THE STRUCTURE OF THE KIDNEY OF SOME TELEOSTEAN FISHES

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(With 8 Plates)

CONTENTS

I—INTRODUCTION

Zoologists from early times have paid attention to the structure, development and nature of the kidneys of fishes. Valuable contributions were made by Müller (1884), Balfour (1882), Sedgwick (1905). Kingsley (1926), Goodrich (1930), Bridge (1932), Parker and Haswell (1940) and

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others. In spite of all these, Owen (1938) remarked that, "The fish kidney has been the subject of several cytological and histological investigations, but confusion has resulted from the extreme diversity of kidney types in this group". Although several cytological and histological studies have been made by Grafflin (1929, 1933 and 1937), Smith (1929). Marshall (1930), Nash (1931), and others, the fish kidney still needs further investigation. This is not merely due to the diversified form and structure of the kidneys found in them, but also to the varying effect of the habitat upon them. It is generally admitted now that the kidneys of fishes bear the impress of the change or changes in habitat that occurred in their phylogenetic and evolutionary history. A study of the structure of the glomeruli and of the uriniferous tubules has enabled the zoologists to arrive at this conclusion. In a previous paper, the urinogenital system of sixteen species of Indian fresh-water fishes has been described by the present author, but we know little about the internal structure of the kidneys of these fishes. It was, therefore, felt that a study of the structure and condition of the glomeruli and of the uriniferous tubules present in the kidneys of these fresh-water fishes would yield useful information on a subject of which we have no knowledge at present.

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II—HISTORICAL RESUMÉ

Much work has been done in the past on the development of the kidneys in fishes. One of the earliest workers in this field was Emery (1882), who worked on the pronephros of *Feirasfer* and *Zoarces*. His studies revealed that in these fishes the pronephros is the functional kidney even in the adult. The developmental history of the pronephric tubule was given by Beard (1895) in the case of *Lepidosteus*, Dean (1897) in *Amia* and teleosts in general by Swean (1901). According to Beard, three pronephric tubules arise in *Lepidosteus*, while Dean and Swean found three to four of them in *Amia* and other teleosts, respectively. Semon and Kerr (1901) found the development of the tubules in the Dipnoi and in *Lepidosiren* to be similar, of the seven tubules in them, only two becoming functional.

Guitel (1906) points out that in *Lepidogaster* the pronephros functions as the adult kidney. Kerr (1907), while tracing the development of the pronephric tubules in *Polypterus*, found that while nine nephrocoeles became enlarged only five tubules developed. Out of these five, only two became functional.

Among those who have followed the development of the vertebrate kidney in general and of the fish kidney in particular mention may be made of Goodrich (1900), Felix (1905), Kingsley (1913) and Kerr (1926).

Renewed interest in the structure and function of the kidneys in fishes was awakened nearly a quarter of a century ago by the work of experimental physiologists. Grafflin (1929) studied in detail the structure of the kidney in several species of teleosts and in the lung-fishes and reported the occurrence of 'Cysts' in their glomeruli. Marshall and Smith (1930) studied the condition of the glomeruli in twenty-four species of fishes belonging to twelve families, both marine and fresh-water. As a result of their observations, they arrived at the conclusion that glomeruii are best developed in fishes inhabiting the fresh-waters, whereas aglomerular condition is found in fishes leading a marine life. Grafflin (1933) observed glomerular degeneration in *Myoxocephalus scorpius*. Owen (1938) described the form and histology of the Kidney of *Cyclothone* (a deep-sea fish).

From the foregoing account, it will be seen that kidneys have acquired a new value in zoological studies, and it is necessary to examine and report upon as many fishes as possible from diverse ecological habitats so that the foundation of the new knowledge may be well laid.

III—MATERIAL AND METHODS

Very great difficulty was experienced in procuring the material required for this work. The kidneys of *Hilsa ilisha*, *Eutropiichthys vacha*, *Wallago attu* and *Mystus aor* disintegrate and alter in structure soon after removal from the water. So they had to be dissected and fixed immediately after capture on the river bank. This necessitated frequent visits to the fishing grounds by the author in the early hours of the morning.

Equal-sized pieces of the head-kidney, the anterior, middle and the posterior parts of the kidneys behind the pericardium were secured as quickly as possible and fixed in Bouin's or Allen's fluid. The duration of fixation varied in different cases. Sections were cut 5 to 7 μ in thickness and stained with Iron haematoxylin, Delafield's haematoxylin or Mayer's Haemalum and counter-stained with Eosin.

The following fishes were selected for this work, because they had already been studied by the author on an earlier occasion and a clear knowledge of the topography and disposition of the parts of the kidneys was known to the author :—

1. *Rasbora rasbora* (Hamilton).
2. *Cirrhina mrigala* (Hamilton).
3. *Labeo rohita* (Hamilton).
4. *Catla catla* (Hamilton).
5. *Notopterus chitala* (Hamilton).
6. *Notopterus notopterus* (Pallas).
7. *Mastacembelus armatus* (Lacepede).
8. *Hilsa ilisha* (Hamilton).
9. *Clarias batrachus* (Bleeker).
10. *Heteropneustes fossilis* (Bloch).
11. *Eutroptichthys vacha* (Bleeker).
12. *Wallago attu* (Bloch).
13. *Mystus aor* (Hamilton).

14. *Ophiocephalus marulius* (Hamilton).
15. *Ophiocephalus gachua* (Hamilton).
16. *Ophiocephalus punctatus* (Bloch).

IV—THE KIDNEY

A close examination of the sections of the kidneys of the above mentioned sixteen species has revealed obvious differences between its several component regions, namely, the head-kidney*, the anterior, middle and the posterior portions of the kidney behind the pericardium. The difference is not confined only to the glomeruli as mentioned by the previous investigators but also to the renal tubules and the surrounding connective tissue.

CYPRINIDAE

1. **Rasbora rasbora** (Hamilton)

(Plate 38, Figs. 1-3)

In the head-kidney there is no trace of tubules or glomeruli. It is an undifferentiated mass of lymphoidal and connective tissues. The mass is poorly vascularised.

Glomeruli are present in all the three regions—anterior, middle and posterior, that is the portion behind the pericardium, but are non-vascularised in the anterior and the posterior regions. In the middle region, where a few of them are vascularised, many of them are *small* and *ill-defined.* On the whole, there are more non-functional glomeruli than functional ones.

In all the three regions, there are a number of renal tubules which lack proper definition. *The connective tissue is thick, vascularised and lymphoidal* (Pl. 38, Figs. 1-3).

2. **Cirrhina mrigala** (Hamilton)

(Plate 38, Figs. 4-6)

The head-kidney is an undifferentiated mass of connective and lymphoidal tissues. There is no trace of uriniferous tubules or glomeruli. The connective tissue is moderately abundant.

In *Cirrhina mrigala* also, glomerular degeneration is common. Different stages of the process of disappearance of the glomeruli are seen in sections of the same fish. Many of the glomeruli although otherwise well developed are non-vascularised, some of them being represented only by means of a few tufts, while others possess only a few scattered cells. Even capsules enclosing an empty space occur (Pl. 38, Figs. 4-6). *Only the posterior part of the kidney possesses a few vascularised glomeruli.*

The renal tubules also show signs of degeneration. The tubules are comparatively fewer in number than in *R. rasbora*, the intertubular spaces being occupied by abundant connective tissue.

**Note.*—The head-kidney has been studied without reference to the inter-ranal

3. **Labeo rohita** (Hamilton)

(Plate 39, Figs. 1-3)

In the head-kidney there is no trace of the tubules or the glomeruli. It is an undifferentiated mass in which the lymphoidal tissue is prominent but vascularization is poor.

Among the Cyprinidae, the kidney of *Labeo rohita* has very few glomeruli. In the anterior and the middle portions they are non-functional, whereas in the posterior portion, a few functional ones exist, but the non-functional ones predominate in number (Pl. 39, Figs. 1-3).

The anterior region of the kidney has a tendency to become lymphoidal because uriniferous tubules are few in number and an appreciable amount of lymphoidal tissue is present in this portion (Pl. 39, Fig. 1). In the middle region, *well-developed* urinary tubules are found and the lymphoidal tissue decreases in quantity. In the posterior region many of the urinary tubules are adversely affected by the presence of the lymphoidal tissue (Pl. 39, Figs. 2, 3), but a few functional ones exist.

4. **Catla catla** (Hamilton)

(Plate 39, Figs. 4-6)

The head-kidney is devoid of functional elements and consists of only an undifferentiated mass of poorly vascularised connective and lymphoidal tissues.

The glomeruli are present in the anterior and the middle portions of the kidneys lying behind the pericardium but they are wanting in the posterior section. A few functional glomeruli occur in the middle region (Pl. 39, Fig. 5), while those in the anterior portion are poorly developed and avascular (Pl. 39, Fig. 4). They are wanting in the posterior region (Pl. 39, Fig. 6).

The uriniferous tubules are fewer in number and surrounded by excess of connective and lymphoidal tissues (Pl. 39, Figs. 4-6).

The picture of the glomeruli, the urinary tubules and of the connective and the lymphoidal tissues indicates that degeneration has set in all the three portions of the kidney and the lymphoidal mass is gaining preponderance.

NOTOPTERIDAE

5. **Notopterus chitala** (Hamilton)

(Plate 40, Figs. 1-3)

The head-kidney which consists of only a dense and closely set lymphoidal tissue is devoid of all functional elements. It is very nearly avascular excepting for a few stray blood vessels.

There is no indication of the presence of glomeruli in the anterior section, but the same are present in the middle and the posterior portions. Some of the glomeruli in the middle region are vascularised, but those in the hinder portion are avascular (Pl. 40, Figs. 1-3).

Uriniferous tubules are absent in the anterior portion, while the few that occur in the middle or in the posterior portions are surrounded by lymphoidal tissue.

The structure reveals that renal function is confined only to the middle portion, while the anterior and the posterior portions are in a process of decay.

6. **Notopterus notopterus** (Pallas)

(Plate 40, Figs. 4-6)

The head-kidney consists of a lymphoidal mass and is highly vascularised, but there is no trace of the uriniferous tubules or the glomeruli.

Glomeruli are absent in the anterior portion of the kidney. A few glomeruli occur in the middle section but those in the posterior portion can be identified with difficulty and are represented only by degenerated glomerular tufts (Pl. 40, Fig. 6). As such their functional utility is doubtful.

In the head-kidney and to some extent in the anterior portion of the kidney there are strands of cells (Pl. 40, Fig. 4) which conform to the interrenals referred to by Chester Jones. In the middle and the posterior portions by far the greater part of the kidney consists of lymphoidal and connective tissues, which explains the paucity of and the damage done to the urinary tubules (Pl. 40, Figs. 4, 6).

MASTACEMBELIDAE

7. **Mastacembelus armatus** (Lacepede)

(Plate 41, Figs. 1-3)

A distinctly defined head-kidney is wanting.

Glomeruli are absent in the anterior portion of the kidney. In the middle region they occur in groups of three (Pl. 41, Fig. 2) of which only one is well developed and the rest are degenerated. Even these glomeruli are avascular. Glomeruli are hard to find in the posterior portion (Pl. 41, Fig. 3). In this species all the three portions of the kidney are therefore damaged.

The uriniferous tubules of the anterior region are indistinct and embedded in a dense lymphoidal mass. The urinary tubules of the middle and of the posterior portions are structurally degenerate and have been adversely affected by the lymphoidal tissue.

CLUPEIDAE

8. **Hilsa ilisha** (Hamilton)

(Plate 41, Figs. 4-6)

In the head-kidney the renal tubules are well defined, but no glomeruli can be identified. The tubules lie embedded in a dense mass of connective tissue, lymphoidal tissue is less prominent and the head-kidney is poorly vascularised.

Glomeruli are indistinct and degenerate in the anterior portion (Pl. 41, Fig. 4). The ones occurring in the middle and in the posterior sections of the kidney are also degenerate and avascular. Therefore, the glomeruli are either pseudo-structures or degenerate ones (Pl. 41, Figs. 5, 6).

Uriniferous tubules are discernible in all the three portions, but many of them are indistinct and hazy in outline both in the anterior and in the middle regions (Pl. 41, Figs. 4, 5). A few of them are recognisable in the posterior region but they are embedded in the connective and the lymphoidal tissues. In the anterior and the posterior portions, the lymphoidal and the connective tissues form the bulk of the kidney and the tubules constitute only an insignificant part of it (Pl. 41, Figs. 4, 6).

CLARIIDAE

9. **Clarias batrachus** (Bleeker)

(Plate 42, Figs. 1-3)

The head-kidney consists of an undifferentiated mass of lymphoidal tissue interspersed with connective tissue which is less prominent than the former and the whole mass is poorly vascularized.

Glomeruli are absent in the anterior region of the kidney of this fish and completely degenerate in the middle and posterior portions of it (Pl. 42, Figs. 2, 3).

Uriniferous tubules are present in all the three portions but their identity is ill-defined. However, their nuclei are large and prominent and acquire a deep stain. These nuclei proclaim the presence of the tubules inside the kidney (Pl. 42, Figs. 1-3).

SACCOBRANCHIDAE

10. **Heteropneustes fossilis** (Bloch)

(Plate 42, Figs. 4-6)

The head-kidney is devoid of all functional elements and the lymphoidal mass is avascular.

Glomeruli are absent from the anterior portion of the kidney of this fish but they occur in the posterior and the middle parts of it. Most of them are, however, degenerate with only a few cells in them and are avascular (Pl. 42, Figs. 5, 6).

The uriniferous tubules are better developed in the posterior portion of the kidney than in the anterior or middle sections. However, the lymphoidal tissue has adversely affected the tubules. Connective tissue occurs abundantly between the tubules (Pl. 42, Figs. 5, 6) in all the three portions of the kindney.

SCHILBEIDAE

11. **Eutropiichthys vacha** (Bloch)

(Plate 43, Figs. 1-3)

There is no well-defined head-kidney in this species.

Glomerular degeneration is evident in this fish. In the anterior portion the glomeruli are non-existant and in the posterior part they are degenerate though signs of their presence are available (Pl. 43, Figs. 1-3). They are well represented in the middle portion of the kidney but are of the avascular type.

The uriniferous tubules are present in the anterior and middle portions of the kidney but destroyed in the posterior section. The lymphoidal tissue displaces and destroys them in the posterior portion (Pl. 43, Figs. 2, 3). Although present in the anterior part of the kidney the tubules are basophylic and according to Grafflin such urinary tubule s are to be looked upon as non-functional. On the whole it looks as if the kidney is losing its pristine structure and becoming transformed into a mass of lymphoidal tissue.

SILURIDAE

12. **Wallago attu** (Bloch)

(Plate 43, Figs. 4-6)

The head-kidney is an undifferentiated mass of poorly vascularised lymphoid tissue in which the connective tissue is less in evidence to view.

The glomeruli in all the three sections of the kidney behind the yericardium are pseudostructures on account of being either degenerate or non-vascular (Pl. 43, Figs. 1, 3). The degeneration of the glomeruli is evident from the fact that often empty spaces or a few avascular tufts exist in their place. Excessive development of the connective tissue has destroyed the glomeruli as well as the urinary tubules.

The surrounding connective tissue is more prominently developed than the uriniferous tubules as mentioned above. Many of the tubules are indistinct and degenerate in appearance (Pl. 43, Figs. 1- 3).

BAGRIDAE

13. **Mystus aor** (Hamilton)

(Plate 44, Figs. 1-3)

The head-kidney is an undifferentiated mass in which the connective tissue is quite abundant but vascularization is poor.

A few glomeruli are present in all the three regions, but many are non-functional and degenerate. Some are degenerate because they are avascular ; others because of infiltration by the lymphoidal tissue. In the middle portion a few functional glomeruli exist.

In all the three parts of the kidney functional and degenerate urinary tubules exist side by side. The basophilic ones are non-functional.

OPHIOCEPHALIDAE

14. **Ophiocephalus marulius** (Hamilton)

(Plate 44, Figs. 4-6)

In the head-kidney and in the anterior and the posterior portions glomeruli are absent (Pl. 44, Figs. 4, 6). The few that occur in the middle portion of the kidney are also degenerate containing only a few scattered cells and being non-vascular (Pl. 44, Fig. 5).

In the anterior region functional and basophilic tubules exist ; those in the middle portion are functional. The tubules in the posterior part are destroyed by the excessive presence of connective and lymphoidal tissues (Pl. 44, Figs. 4, 6). There is a preponderance of the connective and the lymphoidal tissues in the kidney which adversely affects the uriniferous tubules and the glomeruli.

15. **Ophiocephalus gachua** (Hamilton)

(Plate 45, Figs. 1-3)

In the head-kidney the glomeruli are diffused and cannot be made out clearly. There is preponderance of connective and lymphoidal tissues.

Some of the glomeruli are well-developed and vascularised in the head-kidney as well as in all the three portions, but a few degenerate ones also occur among them (Pl. 45, Figs. 1-3).

The uriniferous tubules are better preserved in the middle portion, but many of them being basophilic are non-functional leaving a few functional ones. In the anterior and posterior regions a few of them are distinct and functional. Connective and lymphoidal tissues are present in all the three portions of the kidney.

16. **Ophiocephalus punctatus** (Bloch)

(Plate 45, Figs. 4-6)

There is a gradual increase in the number of glomeruli from the anterior to the posterior end of the kidney. Though some of them are non-vascular, others are vascularised and well-developed (Pl. 45, Figs. 4-6).

Though some of the uriniferous tubules are well-defined, most of them are adversely affected by the encroachment of the connective and the lymphoidal tissues. This is especially so in the middle and the posterior portions (Pl. 45, Figs. 4, 6).

V—FUNDAMENTAL STRUCTURE OF THE KIDNEY

The kidneys are the excretory organs of the fishes and are placed on the dorsal side of the body cavity below the vertebral column, extending from the cardiac region to the posterior end of the body cavity, and in some epecies extending even into the caudal region. In most cases, the kidneys of the Teleosteans are said to be fused (Kingsley). In fact, the present author found that the two halves of the kidney are fused at one or another point on their length. Even the colour, size and shape of the kidneys vary from species to species.

The kidneys are excretory tubules having become specialised and adapted to the needs of the fish and the environment as shown by Krogh (1939). Each renal tubule begins with a cup-like Bowman's capsule lined by a layer of squamous epithelium into which enters a branch of the renal artery that forms the glomerulus. This structure, since the days of Bowman (1842), is believed to perform the function of filtering the excess of water from the blood. Another set of capillaries collect the blood, now freed of extra water, and send it back for re-circulation through the renal veins.

Behind the capsule, there is a short 'neck' which soon passes off into what is termed the 'first convoluted' portion of the 'tubule' This, in turn, is followed by the U-shaped 'Henle's loop' having a descending and an ascending limbs. This again terminates in the second convoluted tubule' which opens into the collecting tubule emptying into the ureter. The tubules are lined by a single layer of glandular epithelial cells performing the function of abstracting excess of salts from the blood. These salts become dissolved in the water filtered by the glomerulus that passes through the tubules and thus the urine is formed which is eliminated from the body by urination. This *modus operandi* holds good in the case of freshwater fishes.

In the developmental history of the kidney of Teleostean fishes, two successive series of tubules known respectively as the Pronephros and the Mesonephros occur. Being transitory in existence, the former become changed into lymphoidal tissue in the adult and have often been referred to as the 'Head kidney' (*vide* Sedgwick (1905) and Kingsley (1926)), while the latter constitutes the functional 'Wolffian body' that persists throughout the life-time of the fish.

Several views are held in regard to the relationship obtaining between them :

"1. That they are parts of an originally continuous excretory organ called the 'Holonephros' which became divided into separate blocks differing in respect of the time of development and functioning.

2. That they are two independent organs.

3. That they are superimposed structures which occasionally overlap, being, therefore, not homologous but homodynamous structures."

Generally the first view finds acceptance at the hands of workers like Hyrtl (1854), Balfour (1886), Kingsley (1926), Goodrich (1930) and others.

According to accepted facts, the pronephros during development in most teleosts extends from one to the sixth somites. These have a tendency to form a common chamber and a glomerulus, but it is a short-lived structure except in *Zoarces*, *Lepidogaster*, and *Fierasfer* where the pronephros remains the functional kidney even in the adult.

The mesonephros that develops later and behind the pronephric tubules becomes the functional kidney of the adult teleosteans.

VI—HISTOLOGY AND PHYSIOLOGY OF THE KIDNEY IN FISHES

A survey of the literature bearing on this subject reveals that attention has been focussed on the piscine kidney only recently.

Grafflin (1929) and Smith (1929) were the pioneer workers in this direction. Subsequently, Marshall and Smith (1930) followed them up, and, more recently, Kempton (1943) has added to our knowledge of the structure of the Elamobranch kidney.

Grafflin (1929) working on *Lophius piscatorius* was amazed to find the limited number of glomeruli in its kidney. Further closer examination of the material revealed that the structure of the glomerulus was indistinct and unconnected with the renal tubules. This led him to doubt the functionalism of the glomeruli.

Working in collaboration with Nash and Marshall (1931-32) on the kidneys of *Myoxocephalus octodecimspinosus*, found the glomeruli well developed, but further tests proved that physiologically they were non-functional because the kidneys failed to eliminate.

"1. Glucose with a high-plasma level (even when phlorizin was administered),

2. Ferrocyanide,

and 3. Cyanol."

Grafflin performed these tests on sixteen individuals in different stages of development and concluded that glomerular degeneration had set in these fishes at a very young stage.

In *Myoxocephalus scorpius*, according to Grafflin, there are present all gradations of glomeruli from very good to very poor ones. In some of these glomerular function seemed possible, in others doubtful and in still others inconceivable. Many of the large sized glomeruli show considerable vascularity, others varying in size or degree of degeneration, and still others show difference in size of the intracapsular space (with or without intra-capsular coagulum).

Closer examination by Grafflin revealed that even the neck region of the urinary tubules are degenerated.

These observations coupled with his tests led him to prove that the glomeruli in *Myoxocephalus scorpius* are functionless.

During the next few years between 1933-1937, Grafflin worked on two lung-fishes, four marine teleosts and a horned toad. His studies showed a certain kind of cyst formation in the glomerular tufts of these species. He was led to believe that the cyst formation is not due to a parasite but due to the degeneration of the glomerular tuft.

"The view that cysts are formed by the degeneration and liquefaction of the central portion of the avascular tufts is upheld by the presence of an amorphous mass in the centre of the cyst of the horned toad and the scattered nuclei in the cyst of Corvina."

Smith (1929) suggests that the aglomerular condition is due to " the peculiar water cycle associated with a marine habitat. Fresh-water fishes take in a large quantity of water orally and this is eliminated through the kidneys, while marine fishes do not take in such a large quantity of the saline water orally and the little that is taken in is discharged extrarenally. Thus a persistent oliguria relative to fresh-water forms occurs in marine fishes and this oliguria is held to be the cause of the glomerular degeneration. "

Marshall's (1929 and 1930) studies revealed that about twenty-five species of fishes belonging to twelve marine and fresh-water families possess aglomerular kidneys. According to him, glomerular development is related to water-excretion. To prove this he advances three arguments.

" 1. The protovertebrate kidney was aglomerular and that the glomerulus was evolved as an adaptation to a fresh-water habitat.

2. That in the lower vertebrates, the extent of the glomerular development is related to the quantity of water normally excreted by the organism.

3. In the mammals (and possibly to some extent in lower vertebrates) the primitive water-excretory function of the glomerulus has been secondarily diverted to a filtration-reabsorption system designed to excrete waste products without the loss from the body of excessive quantities of water. "

Marshall asserts that " there is much evidence to show that the above mentioned twenty-five species of fishes were inhabitants of fresh-water or slightly brackish water. The permanent assumption of a marine life by the teleosts appears to be from Mesozoic times "

The tubular secretion and development depend, according to him on the extent of glomerular development.

Kempton (1943) observes that " Much emphasis has been laid by renal physiologists, including Marshall and Smith, on the presence of a "special segment" preceding the proximal convolutions in the elasmobranch kidney tubule. The existence of such a structure has been attributed to the reabsorption of urea in the Elasmobranchs by the renal tubules." But Kempton is of the opinion that, " If this were to be correct then there will be found a special cell structure associated with a specific cell function. "

By various injections and other experiments Kempton came to the conclusion that there is no " special segment" in the kidney tubule of *Sqalus acanthias* and asserts that such a segment should be absent from other elasmobranchs also, because the cells in the distal portion of the tubule meet with the description of the "special segment" described by other authors.

Owen (1938) described the kidney of a deep-sea fish, *Cyclothone*, as consisting of only two parallel tubules, each starting from a Bowman's capsule. He confines himself to the structural details only and information regarding the functional aspect of the glomeruli is not available from his paper. However, his description of the proximal convolute tubule as " having a droplet-like appearance as if about to be pinched off into the lumen " deserves our attention.

VII—DISCUSSION AND CONCLUSIONS

A close and careful study of the structure of the kidneys of sixteen species of common teleostean fishes found in the river Ganges or in the tanks and pools of Banaras has revealed several interesting and hitherto unsuspected features to be present in them.

Krogh (1939), Marshall (1930) and Smith (1929) assert that glomerulus is the structure or apparatus meant for filtering excess of water from the blood. Therefore, these structures ought to be fully developed in fresh-water fishes and according to Smith and Krogh they are so. An important difference between the fresh-water and the marine fishes is that the blood of the former is higher in concentration than the surrounding water whereas in the marine fishes the sea-water is higher in concentration than the blood. To make up for this loss, some marine teleosts have been reported to swallow water. Much of this swallowed water is retaind in the body by excreting a very concentrated urine. To enable them to maintain this equilibrium the glomeruli have become either non-functional or degenerate.

The reverse of this is said to hold good for the fresh-water fishes. That is, water from outside tends to enter the body of the fish as the concentration of the blood of fresh-water fishes is higher than that of the water surrounding them. Thus, there is always the chance of excess of water being present in the body. To avoid this, these fishes have developed an efficient water filtering system—the glomeruli.

Out of the sixteen species of fishes studied by the present author not a single case was found where the glomeruli and the renal tubules were present in full strength or in the normal condition as will be evident from the appended Table :—

TABLE.—*Showing the presence, absence and condition of the glomeruli and of the renal tubules in the kidneys.*

I Name of the fish	II Anterior portion	III Middle portion	IV Posterior portion	V Renal tubules
Rasbora rasbora	Avascular	A few of them vascularised	Degenerated	Urinary tubules lack definition.
Cirrhina mrigala	Degenerated	Degenerated	A few of them vascularised	Urinary tubules show signs of degeneration.
Labeo rohita	Degenerated	Degenerated	A few functional ones	Lymphoidal tissue present. Urinary tubules affected by it.
Catla catla	Glomeruli poorly developed and avascular.	A few functional ones present	Absent.	Urinary tubules few, exceesive connective and lymphoidal tissue present ; lymphoidal mass in preponderance.
Notopterus chitala	Absent	Present, some of them vascularised.	Present and avascular	Urinary tubules absent in the anterior portion present in the middle and the posterior portions Lymphoidal tissue present.
Notopterus notopterus	Absent	A few of them present	Degenerated glomerular tufts present.	Lymphoidal tissue excessively present ; urinary tubules damaged.
Mastacembelus armatus	Absent	Present but avascular. Several degenerated ones present.	Absent	Cell walls indistinct but nuclei are prominent. Connective tissue is in abundance.

Hilsa ilisha . . .	Indistinct and degenerated	Degenerated and avascular .	Degenerated and avaseular	Urinary tubules indistinct in the anterior and the middle portions. A few present in the posterior portion though embedded in lymphoid tissue.
Clarias batrachus .	Absent . . .	Degenerated . .	Degenerated	Urinary tubules lack definition.
Heteropneustes fossilis	Absent	Present, but degenerated and avascular.	Present, but degenerated and avascular.	Connective tissue copiously present. Urinaıy tubules better defined in the posterior portion.
Eutroplchthys vacha	Absent	Well-represented but avascular	Present but degenerated	Anterior region basophilic ; middle and posterior regions destroyed by lymphoidal tissue.
Wallago attu	Degenerated . .	Degenerated . .	Degenerated	Tubules destroyed by excessive development of connective tissue. A few functional tubules are present in the anterior region.
Mystus aor . .	Non-functional and degenerated glomeruli present.	Non-functional and degenerated.	Non-functional and degenerated.	Functional and basophilic tubules exist side by side
Ophiocephalus marulius	Absent	A few present but degenerated and avascular.	Absent .	Functional and basophilic tubules exist in the anterior and the middle portions, but destroyed in the posterior part.
Ophiocephalus gachua	Well-developed and degenerated glomeruli exist.	Well-developed and degenerated glomeruli exist.	Well-developed and degenerated glomeruli exist.	A few functional and many non-functional urinary tubules present in the middle portion, only a few functional tubules present in the anterior and the posterior portions. Connective and lymphoidal tissues present in all the three regions.
Ophiocephalus punctatus	Well-developed but avascular.	Well-developed and vascularised.	Well-developed and vascularised.	The middle and the pcsterior portions affected by the lymphoidal mass.

A close study of the sections of the various portions of the kidneys of sixteen species of fishes has shown them to be in a degenerated condition. The degree of degeneration varies with the different species. In the majority of the cases studied by the present author, the anterior portion contains avascular glomeruli and degenerate urinary tubules. The middle and the posterior portions are not free from signs of degeneration (see columns III & IV of the Table) as evinced by the condition of the glomeruli and the urinary tubules. But *Ophiocephalus gachua* and *O. punctatus* are exception to this rule. In most cases an excessive development of the connective and the lymphoidal tissues has been noticed. This shows that the kidneys of these species have to a large extent been put out of action by the inroads made by the lymphoidal and connective tissues.

It may be that these fishes originally inhabited the seas from where they migrated into the fresh-waters, where they have now come to stay. This view is in accord with the findings of Smith (1929), Grafflin (1931) and Krogh (1938).

The three species of *Ophiocephalus* differ among themselves in regard to the internal structure of the kidney. *O. gachua* and *O. punctatus* do not fall into a line with the condition found in other teleosts described here, but *O. marulius* shares their traits. It will be idle to speculate on the probable cause of this difference because our knowledge of this subject is still far from being complete in all respects.

VIII—SUMMARY

1. One important result of this study is that aglomerular or degenerate kidneys are found in these sixteen species of fresh-water fishes. This lends support to Grafflin's (1931) work.

2. The other important result is that degenerate and aglomerular kidneys of the marine fishes was due to oliguria in them as compared to fresh-water fishes. This is Smith's view. The presence of aglomerular and degenerate kidneys in these fresh-water fishes proclaims their marine ancestry. This is in consonance with Smith's view.

3. That these fishes have in all probability migrated to the fresh-water from the sea.

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