observed smooth muscle cells with myofibrils, besides the usual epitheloid cells in the area of the polkissen.

McManus (1947b), Prez (1948), Dalton(1951), Wilson (1952) and Chandra & Skelton (1964) demonstrated granules in the juxtaglomerular cells.

Goormaghtigh (1951) pointed out that the granules were absent in the juxtaglomerular cells of the human and dog kidneys.

Gomori & Oltvanyi (1951) and Barajas (1964) studied the innervation of the juxtaglomerular apparatus. The first two workers observed a nerve plexus among the juxtaglomerular cells. The latter found numerous non-myelinated nerve fibres associated with the afferent and efferent glomerular arterioles in the monkey and fewer associated with the juxtaglomerular apparatus of the rat.

Maximow & Bloom (1952) observed that the juxtaglomerular cells were absent in lower vertebrates and in children below the age of two years.

Oberling & Hatt (1960) and Iatta et al.(1962)described that the juxtaglomerular apparatus was made up of three elements.

(1) The epitheloid cells - located in the media of the afferent arteriole, different from the smooth muscle cells and showing the appearance of glandular cells.

(2) The macula densa.

(3) The net work of ground substance - consisting of cells of only slightly functional aspect with numerous projections,constituting the mesangium of the glomerulus.

Bucher & Reale (1961) noticed the myofibrils besides the granules in the juxtaglomerular apparatus.

Ito et al.(1962) studied the juxtaglomerular apparatus of the bat kidney. Granular epitheloid cells of the tunica media, macula densa and Goormaghtigh cell group as a whole were called the juxtaglomerular apparatus by them.

Barajas & Latta (1963) with the aid of electron microscope observed that in rat, even the brief contact of the tubule before becoming distally convoluted with the afferent arteriole was not too intimate,as one or more juxtaglomerular cells might be interposed between the basement membrane of the tubule and the media of the arteriole.

Friedberg (1964) showed that in mouse kidney, there was an inverse relationship between urinary concentrating ability of the nephron, as reflected by the length of Henle's loop and the degree of the granulation of the nephron; the short looped nephrons were associated with more heavy granulation of the juxtaglomerular cells. He found greatest proportion of granule bearing glomeruli in the outer zone of the cortex.

The function of the juxtaglomerular apparatus.

Goormaghtigh (1939,1940,1945a,1945b, 1947,1949,1951) attributed endocrine function to the afibrillar cells of the juxtaglomerular apparatus. It was suggested that the endocrine function was to regulate the tonus of the renal arterioles in the normal condition and to produce the hypertensive substance in the ischaemic kidney. His view, that the juxtaglomerular apparatus had an endocrine function was supported by Kaufmann (1942), Dunihue(1947,1949), and Hartroft & Hartroft (1952).

Oberling (1944), Fox & Jones (1945), Schloss (1946,1948) and Prez (1948) were unable to find any evidence in favour of Goormaghtigh's hypothesis.

Graef & Proskauer (1945), Becher (1949,1950) and Prez (1948) believed that the juxtaglomerular cells might play a role in the regulation of the renal circulation.

Hartroft & Hartroft (1953) reported that the juxtaglomerular cells were involved in the hormonal regulation of sodium metabolism and blood pressure.

Demopoulos et al. (1960) indicated that the juxtaglomerular cells in the wall of the afferent arteriole were the cellular site of origin of renin in the rat and rabbit kidneys.

Cook & Pickering (1961) extended their views that the juxtaglomerular cells seemed to be the most likely site of renin storage, but the other cell groups in that region could not be excluded.

Kohlhardt & Voth (1963) showed that a fall of aldosterone production led to a heightened activity of the epitheloid cells of the juxtaglomerular apparatus, with increased renin production.

The proximal tubule. Huber (1932,1935) found a relatively low epithelium with a wide lumen, or a high epithelium with a relatively narrow lumen in the proximal convoluted tubule of the rabbit kidney.

Grafflin (1942) observed a deposition of yellow to golden-brown iron-containing pigment in the cells of the proximal tubule in rat.

Mayer & Ottolenghi (1947) observed irregular protrusion of proximal tubule into Bowman's capsule of the renal corpuscle of dog and cat.

Harman & Hogan (1949), and Sulkin (1949) noted more than one nucleus in the epithelial cell of the proximal tubule of human and rat respectively.

Caulfield & Trump (1962) observed two types of epithelial cells in the proximal tubule of the rat kidney, viz:(i) cells with homogenous cytoplasm and (ii) cells with relatively clear cytoplasm.

Longley & Burstone (1963) described and identified the frequently ejected nuclei into the tubular lumen from the disrupted epithelium of the proximal convoluted tubule in the rat kidney and considered them to be agonal artifacts.

Mukherji & Sen (1964) observed a considerable amount of argentaffin granules in the proximal tubules of the toad kidney.

Bulger (1965a) found an interdigitation of processes confined to the apical region, and an interdigitation of more extensive processes that extended to the full height of the cell of the proximal tubule in the rat kidney. These two were the further specialisations, besides the well known lateral processes seen in the basal region of many tubular cells.

Ericsson et al.(1965) indicated that protrusions of variable sizes towards the lumen of the proximal tubules containing cellular debris and as well as the usually encountered enlarged intercellular spaces in the proximal tubular cells of the human kidney were probably the preparation artifacts.

The brush border. Sjostrand & Rhodin (1953) found the brush border of the mouse proximal tubule to be made up of densely arranged cylindrical ducts closed towards the lumen of the tubule.

Hall et al. (1953b) observed that the brush border of rat's proximal tubule consisted of tubular fibres having separate origin from the cell surface.

Yadava (1955) found that the brush border in the proximal tubule of pig was in clusters.

Navarro et al. (1963) noted brush border in the superficial cells of the renal tubule. The brush border consisted of micro-hairs, one micron in length and a diameter of 500Å, among which there were small invaginations and adjacent to them pinocytotic vesicles.

Fat content of the proximal tubule. Modell (1933) & Foote (1936) found fat in the proximal tubule of the cat.

Foote & Grafflin (1938,1942) observed fat in the proximal tubule of both, dog and cat.

Dallemagne et al. (1950), Silver (1951), and Platt (1957) noticed fat in the proximal tubule of the dog.

Yadava (1955) observed fat globules in the cells of the proximal tubule of the dog and cat.

Thoenes (1962) studied the fine structure of the lipid granules in the cells of the proximal tubule in the mouse kidney. He subdivided the lipid granules into two types.

(1) "ordered pattern" - having only lipid.

(2) "Disordered pattern" - having lipoprotein.

The loop of Henle. Huber (1932,1935) found that the lining cells of the thin segment of Henle's loop were of squamous type with relatively large nuclei.

Smith (1958) reported the presence of the thin segment only in mammals and in a small percentage in birds.

Bulger (1965a) noted indistinct morphological differences between the cells of the ascending and descending limbs of the loop of Henle in rat kidney.

The distal tubule. Huber (1932,1935) observed that the distal tubule of rabbit kidney was lined by a low columnar or cuboidal epithelium, presenting a clear supranuclear zone of cytoplasm. The basal striations were present but brush border was absent.

Pease (1955b) with the aid of electron microscope, noticed in rat kidney that the apical ends of the cells of the distal tubule had scattered short cytoplasmic processes, symbolic of rudimentary brush border.

Smith (1958) describing the distal tubule of human kidney, stated that all portions of the distal segment were devoid of brush border but the tubules showed distinct basal striations.

The macula densa. Zimmermann (1933) noted in the mammalian kidney, the crowding of nuclei in the region of tangential contact of distal tubule over the afferent arteriole. Hence he called the area of contact, "the macula densa".

Edwards (1940) preferred the term "epithelial plaque" instead of macula densa. He observed variably elliptical epithelial plaque in mammals, birds, and frogs.

McManus (1943) and Okkels (1950) found reversal of Golgi material in the macula densa of mammals. The location of Golgi element in the macula densa was seen towards the basal side of the nucleus but towards the luminal side of the nucleus in the rest of the distal tubule.

McManus (1947a) observed that the basement membrane was absent in the macula densa of vertebrate kidney.

Yadava (1955) discovered that the macula densa in horse kidney was stratified. The cytoplasm of the cells of the macula densa was found non-granular in horse but granular in ox,pig, sheep,goat, dog and cat.

Bucher (1960) studied the macula densa of rats, mice and human, and concluded that differences in techniques might be responsible for many of the structural differences observed.

De la Pena and De Castro (1960) found no exact representation of the macula densa of animals, in the normal human kidney.

Friedberg (1964) found that the distribution of the macula densa was equal in all zones of the cortex of the mouse kidney.

Faarup (1965) demonstrated highest number of cells in the macula densa of the subcapsular region in rat kidney.

<u>The function of the macula densa.</u> Oliver (1944-45) stated that the modification of cell arrangement and structure in the macula densa had no functional significance and represented only a reaction to mechanical strain where the tubule acquired fibrous attachment to the glomerulus.

Schloss (1946) considered the macula densa as a sensory area, probably a chemo-receptor, influencing the contraction of the vessels.

Becher (1949,1950) thought that the flow of blood through the Malpighian bodies of the kidney was regulated by the macula densa.

Okkels (1950) attributed an angiotrophic role to the macula densa.

Oberling & Matt (1960) believed that small samples of urine were taken from the macula densa and transferred by the ground-substance reticulum to the afferent arteriole and into the mesangium of the rat glomerulus. Thus the auto-regulatory function of the juxtaglomerular apparatus of which macula densa was the second element,was evidenced by them.

Friedberg (1964) stated that the equal distribution of the macula densa in all zones of the cortex of the mouse kidney did not correlate with that of pressure substance.

Collecting tubule

Almost all writers conceded that the collecting tubule comprised of an initial or arched collecting tubule, the straight collecting tubule and the duct of Bellini or papillary duct.

However, Young and Wissing (1964) subdivided the collecting tubule into four segments, based on the types of epithelial cells that form its lining in rat kidney. The sub-divisions were as follows.

(a) Initial segment

(b) Second segment

(c) Third segment

(d) Terminal segment.

They further, observed two types of cells in the epithelium of collecting tubule i.e. type I and type II. The first type of cells were termed as "light" cells because of their homogenous cytoplasm with few granules, vacuoles and mitochondria. The second type of cells were called as "dark" cells or "intercalated" cells due to the presence of abundant cytoplasmic granules. The "light" cells were numerically preponderant and were ordinary lining cells i.e. broad cells of cuboidal height. The "dark" cells were less numerous and broader and taller than type I.

Bulger (1965b) observed that the lining cells of the collecting duct of the aglomerular nephron of toad-fish were higher and narrower than the renal tubular cells. The nuclei of the lining cells of the collecting duct were found to be irregular in shape and basal in location. He further demonstrated variable amount of collagen and circumferentially oriented smooth muscle cells surrounding the collecting ducts.

<u>The arched collecting tubule.</u> Huber (1932,1935) observed in rabbit kidney that the primary collecting ducts of the cortex were united in the periphery of the cortex to form collecting tubules which passed through the cortex without receiving any further branches. But in the human kidney it was found that a few primary collecting tubules united in the

periphery of the cortex and the collecting ducts thus formed received further branches while traversing the cortex. The lining cells of the collecting tubules were columnar in type, with clear protoplasm and large spherical or ovoid nuclei.

Greep (1954) stated that the lining cells of the initial collecting tubules of the human kidney were cuboidal in type.

Yadava (1955) noted cuboidal epithelial cells in the arched collecting tubules of the kidney of domestic animals.

Trautmann & Fiebiger (1957) described the lining cells of the connecting tubule in the domestic animals, which were polygonal, light-coloured and of lesser height than that of the collecting tubules.

Ruber (1959) noted peculiar phenomenon i.e.pleomorphism of the nuclei and certain polymorphism of the cells at the junction of the renal tube-apparatus in the kidney of rabbit. He suggested that that region might be the merging place of metanephrogenic elements and materials from the ureteric bud of the foetus.

<u>The straight collecting tubule</u>. Greep (1954) described that the straight collecting tubules in human kidney were the major substance of the pyramid. These tubules were located in the medullary rays. The fusion of straight collecting tubules in succession, finally entered into the formation of sixteen to twenty large papillary ducts. The lining epithelial cells were cuboidal in the proximal portion, but gradually they increased in height as the diameter of the tubule went on increasing.

Trautmann & Fiebiger (1957) stated that in the smaller collecting tubules, numerous fat droplets, especially in large animals were present. The epithelial lining of the smaller collecting tubule was of irregularly cuboidal cell with a central nucleus and clear cytoplasm. The height of the epithelial cells of the larger tubules grew higher until in the papillary ducts. The epithelial lining of the large collecting tubules was made up of hexagonal columnar cells with usually eccentrically located nuclei.

The papillary duct. Langham et al.(1942) reported that the epithelium of the papillary duct of the bovine kidney retained all the other features of that of the smaller collecting tubule, barring the height of the cells which was sufficient to group them under columnar type.

Duran-Jorda (1953) was doubtful about the existence of the openings of the papillary ducts, especially in the cat. Instead of direct excretion into the renal pelvis by the ducts of Bellini, the urine was thought to be dialysed through the papillary epithelium.

Yadava (1955) observed that the transitional epithelium of the papillary duct in bovine kidney was a normal feature and not a pathological one, as stated by Langham and Hallman (1939). He demonstrated the extension of transitional epithelium to a varying extent into the papillary ducts in all animals except the dog. Further, he removed the doubt of Duran-Jorda (1953) by showing the openings of the papillary ducts in the cat kidney. He noted that the papillary ducts opened directly onto the papilla of all animals.

Trautmann & Fiebiger (1957) described that the epithelium of the papillary duct in animals was comprised of two layers i.e. basal and luminal cells of cuboidal and columnar types respectively. A change from two layered-epithelium to a transitional type was usually noticed towards the opening of the papillary duct.

Basement membrane of the uriniferous tubule

Bensley & Bensley (1930) found a thin, structureless basement membrane interposed between the epithelium of the tubules and the reticular framework.

Pease and Baker (1950) and Pease (1955b) observed that the structure of the basement membrane was entirely homogenous throughout the whole length of the uriniferous tubules. Connective tissue cells were observed so few and apart from each other that they presumed that the basement membrane might be maintained by the overlying epithelia rather than by fibroblasts.

Faarup & Christensen (1965) observed three different layers in the basement membrane of the medullary capillary, viz: external, middle and internal. They stated that the basement membrane of the medullary tubules, in the mouse kidney, differed from that of the capillaries. The middle or dense layer when present, was without specialised sub-structures.

Papilla

Langham et al. (1942) noticed transitional epithelium covering the surface of the papilla in the bovine kidney.

Maximow & Bloom (1952) described that in the human kidney, the simple columnar epithelium of the ducts of Bellini continued onto the surface of the papilla.

Yadava (1955) found that in the kidney of ox,horse, dog, sheep,goat,pig and cat, the papillary transitional epithelium was of almost uniform height over the entire surface of the papilla except on the sides near the angle of reflection, where the transitional epithelium was very low.

Trautmann & Fiebiger (1957) described that with the exception of the pig and the goat, the transitional epithelium was replaced by two-layered cuboidal to columnar epithelium on the renal papilla.

Abrahams (1964) studied the ultra structures of the interstitial tissue of the renal papilla of the rat. He found that the renal papilla was the site of interstitial cells which had fat droplets in the cytoplasm. These cells appeared to them, mesenchymal in type. The interstitial tissue of the papillae also contained numerous lipid droplets.

Young & Wissing (1964) demonstrated the following diverse appearances of some capillaries at the tip of the papillae in the rat kidney.

A: Erythrocytes - crenated; Plasma - not visible.

B: Erythrocytes - crenated; Plasma - appreciably visible.

C: Erythrocytes - almost invisible; Plasma - almost completely obscuring the erythrocytes.

Interstitial space

Kirkman (1943) observed fibroblasts and macrophages in the interstitial space of the rat kidney.

Yadava (1955) noted the presence of mast cells besides fibroblasts and histiocytes in the interstitial space of the kidney of domestic animals. However, he noticed that the mast cells were present in the kidneys of ox,horse,pig, sheep and goat but absent in dog and cat. He observed that the interstitial space was chiefly occupied by reticular fibres, even though collagenous fibres were found surrounding the large blood vessels and uriniferous tubules.

Takeuchi et al.(1958) found that a relatively well vasculated interstitium surrounded the groups of urinary tubules between the outer medulla and the papilla. He noticed lymph spaces in the apex of the papilla.

Montfort & Perez-Tamayo (1962) carried out an experiment over the ratio of parenchyma and collagen in normal and hypertrophic rat kidney and he found that the ratio was the same in both the conditions.

Intertubular cell group or Becher's cells

Schloss (1946) observed the intertubular group of cells in the human kidney. He attributed endocrine function to these cells.

Neumann (1949) found that the intertubular cell groups were absent in proximity of the glomeruli of the human kidney.

Becher (1949,1950) observed that these cell-isletes were located in the close proximity of the afferent arteriole and other cortical vessels in human kidney. He termed these cell-isletes as "paraportal cell-isletes". He stated that these cells were probably responsible for the regulation of the blood flow through the Malpighian corpuscles of the kidney.

Yadava (1955) demonstrated Becher's cells in all animals of his investigation save the cat.

Bucher & Reale (1961) advocated for further study of Becher's cells, because these cells were not definitely observed even in ultra thin sections.

Cell unit of Goormaghtigh or socleplasmodium

Kaufmann (1942), Schloss (1946), Neumann (1949) and Becher (1949,1950) observed a cluster of small cells (cells of Goormaghtigh) in the angle between afferent and efferent arterioles of the glomerulus in human kidney.

Becher (1950) considered this cluster of small cells to be an area of nerve receptors.

Yadava (1955) observed the cell unit of Goormaghtigh in the kidneys of all the species of his experiment i.e. ox, horse, dog, sheep, goat, pig and cat.

Ham (1961) described that these small cells with pale nuclei were situated between the macula densa and the glomerulus proper, in the concavity between the afferent and efferent arterioles in human kidney. He stated that their nature, function, or nomenclature were obscure.

Bucher & Reale (1962) with the aid of electron microscope, found that the cells of Goormaghtigh were embedded in a framework of irregularly running basement membranes in the mouse kidney. They maintained that Goormaghtigh cells were in close topographical and most probably functional relationship with the juxtaglomerular cells and the macula cells, although separated from them by an uninterrupted basement membrane. They observed that there were no blood capillaries within the heaps of Goormaghtigh cells. The nuclei were seen some what flattened ellipsoids with nucleoli occasionally visible. The cytoplasm was found very poor in the cell unit of Goormaghtigh.

Ito et al.(1962) found that the Goormaghtigh cell group was present between the macula densa and the vascular pole of the renal corpuscle in the bat kidney. It was located in the tunica propria of the epithelium of the intercalated tubule in contrast to the macula densa, being contained in the connective tissue continuous with the axial connective tissue of the glomerulus and with the tunica externa of the afferent duct.

Faarup (1965) made an investigation on the Goormaghtigh cells in the rat kidney. He observed that cell group of Goormaghtigh was largest in the juxtamedullary region. This was in contrast to the highest number of macula cells found in the sub-capsular region.

Blood Vessels

MacCallum (1926) observed "arteriolae rectae spuriae" in the kidneys of dog and cat. He did not find the "arteriolae

rectae verae".

Bieter (1929) stated that an aglomerular arteriole extending directly from an afferent arteriole to the peritubular capillary plexus was observed by Ludwig and hence the term "Ludwig's arteriole" was employed in honour of the scientist.

Fitzgerald (1940) found in 10% of the horses and 5% of the dogs, that each kidney was supplied by two main renal arteries.

Cowdry (1950) reported that the interlobular arteries were typical "end-arteries" and they did not anastomose with one another. However, occasional anastomoses between these arteries and the branches of the phrenic, adrenal,intercostal or capsular arteries were observed.

Kazzaz & Shanklin (1951) observed that the kidney of dog had a system of stellate veins which were drained into interlobular veins on the lateral side and directly into the renal vein on the medial side of the kidney. In case of the cow and sheep, the veins were found to start as spur-like projections which joined the interlobular veins.

Christensen (1952) observed the presence of a few isolated "arteriolae rectae verae" and "Ludwig's arterioles" in the kidney of dog.

Smith (1958) stated that the efferent arterioles of the cortical glomeruli were much smaller than the afferent arterioles, whereas in the juxtamedullary glomeruli, the efferent arterioles were nearly as large as the afferent

arterioles in man and animals.

Fourman & Moffat (1963) observed that in the rat kidney, some of the glomeruli which lay just deep to the pelvic mucosa had an efferent vessel which passed along the crescentic mucosal margin to anastomose with the efferent vessel of a neighbouring glomerulus to constitute a "marginal artery". This marginal artery supplied branches to the pelvic plexus and gave off a series of vasa recta which left it at right angles. The plexus was seen to be drained by vessels which entered the main hilar vessels, either directly or in conjunction with the collecting veins from the medulla.

Wrobel (1963) found that each lobe of the sea-lion kidney was supplied by 2 to 4 lobar arteries. Each lobar artery was observed to have 3 to 5 sub-cortical arteries at the corticomedullary junction. Further, they saw that each lobe of the kidney was drained by interlobar veins.

Copenhaver (1964) presented a nice and systematic description of the renal artery of man. He stated that the renal artery gave off "interlobar arteries" which bent sharply at the corticomedullary zone to be continued as "arcuate or arciform arteries". He contended that there was no communication between these arcuate arteries. Further, he described that the large arcuate arteries were split into a large number of "interlobular arteries" which ascended perpendicularly through the midway between the adjacent medullary rays, where they broke off into afferent glomerular vessels. Referring the blood vessels of medulla, he maintained that

the efferent glomerular artery of the juxtamedullary region, descended as "arteriolae rectae spuriae" and the direct branches from the arcuate artery as "arteriolae rectae verae" in the medulla.

Plakke & Pfeiffer (1964) demonstrated that the specialised blood vessels of the renal medulla (vasa recta) comprised of parallel, relatively unbranched vessels which broke up into plexus at different levels of the medulla.

Circulation through the kidney

Morison (1926) noted that the parenchyma of the cortex was supplied by the efferent glomerular vessels and in addition by the occasional nutrient branches from the interlobular arteries in the kidneys of man, cat, dog, rabbit, monkey, deer, sheep and pig. He observed only arteriolae rectae spuriae supplying blood to the medulla.

MacCallum (1939), Oliver (1939), Loomis et al. (1942) and Shonyo and Mann (1944) established that in human pathological kidneys, many degenerated glomeruli might be seen in which capillary tufts had virtually disappeared. The afferent and efferent arterioles formed a continuous trunk through the vestige of the glomeruli and were united by a single dilated glomerular capillary.

Trueta et al. (1947) thought that the aglomerular vessels formed by the glomerular degeneration were identical with the "arteriolae rectae verae" of other investigators. The authors believed that similar degenerative changes led to the formation of "Ludwig's arterioles". Thus they reaffirmed

that in the normal human kidney all the renal blood was made to pass through the glomeruli (cortical or juxtamedullary) and the medullary blood supply was wholly through the juxtamedullary glomeruli.

Moses and Schlegel (1952) demonstrated blood in the juxtamedullary glomeruli and vasa recta of the medulla, but there was ischaemia of the outer cortex after ligation of the renal artery. They also found direct vascular connections between the vessels of the renal capsule and those of perirenal and perihilar tissues. They observed that the stripping of the capsule and periureteral tissues let to complete renal ischaemia.

Moffat & Fourman (1963) distinguished four well-marked vascular zones in the rat kidney.

(1) Cortical zone - consisting of interlobular vessels, the glomeruli and a profuse intertubular network of capillaries.

(2) Sub-cortical zone - consisting of wide-meshed capillary network besides the juxtamedullary efferent vessels.

(3) Outer medullary zone - consisting of a number of vascular bundles surrounded by a dense intertubular capillary network.

(4) Inner medullary zone - consisting of a capillary plexus like outer medullary zone and free capillary loops.

Rollhauser et al.(1964) studied the vascular pattern around the convoluted and straight tubules in the cortex of rat kidney. They observed that the arteries of both capillary regions were vasa efferentia which ran parallel but joined one venous pathway.

Arteriovenous anastomosis

Simkin et al. (1948), by the recovery of glass spheres measuring 50 to 180 μ and 90 to 400 μ in diameter from the venous circulation after being injected into the renal arteries of rabbit and human kidneys respectively, came to know the certain evidence of renal arteriovenous anastomoses as the spheres of those sizes could hardly pass through the capillary bed.

Barrie et al. (1950) found that in the corticomedullary junction, certain tightly coiled arterioles derived from the arcuate arteries made direct communications with adjacent veins through one or more sinusoids and thus constituted arteriovenous anastomosis in the human kidney.

Christensen (1952) observed no arteriovenous anastomoses in the kidney of dog.

Moffat & Fourman (1963) observed that there was no direct communication between the vasa recta loop and the venous system.

Lymphatic Vessels

Pierce (1944) observed lymph capillaries in the vicinity of the Bowman's capsule and interconnections between the cortical and perirenal lymphatics, in the kidneys of dog and rabbit.

Takeuchi et al. (1961) demonstrated renal lymphatics which were generally accumulated in the corticomedullary zone. The medullary lymphatics were seen running parallel to the peritubular capillaries with occasional direct contact with the

basement membrane of the tubule at the level of the distal nephron, the loop of henle and the distal portion of the proximal tubule. This finding suggested an important role for absorption of water and some electrolytes on the one hand and for the mechanism of interstitial oedema in the medulla on the other.

Nerves

Bradford (1889), Gruber (1933), Harman & Davies (1948a,1948b) and Smith (1958) observed that the afferent fibres, atleast from the renal pelvis and ureter and possibly from the renal parenchyma, had to play an important role in renal pain and in some types of anuria involving reflex vasoconstriction. Some of the preganglionic sympathetic fibres had synaptic junction in the lateral ganglia, others in the collateral ganglia and still others in the kidney itself. Neither sympathetic vasodilators nor vagal fibres to the kidney were demonstrated.

Smith (1958) stated that sympathetic vasoconstrictor nerves richly supplied the kidney of dog. These nerves were said to arise from the last four dorsal segments in the dog but from the fourth dorsal to the fourth lumbar segments in man. The renal plexus was described to be an outcome of all these fibres which after passing through the splanchnic and abdominal ganglia entered into its formation. From the renal plexus, the nerve fibres were said to enter into the kidney with the renal vessels and finally terminate among the afferent and efferent arterioles. Further, he mentioned that the nerve fibres were

found to penetrate the basement membrane to be ended adjacent to the tubular cells, especially in the proximal segment, and others terminated among the juxtaglomerular cells, in the parietal layer of Bowman's capsule and in the perivascular spaces of the glomerular tuft. However, the recognition of such fibres as afferent or efferent remained unsettled.

Schwalew (1963) studied the innervation of the nephron in mice, cats, rats, dogs and rhesus monkeys by silver impregnation method. He also examined the development of the innervation of rabbit and human kidneys during ontogenesis. It was established that the nephron was supplied with afferent and vegetative nerve fibres growing up above the blood vessels and out of the connective tissue and smooth muscle capsule of the organ as well.

Shvalev (1964a) studied the afferent elements of the intrinsic nervous apparatus in the kidney of cat,white mouse and dog.

Shvalev (1964b) observed that in the kidneys of rat, mouse, rabbit, cat, dog,Macaca rhesus and man, the nephron had an abundant innervation. The typical feature in the structure of the afferent nerve endings of the nephron was the distribution of endings both on the Malpighian body and on the adjacent uriniferous tubules.

Simpson & Devine (1966) found that the arterioles of sheep renal cortex had a rich innervation. Bundles of 3 to 5 axons were seen to lie down in the adventitial coat of the arterioles, widening out at intervals to form little nodes.

MATERIALS AND METHODS

Source of Animals

The present investigation included observations on forty kidneys from twenty Indian buffaloes, of which eight were female between 9 to 14 years of age and the rest twelve were males between 2 to 3 years of age. All the adult females were slaughtered in the local slaughter house at Sahganj, Patna. Out of twelve calves only three were killed by bleeding through the common carotid artery and embalmed with freshly prepared 10% formalin solution and the rest nine were killed by injecting super saturated solution of magnesium sulphate into the heart. The embalmed carcases belonged to the Department of Anatomy and the rest to the Department of Surgery, Bihar Veterinary College, Patna.

Techniques

Gross

Both, right and left kidneys were weighed with the aid of physical balance. The greatest length, breadth and thickness of both the right and left kidneys were measured separately with an ordinary tape due to non-availability of slide callipers. The superficial lobes were counted in each kidney with the intact capsule of the organ.

Histological

Fixation: The kidneys taken from the freshly killed animals of abattoir and Department of Surgery were split longitudinally with a sharp knife and put into 10% formalin solution in which they were allowed to remain for atleast two days for fixation. The kidneys from embalmed carcases did not require further preservation.

Preparation of blocks: In preparation of the blocks from the fixed tissues, the technique employed by Barrie (1953) was closely followed to have anatomic continuity of renal tubules. Small blocks of approximately one centimetre wide and half centimetre thick were obtained from four different parts of each kidney. Out of four blocks, two blocks were cut in the vertical plane of the straight collecting tubules and the papillary ducts in such a way as to include the capsule, cortex, medulla and papilla of the organ. The third and fourth blocks were cut transversally in the medullary and cortical regions respectively.

Water and alcoholic wash: Some blocks thus obtained were then washed in running tap water for 6 to 12 hours and then put in a jar containing 70% alcohol for 12 to 16 hours.

Some blocks on the other hand were only kept in the jar containing 70% alcohol for alcoholic wash of the tissues.

Dehydration: The tissues after getting rid of the fixative under the preceding process were then passed through

the three jars of dehydration as follows.

1. Jar I - containing half N-butyl alcohol and half 95% of ethyl alcohol --- 4 hours
2. Jar II- containing N-butyl alcohol --- 4 "
3. Jar III- containing N-butyl alcohol ---16 "

Clearing and infiltration: After dehydration the tissues were made to pass through the four jars of this process which were kept inside the paraffin oven at 60°C.

1. Jar I - containing half N-butyl alcohol and half 52°C paraffin --- --- 2 hours
2. Jar II - containing 52°C paraffin --- 2 "
3. Jar III- containing 52°C paraffin --- 2 "
4. Jar IV - containing 56°C paraffin --- 18 "

Embedding: The tissues were embedded in hard paraffin (62°C) as the work was carried on during summer days.

Sectioning: Usually the sections were cut at 5 microns but a few at 3, 7 and 10 microns. Approximately fifteen hundred slides were prepared.

Staining: Nearly seven hundred slides were stained with the following different stains.

I. Harris's alum haematoxylin and counter stain ethyl eosin were used as a routine method of staining. The majority of the slides were stained with these stains.

II. Weigert and VanGieson's stains were employed for elastic and collagenous tissues and muscle fibres (Mallory,1942).

III. Gallego's iron fuchsin stain was adopted for collagen and reticulum, muscle, elastic fibres and mast cell granules (Lillie,1948).

IV. Gridley's reticulum stain was selected for reticular fibres (Gridley,1951).

V. Periodic Acid Schiff reaction technique was practised for the granular cells of the juxtaglomerular apparatus, and the basement membrane of the glomerulus (McManus, 1948).

The Schiff's leuco-fuchsin solution was prepared according to the prescribed formula of McManus but for the addition of animal charcoal (1 gram in 100 cc. of the standard solution) which improved the results (followed at I.V.R.I., Izatnagar).

Mounting: The mounting of all the stained sections was done with 'Depex'.

Methods of Measuring

The diameters of the cortical renal corpuscle, juxtamedullary renal corpuscle, cortical renal glomerulus, juxtamedullary renal glomerulus, proximal convoluted tubule, thin segment of Henle's loop, distal convoluted tubule, straight collecting tubule and the papillary duct were measured with the aid of an'ocular micrometer'which was standardised with a

'stage micrometer'. Similarly the heights of the lining epithelial cells of the proximal tubule, thin segment of Henle's loop, distal tubule, collecting tubule and papillary duct were measured with the help of an 'ocular micrometer'. As the average of six measurements were considered statistically significant, only six slides from all the eight she-buffaloes and only ten male calves were selected for the measurements of the different structures seen under the light microscope. Thus the average of six measurements from each animal gave the measurement of the particular structure of that animal. Further, the mean of the averages of all the measurements in different animals of the same age group gave the final average measurement of the particular structure in the animals of that age group.

RESULTS AND DISCUSSION

Gross Anatomy

The kidneys of Indian buffaloes present the following features.

They are red-brown in colour. The colour is darker than that of ox. The left kidney is oval and some what elongated in shape. The right kidney is more or less triangular in shape and some what flattened dorsoventrally, with the angles rounded off. The superficial lobations are clear with their number varying from 16 to 21. The fissures, of varying depths which demarcate the lobes, are filled with connective tissues. The sizes of the lobes are greater in the adults than in the young animals, but reverse in the case of number. The approximate weight of the right kidney is 394 gms. and that of the left is 434 gms. in the adult animals. The greatest dimensions of the adult kidneys are more or less similar to the kidneys of ox as described in "Anatomy of the ox" (I.C.A.R.publication,1964). The greatest length, breadth and thickness of the right kidney of the Indian buffaloes are 15.0 cms., 9.7 cms. and 4.3 cms. respectively.The left kidney measures 13.4 cms. in length, 7.6 cms. in breadth and 6.8 cms. in thickness. The weights and dimensions of the kidneys of young calves do not present any special feature.

The hilus in the left kidney is a deep fissure situated on the anterolateral part of the dorsal surface. The hilus of the right kidney is located almost in the centre of the ventral

TABLE - I

WEIGHT, LENGTH, BREADTH AND THICKNESS OF THE KIDNEYS OF INDIAN BUFFALOES

Male

Sl. No.	Age (Yrs)	Weight (Gms)		Length(Cms)		Breadth(Cms)		Thickness(Cms)	
		Right	Left	Right	Left	Right	Left	Right	Left
1	2	165.0	172.0	11.7	11.2	6.2	5.5	3.3	4.3
2	2½	170.0	173.0	11.7	10.4	6.5	7.0	3.2	3.7
3	2	151.0	157.0	10.5	10.4	6.6	7.2	4.0	4.3
4	2	141.0	153.0	10.7	10.2	6.8	6.8	3.0	3.4
5	3	202.5	233.5	12.8	11.0	7.9	5.5	4.0	4.4
6	2	133.5	143.5	11.5	11.2	6.8	4.3	3.1	3.8
Total		963.0	1032.0	68.9	64.4	40.8	36.3	20.6	23.9
Average		160.5	172.0	11.5	10.7	6.8	6.1	3.4	4.0

Female

Sl. No.	Age (Yrs)	Weight (Gms)		Length(Cms)		Breadth(Cms)		Thickness(Cms)	
		Right	Left	Right	Left	Right	Left	Right	Left
1	10	465.2	511.2	14.9	14.0	10.4	9.1	5.3	8.4
2	9½	410.8	435.8	14.3	13.0	8.1	7.9	4.1	5.6
3	14	510.6	524.6	16.2	13.5	11.2	8.3	4.1	7.8
4	13	397.2	439.2	14.9	13.2	10.4	6.1	4.3	7.7
5	13½	387.2	361.2	14.6	13.0	10.2	8.9	4.1	6.4
6	15	332.8	388.8	15.3	14.1	8.9	6.6	5.5	6.3
7	13	255.8	373.8	14.8	13.2	8.9	6.3	3.1	5.4
Total		2759.6	3034.6	105.0	94.0	68.1	53.2	30.3	47.6
Average		394.2	433.5	15.0	13.4	9.7	7.6	4.3	6.8

surface. The renal pyramids are easily demarcated from one another when seen in a longitudinally split up specimen from its cut surface. The renal papillae project into the calyces minores which are snugly fitted to them. The calyces minores join each other to form two calyces majores which finally unite to form the ureter. The pelvis is absent in the kidney of Indian buffalo.

Blood Vessels

The renal artery and renal vein are seen in the hilus of the organ along with the ureter, nerves and lymphatics. The renal artery divides into interlobar arteries which are sharply bent at the bases of the renal pyramids and are hence called arciform or arcuate arteries. The arciform arteries give off several interlobular arteries which ascend towards the capsule through the middle of the two adjacent medullary rays. On its way the interlobular artery gives of numerous branches which are the afferent arterioles of the glomerulus. The efferent arterioles of the glomerulus in the cortical region of the organ supply the uriniferous tubules and the capsule of the organ. The efferent arterioles of the juxtamedullary zone on the other hand form the "arteriolae rectae spuriae" to supply the medulla of the kidney.

The renal vein has the same course as that of the artery. The calibre of the vein is greater than that of the artery. The main renal vein is formed by the interlobar veins which are the resultants of the fusion of the interlobular veins. The sharp bending of the interlobar vein is called the arcuate

vein which is the satellite vein of the corresponding artery. The interlobular vein is formed by the confluence of the stellate veins which are the out come of the union of the small vennules draining the capsule and the cortex of the kidney. The "venae rectae" are the satellites of the arteriolae rectae spuriae and they join the arcuate veins.

Nerves

From the renal plexus which is the part of the sympathetic nervous system, the mostly amyelinated nerve fibres enter the kidney in company with the renal vessels. These nerve fibres finally terminate among the afferent and efferent arterioles.

Microscopic Anatomy

Capsule

The kidney of the Indian buffalo is enveloped in a "fibrous capsule" which is easily removable in normal condition. A fibrous hyperplasia leads to a firm attachment of the capsule with the parenchyma of the organ.

The "tunica fibrosa" (fibrous capsule) is morphologically divisible into an outer and inner layers. The outer layer contains mostly the dense collagenous fibres. These dense collagenous fibres take red stain with Weigert & Van Gieson's stain. The fibres almost run parallel to the outer surface of the kidney. A few elastic fibres are also present besides the collagenous fibres in the outer layer of the capsule.

The inner layer comprises of a mixture of loose collagenous, reticular and smooth muscle fibres. With the aid of

Gridley's stain it has been seen that the reticular fibres form the meshes for fibroblasts and muscle cells. The presence of blood vessels in this layer is not uncommon. It is with the Gallego's stain that the clear demarcation between the external collagen and reticular fibres and internal smooth muscle cells can be evidenced by the deep blue colour of the former and greenish to orange-yellow of the latter. A definite layer of the muscle fibres thus seen can lead to an establishment of a third layer in the innermost part of the capsula fibrosa. The muscle cells are seen descending into the intertubular spaces with the collagenous and reticular fibres. Some muscle cells are seen surrounding the secretory tubules which lie in the close proximity of the capsule. The notable difference between the capsules of adult and young kidney is regarding the muscle cells which are less developed in the latter. Due to the close contact of the inner layer of the capsule with the underlying renal tubules, a corrugation is observed in between the capsule and the kidney parenchyma.

Outside the fibrous capsule, the white adipose tissue form a distinct layer which can be termed as "capsula adiposa". The cells of this layer are white fat cells with the clear eccentric nuclei seen under the light microscope.

The renal fascia as described by Rayner (1956) is also seen outside the perinephric fat in the buffalo kidney. This first fascial membrane (renal fascia) is made up of loose collagenous fibres and is of meagre thickness.

Rammersen & Staubesand (1961) described a simple fibro-lipo-vascular capsule in the dog kidney. But the present investi-

gation

-gation suggests that a capsule of complex nature is present in the kidney of buffalo.

Uriniferous Tubule

The kidney is an agglomeration of chiefly a large number of uriniferous tubules. As such this is called a compound tubular gland. Each uriniferous tubule has two segments.

(i) A secretory tubule or nephron

(ii)A collecting tubule.

Nephron

The nephron is unit structure of the kidney, both from morphological and physiological stand points. It is made up of the following different parts.

(i) The renal corpuscle

(ii) The proximal tubule

(iii)The thin segment of Henle's loop

(iv) The distal tubule.

The renal corpuscle. The renal corpuscle or Malpighian corpuscle comprises of Bowman's capsule and the glomerulus. It has two poles - vascular and urinary. The vascular pole is the place where afferent and efferent arterioles enter and leave the corpuscle. The urinary pole on the other hand is nearly opposite to the vascular pole and is marked by the point where the proximal tubule starts dilatation to form the Bowman's capsule.

The renal corpuscle of the kidney of Indian buffalo shows variation in diameters between cortical and juxtamedullary regions. The average transverse diameters of the cortical and juxtamedullary renal corpuscles in young are 139 μ and 130 μ respectively. In adult their measurements are 168 μ in the cortical region and 156 μ in the juxtamedullary zone. This observation tallies with the findings of Yadava (1955) who observed that the cortical renal corpusces were greater than those of juxtamedullary zone in ox.

The glomerulus. It is the tuft of capillaries formed by the abrupt divisions of the afferent arteriole which further subdivide to form the complex capillary loops.

Just like the renal corpuscles, the cortical glomeruli are larger in diameter than those of the juxtamedullary zone. The cortical and juxtamedullary glomeruli are 107 μ and 95 μ in young and 138 μ and 123 μ in adults respectively.

Yadava (1955) observed that the cortical glomeruli were greater than those of the juxtamedullary zone in the case of ox kidney. In the present investigation also a similar difference has been observed.

The glomerular capillary tuft. The tuft of glomerular capillary in the kidney of Indian buffalo is formed by the further subdivisions of the ramifications of the afferent arteriole. The efferent arteriole is formed by the fusion of the capillaries of the tuft. The capillary lumina is seen to have erythrocytes, almost all devoid of crenation.

TABLE - II

DIAMETER OF THE CORTICAL AND JUXTAMEDULLARY RENAL CORPUSCLE AND GLOMERULUS IN THE KIDNEY OF INDIAN BUFFALO

(in microns;average based on six counts/animal)

MALE

Sl. No.	Age (yrs.)	Renal Corpuscle		Glomerulus	
		Cortical (diam.)	Juxta-medullary (diam.)	Cortical (diam.)	Juxta-medullary (diam.)
1	2	133	123	103	93
2	2	137	129	106	92
3	2½	146	138	110	99
4	2	144	133	110	98
5	2½	142	132	101	93
6	2	136	130	101	96
7	2	129	118	96	88
8	3	147	137	112	99
9	2	141	134	116	105
10	2	141	136	108	91
11	2	133	123	104	87
12	2	139	131	111	94
Total -		1668	1564	1278	1135
Mean average (approx.)		139	130	107	95

TABLE - III

DIAMETER OF THE CORTICAL AND JUXTAMEDULLARY RENAL CORPUSCLE AND GLOMERULUS IN THE KIDNEY OF INDIAN BUFFALO

(in microns;average based on six counts/ animal)

FEMALE

Sl. No.	Age (yrs.)	Renal Corpuscle		Glomerulus	
		Cortical (diam.)	Juxtamedullary (diam.)	Cortical (diam.)	Juxtamedullary (diam.)
1	10	159	150	141	123
2	9	174	162	140	128
3	9½	153	142	125	103
4	14	198	184	161	148
5	13	176	159	135	123
6	13½	160	143	138	125
7	15	175	163	137	114
8	13	151	144	128	118
Total		1346	1247	1105	982
Mean average (approx.)		168	156	138	123

In the present investigation, a dilatation in the afferent arteriole after its entrance into the renal corpuscle, has not been found. Thus this goes to support the finding of Codden (1949) who did not observe any such dilatation in the afferent arteriole of the human kidney.

The intercapillary or axial space. The axial space in the glomerulus of the buffalo kidney has been found to contain the collagenous and reticular fibres surrounding the tuft. Periodic Acid Schift (P.A.S.) positive deposits in the glomerulus have been also noticed in a few cases. Among the cellular elements, fibroblasts and histiocytes have been observed in the axial space of the glomerulus.

The presence of collagen and reticular fibres, and fibroblasts and histiocytes are in support of the similar observations made by Yadava (1955) who found all these structures present in the kidneys of ox, horse, dog, pig, sheep, goat and cat.

Though much attention has been paid by the recent investigators towards the mesangium of the axial space, the field is still open for further investigation. As regards the present investigation is concerned, the attempts have not been made to solve the existing controversy over the mesangium because of the confinement of the present work with light microscope.

The three primary membranes of glomerulus. The three primary membranes of the glomerulus comprises of -

(a) Visceral layer of the Bowman's capsule

(b) Basement membrane

(c) Endothelium

The present investigation reveals the presence of all these three membranes in the kidney of Indian buffalo.

Bowman's capsule. This capsule is the invagination of the terminal portion of the proximal tubule which expands to envelope the glomerulus of the kidney. The Bowman's capsule thus formed is made up of two layers - Parietal and visceral. In between parietal and visceral layers, a space termed "capsular space" is formed because the two layers do not come in contact with each other. This space is continued into the lumen of the proximal convoluted tubule.

The parietal layer of the Bowman's capsule is made up of flattened epithelial cells. The basement membrane of this layer is composed of collagen and reticular fibres.

This visceral layer of the Bowman's capsule has epithelial cells like those of the parietal layer. The glomerular capillaries are enveloped by this layer.

The capsular space has been found of greater width in the adult kidneys than those of the young calves.

The observation made during the present investigation tallies with that of Yadava (1955) so far the lining cells of the parietal and visceral layers of Bowman's capsule are concerned.

The juxtaglomerular apparatus or polkissen. The juxtaglomerular apparatus consists of myoepitheloid cells which are the modified cells of the media of the afferent arteriole of the glomerulus. This modification of the cells of the media of afferent arteriole takes place just before the entrance of the afferent arteriole into the glomerulus.

The afferent arteriole of the glomerulus of the buffalo kidney, near the macula densa presents a cuff of large and pale-staining cells which have been found more dense towards the macula densa. A material difference has been noted between the juxtaglomerular cells of young and adult animals. The juxtaglomerular cells with the typical rounded nuclei are less numerous in the calves than in the adult buffaloes. The cell cytoplasm of the juxtaglomerular cells contains granules in place of the myofibrils. These granular cells which are P.A.S. positive are found more in the adult than in the young ones.

Maximow & Bloom (1952) observed that the juxtaglomerular cells were absent in the kidneys of children below 2 years of age. In this investigation also it has been seen that the juxtaglomerular cells are more distinct in adults than in the young animals.

The proximal tubule. The proximal tubule has two portions - pars convoluta and pars recta. The pars convoluta is the looped and tortuous portion of the proximal tubule, situated in the close proximity of the renal corpuscle from which it originates. The proximal convoluted tubule enters

the medullary rays and becomes pars recta. The pars recta descends down as the descending thick limb of the Henle's loop. The other structures are similar in both subdivisions of the proximal tubule.

The proximal tubule of the kidney of calves has an average diameter of 36/μ, but in the case of adult females the diameter is 49/μ . The lining cells of the proximal tubule have an average height of 9/μ in young and 10/μ in adults. The lining cells are truncated pyramidal in shape. The cytoplasm of the lining cell contains P.A.S. positive granules which mask the cell boundaries. The basal striations are quite distinct. The nuclei of the lining cells are spherical in shape and they are usually situated towards the basal side of the cells. The brush border is distinct.

Mukherji & Sen (1964) found a considerable amount of argentaffin granules in the proximal tubules of the toad kidney. But in the present investigation no such granules have been noticed in the proximal tubules of the buffalo kidney.

<u>The loop of Henle</u>. The loop of Henle is comprised of a descending and an ascending limb joined by a sharp bend. Each limb has a thick and thin portion. The latter constitutes the thin segment of Henle's loop. The thick descending limb is formed by the pars recta of the proximal tubule. The thick ascending limb is formed by the pars recta of the distal tubule.

TABLE - IV

DIAMETER AND EPITHELIAL HEIGHT OF THE DIFFERENT TUBULAR SEGMENTS OF THE URINIFEROUS TUBULE IN THE KIDNEY OF INDIAN BUFFALO

(in microns;average based on six counts/ animal)

MALE

Sl. No.	Age (yrs)	Proximal tubule.		Thin segment of Henle's loop.		Distal tubule.		Straight collecting tubule.		Papillary duct.	
		diam.	EH*	diam.	EH	diam.	EH	diam.	EH	diam.	EH
1	2	35	8	17	4	29	5	33	8	47	18
2	2	36	11	15	4	25	5	35	8	48	18
3	2½	36	7	20	3	28	5	43	6	49	16
4	2	38	6	10	4	23	5	35	6	42	13
5	2½	31	8	15	4	25	5	33	6	50	14
6	2	33	10	15	4	27	6	37	6	47	13
7	2	35	8	17	4	28	6	35	6	43	18
8	3	41	10	16	4	30	6	36	6	55	20
9	2	38	10	18	5	30	7	32	7	48	18
10	2	40	11	14	4	30	6	35	6	50	18
Total		363	89	157	40	275	56	354	65	479	166
Mean average		36	9	16	4	28	6	35	7	48	17

TABLE - V

DIAMETER AND EPITHELIAL HEIGHT OF THE DIFFERENT TUBULAR SEGMENTS OF THE URINIFEROUS TUBULE IN THE KIDNEY OF INDIAN BUFFALO

(in microns; average based on six counts/ animal)

FEMALE

Sl. No.	Age (yrs)	Proximal tubule.		Thin segment of Henle's loop.		Distal tubule.		Straight collecting tubule.		Papillary duct.	
		diam.	EH*	diam.	EH	diam.	EH	diam.	EH	diam.	EH
1	10	51	10	24	5	45	8	46	6	72	22
2	9	48	9	25	6	41	8	45	8	73	22
3	9½	45	10	24	5	38	6	48	10	72	24
4	14	52	9	24	5	42	7	53	7	101	30
5	13	50	10	27	6	45	8	60	7	98	26
6	13½	53	12	26	6	45	8	53	7	78	24
7	15	46	11	23	5	41	6	47	9	98	29
8	13	48	11	23	5	41	8	48	8	78	26
Total		393	82	196	43	338	59	400	62	670	203
Mean average		49	10	25	5	42	7	50	8	84	25

*EH = Epithelial height. Mean average - Approximate.

The thin segment of the Henle's loop is smaller in diameter than either of the proximal and distal tubule. The diameter of the thin segment measures 16 μ in calves and 25 μ in adult animals. The epithelial cells are of simple squamous type with their nuclei bulging into the lumen of the tubule. The height of the epithelial cell is 4 μ in young and 5 μ in adult animals.

The distal tubule. The distal tubule is made up of two parts:

(i) Pars recta

(ii) Pars convoluta

The pars recta forms the thick ascending limb of Henle's loop. The pars convoluta lies near the glomerulus. The distal tubule makes a tangential contact over the afferent arteriole of the glomerulus where the crowding of the nuclei of the lining cells of the distal tubule along with the associated structures constitute the "macula densa".

The distal tubule is lined with a single layer of cuboidal cells with basal nuclei. The nuclei are oval or spherical in shape. The cytoplasm is granular and less eosinophilic. The basal striations are present but the brush border is absent. The lumen of the tubule is greater than that of the proximal tubule.

The diameter of the distal tubule is 28 μ in young and 42 μ in adult animals. The epithelial cell height has been observed 6 μ in calves and 7 μ in adult buffaloes.

The macula densa. The macula densa in the kidney of buffalo is constituted at the tangential contact of the distal convoluted tubule over the afferent arteriole. The cells taking part in the formation of this dense body are comparatively taller than those of the rest portion of the distal tubule. The cytoplasm of these cells take faint stain around the nuclei. The nuclei are seen spherical to oval in shape. The chromatin granules of these nuclei take dark stain. The macula cells are seen in the close vicinity of the juxta-glomerular cells.

Collecting tubule

The collecting tubule is made up of the following segments:

(i) Initial or arched or connecting tubule

(ii) Straight collecting tubule

(iii) Papillary duct or the duct of Bellini.

The arched collecting tubule. The arched collecting tubules are situated in the cortical labyrinth of the kidney. The lumen of the tubule is regular in out line. The cytoplasm of the lining cuboidal cells take faint stain and lack the characteristic granules of the nephron. The nuclei are basally located and more or less spherical in shape. The findings of the present investigation tally with those of Yadava (1955) who made an observation on the kidneys of domestic animals.

The straight collecting tubule. The straight collecting tubules are seen lying side by side in the renal pyramids. The lumen of the tubule is wider than that of the arched collecting tubule. The diameter of the straight collecting tubule in the young calves have been found to be of 35/μ as against 50/μ in those of the adult animals. The lining epithelial cells are from cuboidal to columnar in type. The cytoplasm of the lining cells is seen clear under the ordinary light microscope. The nuclei of the lining cells contain deeply stained chromatin granules. The nuclei are also seen with deeply stained nucleoli. The cell boundaries are clear. The height of the epithelial cell is 7/μ in young and 8/μ in adult animals.

Trautmann & Fiebiger (1957) described fat droplets in the smaller collecting tubules of large animals. No such fat droplets have been noticed in the kidneys of Indian buffaloes under this investigation.

The papillary duct. The lining epithelium of the papillary duct of the buffalo kidney has tall columnar cells which become transitional towards the opening of the papillary duct. The lining cells have non-granular cytoplasm. The nuclei are large and spherical in shape. They are almost located in the centre of the lining cells. The nucleoli and chromatin granules of the nuclei take darker stains. The transitional epithelium of the papillary duct in the kidney of Indian buffalo has been seen continuing over the renal papilla as the papillary epithelium.

The diameter of the papillary duct is 48/μ in young but 84/μ in adult animals. The height of the epithelium of the papillary duct is 17/μ in calves and 25/μ in the adult females.

The clear cut two layered epithelium as described by Trautmann & Fiebiger (1957) has not been seen in the papillary duct of the buffalo kidney. However, a few two layered cells have been seen at the junction of the simple columnar and transitional epithelium in some papillary ducts of the buffalo kidney.

The basement membrane of the uriniferous tubule

The basement membrane of the renal tubule in the kidney of Indian buffalo contains collagen fibres and reticular fibres. A few fibroblast cells have been also observed along with the collagen fibres. It has been seen with the aid of Gridley's stain that the reticular fibres form a thready periphery of the renal tubules.

Papilla

The papilla is the apex of the renal pyramid. It contains the openings of the papillary ducts at its surface i.e.on the "area cribosa". The transitional epithelium of the calyx minor is reflected over the surface of the papilla and is further continued on to the surface of the papilla as the papillary epithelium. The height of the transitional papillary epithelium becomes reduced towards the angle of reflexion. It has been observed that the papillary epithelium

is made up of only 2 layers of cells in the angle of reflexion. The transitional epithelium has been found to extend from the papillary surface to a varying distance into the papillary duct.

Interstitial Space

The interstitial space is occupied mostly by the reticular fibres which form network between the renal tubules. The reticular fibres are concentrated in the region of the aggregation of the "arteriolae rectae spuriae". Collagen and elastic fibres have been seen in the walls of the blood vessels situated in the interstitial tissue of the buffalo kidney. Along with the blood vessels, delicate collagenous fibres enter the glomerulus. Histiocytes and fibroblast cells are seen scattered in the interstitial tissue of the buffalo kidney.

The intertubular cell groups or Becher's cells

The intertubular cells are present in the interstitial space between the uriniferous tubules, near the Bowman's capsule and around the cortical arteries. The cytoplasm of the Becher's cells is non-granular. The cell boundaries are not discernible. Some cell groups are encapsulated with the collagen fibres. The nuclei are usually spherical in shape. Some oval nuclei have been also observed. Each nucleus has one deeply stained nucleolus in the centre of the cell and many in the periphery. The space between the nucleoli is almost clear having no chromatin granules.

Cell unit of Goormaghtigh or Socleplasmodium

The cell unit of Goormaghtigh is located in the angle formed by the afferent and efferent arterioles of the glomerulus in close association with the juxtaglomerular apparatus. It is comprised of small cells which are elongated in outline and are closely associated with each other. The cells take a faint stain. The nuclei of the cells are elongated. The cells are not distinctly demarcated from one another.

Bucher & Reale (1962) observed that there were no blood capillaries within the heaps of Goormaghtigh cells. In the present investigation also no such blood capillaries have been detected.

SUMMARY AND CONCLUSIONS

1. Gross and microscopic studies were made on the kidneys of twenty Indian buffaloes. The tissues were preserved in 10% formalin solution and sections were cut mostly at 5 & 7 microns. Haematoxylin and eosin were used as routine stains. Special stains, viz: Weigert & Van Gieson's stain, Gallego's stain, Gridley's stain and PAS technique were also employed for manifestations of the special structures.

2. The weights of the right and left kidneys are 160.5 & 172.0 gms. in the young calves and 394.2 & 433.5 gms. in the adult buffaloes respectively. The length, breadth and thickness of the right kidney are 11.5, 6.8 and 3.4 cms. and that of the left are 10.7, 6.1 and 4.0 cms., respectively in the young calves. But the dimensions of the right kidney are 15.0, 9.7 and 4.3 cms. and that of the left are 13.4, 7.6 and 6.8 cms., respectively in the adult animals.

3. The right kidney is triangular in outline, resembling the heart of the playing card. The hilus is situated almost in the centre of the ventral surface of the right kidney.

4. The capsule of the kidney of Indian buffalo presents a definite layer made up of smooth muscle cells in the deeper part of the tunica fibrosa. The first fascial membrane (renal fascia) has also been observed outside the perinephric fat. The blood vessels have been noticed in the inner part of the tunica fibrosa.

5. The cortical renal corpuscles are larger than those of the juxtamedullary zone. The cortical renal corpuscle has a transvers diameter of 139 /μ in young and 168 /μ in adult animals. On the other hand the juxtamedullary renal corpuscles are 130 /μ and 156 /μ in young and adult animals respectively.

6. The cortical glomeruli are also greater than those of the juxtamedullary zone. The cortical glomeruli are 107 /μ in young and 138 /μ in adult kidneys. The juxtamedullary glomeruli are 95 /μ and 123 /μ in young and adult animals respectively.

7. The axial space of the glomerulus contains fibroblasts and histiocytes besides the collagen and reticular fibres.

8. The capsular space has been found of greater width in the adult kidneys than those of the young ones.

9. The juxtaglomerular cells with the typical rounded nuclei are less numerous in the calves than in adult buffaloes. The PAS positive granular cells are more in the adult than in the young animals.

10. The proximal tubules of the kidney of young and adult animals have diameters of 36 /μ and 49 /μ respectively. The lining cells are 9 /μ in height in young and 10 /μ in adult animals. The lining cells have PAS positive granules which mask the cell boundaries. The brush border and basal striations are distinct.

11. The thin segment of the Henle's loop is smaller in diameter than either of the proximal and distal tubule. The

diameters of this segment in young and adult animals are 16/^{u} and 25/^{u} respectively. The height of the lining epithelial cell is 4/^{u} in young and 5/^{u} in adult animals.

12. The distal tubule of the buffalo kidney has a diameter of 28/^{u} in young and 42 /^{u} in adult animals. The epithelial cell height is 6/^{u} and 7/^{u} in young and adult animals respectively.

13. The macula cells are comparatively taller than those of the rest part of the distal tubule. The chromatin granules of the nuclei of these cells are deeply stained.

14. The diameters of the straight collecting tubules in young and adult animals are 35 /^{u} and 50 /^{u} respectively. The heights of the lining epithelial cells are 7 /^{u} in young and 8 /^{u} in adult animals.

15. The paillary duct is lined by a single layer of tall columnar cells except at the terminal portion where the epithelium becomes transitional. The transitional epithelium of the papillary duct is seen continued onto the surface of the renal papilla. The duct has a diameter of 48 /^{u} in young but 84/^{u} in adult animals. The heights of the lining epithelial cells in the transitional portion are 17 /^{u} and 25 /^{u}in the kidneys of calves and adult buffaloes respectively.

16. The reticular fibres surround the renal tubules. The fibres become more concentrated in the region of the "arteriolae rectae spuriae".

17. The papilla is lined by transitional epithelium which becomes two layered in the angle of reflexion.

18. The cell boundaries of Becher's cells are not discernible. The nuclei of these cells have a deeply stained nucleolus in the centre and many such in the periphery.

19. The cells of Goormaghtigh are not distinctly demarcated from one another. The heaps of Goormaghtigh cells are devoid of blood capillaries in the kidneys of Indian buffaloes.

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