THE URINARY BLADDER OF SOME INDIAN TELEOSTEAN FISHES*

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(With 4 Plates)

CONTENTS

*Part of the thesis submitted to the Banaras Hindu University for the award of the Ph. D. degree in 1954.

I—INTRODUCTION

(*a*) *General*

From early times zoologists have paid considerable attention to the study of the urino-genital organs of fishes. However, inspite of the valuable contributions made by Muller (1875), Balfour and Parker (1882), Wheeler (1899), Woods (1902), Price (1904), Conell (1917), Kingsley (1926), Pfeiffer (1933), Owen (1938) and Parker and Haswell (1940), there still remain gaps in our knowledge. In a previous paper (Kamalaveni, 1962) the urino-genital organs of a number of freshwater fishes have been described by the author. During the course of that study several new features were noticed, and in this paper the urinary bladder of the fishes in question is dealt with.

(*b*) *Historical Résumé*

A survey of the literature on the urino-genital organs of fishes shows that one of the earliest workers on the subject was Rathke (1827), who described, probably for the first time, the development of the renal organs in the Ammocoetes larva. Later other workers like Muller (1875), Schneider (1879) and Bujor (1891) studied them and added to our knowledge on the subject. Detailed account of the development of the pronephros and mesonephros was given by Wheeler (1899) and of the pronephros alone by Hatta (1900). The early development of the mesonephros was described by Price (1904) in *Bdellostoma*.

The following excerpt from Goodrich (1931) indicates the present position :

> "The origin, growth and prolongation of the pronephric duct has remained a controversial problem and even now it remains so. But many have carried out researches on the problem, prominent among them being Beard (1887) and Ruckert (1888). The controversy has been set at rest to some extent by some of the later writers like Field (1891) and others, who have come to the conclusion that the ducts are purely mesodermal in origin. Work on the Teleostean pronephric duct has been carried out by Sween and Brachet (1901) *but many points still remain to be clarified*"

Sedgwick (1905), Goodrich (1931) and Parker and Haswell (1940) mention the occurrence of a median, posterior dilatation of the mesonephric duct. Sedgwick (1905) opines that this dilatation opens into the rectum in some teleosteans, while Goodrich (1931) holds that this contributes towards the formation of the urino-genital sinus. Parker and Haswell (1940) suggest that this dilatation is analogous to the allantoic bladder of the higher vertebrates. Owen (1938) casually refers to the structure of the urinary bladder in the genus *Cyclothone*.

Apart from these citations, little is known about the urinary bladder of the teleostean fishes.

(*c*) *Acknowledgment*

The author is deeply indebted to Professor A. B. Misra, Professor of Zoology, for his constant encouragement, valuable criticisms and guidance throughout the course of this work.

II—MATERIAL AND METHODS

The material required for this work was obtained from the river Ganges at Banaras, or from the tanks and ponds in the adjoining areas. Freshly caught fishes were decerebrated and then dissected on the river bank. Usually the fixative was injected into the bladder through the urinary pore by means of a pipette, then it was quickly removed and dropped into Bouin's fluid. Sections were cut 7 to 10μ thick, and stained in Delafield's Haematoxylin, Iron Haematoxylin or Mayer's Haemalum, and counter-stained with Eosin. The following fishes were employed in this study.

1. *Ophiocephalus gachua* Ham.	Ophiocephalidae
2. *Ophiocephalus punctatus* Bloch	Ophiocephalidae
3. *Ophiocephalus marulius* Ham.	Ophiocephalidae
4. *Hilsa ilisha* (Ham.)	Clupeidae
5. *Heteropneustes fossilis* (Bloch)	Saccobranchidae
6. *Clarias batrachus* (Linn.)	Claridae
7. *Wallago attu* (Bloch & Schneider)	Siluridae
8. *Mystus aor* (Ham.)	Bagridae
9. *Eutropiichthys vacha* (Ham.-Buch.)	Schilbeidae
10. *Notopterus notopterus* (Pallas)	Notopteridae
11. *Notopterus chitala* (Ham.)	Notopteridae
12. *Mastacembelus armatus* (Lacép.)	Mastacembelidae
13. *Catla catla* (Ham.)	Cyprinidae
14. *Labeo rohita* (Ham.)	,,
15. *Cirrhina mrigala* (Ham.)	,,
16. *Rasbora rasbora* (Ham.)	,,

III—THE URINARY BLADDER AND ITS STRUCTURE

The fundamental plan of the structure appears at a glance to be similar in almost all fishes studied by the author except in the case of the *Notopteridae*. But, inspite of the similarity, there are differences that are noteworthy. It is therefore essential that a short description of the structure of the urinary bladder of each fish be given. Since the general structure of the urinary bladder has not been described by any worker, an account of it is being given here before emphasising the differences.

The epithelium.—The lumen of the urinary bladder is an undivided chamber in all fishes excepting in *Catla catla* (Ham.) in which it is divided into two (Plate 5, Fig. 13 *a*). The lumen is lined by stratified epithelium (endothelium) disposed in several layers of cells, ranging from four to six. Some of these cells appear to be secretory in function as shown by the occurrence of goblet-cells in them and the discharge of secretory matter from them. These secretory cells occur in a continuous row in some cases (Plate 5, Figs. 10-12), while in others they occur in isolated groups scattered irregularly (Plate 4, Fig. 9*b*) or even singly distributed here and there (Plate 4, Fig. 5). In most of the fishes, they are very prominent and appear in the sections like vesicles filled with some kind of secretion ready to burst into the lumen (Plate 3, Fig. 4*b*; Plate 4, Fig. 9*b*). In some fishes apical portions of the cells become detached or "pinched off" from the parent cell. Groups of erythrocytes occur among the cells of the stratified epithelium or under the epithelium which shows that the epithelium is traversed by capillaries. The capillaries lie at different levels in the epithelium, especially in the Ophiocephalidae, where they are so superficial as to even burst forth into the lumen of the bladder (Plate 3, Figs. 1, 3). Generally the capillaries do not enter the epithelial layer but stay below it. Here we have ample evidence to the contrary.

The cells composing the stratified epithelia in various fishes are of different shapes and sizes. In some, they are longer than broad bearing a prominent nucleus ; in others, they are nearly pentagonal or hexagonal in shape with a small nucleus, and in still others the cells are elongated without the nuclei prominently defined.

The Submucosa.—The epithelium is followed by the submucosa in which connective tissue and strands of plain muscle fibres exist. It bears a superficial resemblance to the submucosa of the intestines of vertebrates.

The Muscular layers.—The connective tissue is followed by a layer of plain muscle fibres, the thickness of which varies according to the size and age of the fish. In some cases, they occur as broad, uninterrupted bands, while in others they occur in groups or bundles interspersed with connective tissue. The muscular layer is divisible into an inner layer of circular muscle fibres and an outer layer of longitudinal muscle fibres. Both these layers are highly vascularised.

IV—Description of the Urinary Bladder

1. **Ophiocephalus gachua** Ham.

(Plate 3, Fig. 1*a*, *b*)

In this fish, the epithelium is very prominently developed and greatly vascularised. It is several layers thick, seven to eight of them being easily discernible. The cells are hexagonal or polygonal in outline.

Closely associated with the epithelium and often aggregated on one side is a lymphoidal mass traversed by capillaries which extend even into the epithelium.

2. **Ophiocephalus punctatus** Bloch

(Plate 3, Fig. 2*a*, *b*).

3. **Ophiocephalus marulius** Ham.

(Plate 3, Fig. 3*a*, *b*)

In these two species, the epithelium is several layers thick as in the foregoing case and is thrown into folds. The cells in *Ophiocephalus punctatus* as well as in *Ophiocephalus marulius* are somewhat long and irregularly arranged. The cells in the lower strata are grouped into bundles, while those towards the lumen are arranged in rows. Here also the epithelium is vascular and the blood vessels reach even the free border where some of them burst into the lumen (Plate 3, Fig. 1*b*.)

The epithelium is surrounded by a thin layer of connective tissue which in turn is covered by loose muscular strands with sparsely scattered nuclei. This kind of disposition of the muscular layers is peculiar to the Ophiocephalidae. Another distinguishing mark of the urinary bladder of these fishes is the absence of the secretory vesicles as described in the species to follow.

4. **Hilsa ilisha** (Ham.)

(Plate 3, Fig. 4*a*, *b*)

The epithelium is generally three to four cells thick and bears prominent nuclei. The epithelium is thrown up into folds and the cells lying at the summit of the folds show considerable secretory activity. The secretory matter is discharged into the lumen of the urinary bladder along with some erythrocytes discharged by the disrupted capillaries.

The submucosa is seen only at certain points because the thick development of the muscular layers has practically obliterated it.

The nuclei of the muscles lie enmeshed within the strands of muscles.

5. **Heteropneustes fossilis** (Bloch)

(Plate 4, Fig. 5*a*, *b*)

The epithelium is thrown into folds at some points. The epithelial cells are disposed in three to five layers and form the inner lining of the bladder. The cells are small and possess round nuclei. The secretory cells are not so numerous as in the case of *Hilsa ilisha*, but are scattered at irregular intervals at different levels. When actually secreting they become vesicular in appearance. Blood capillaries lie scattered amongst the epithelial cells and extend even up to the free margin of the border.

The submucosa is traversed by strands of muscles (Plate 4, Fig. 5*a*).

The circular muscle fibres are grouped into bundles (Plate 4, Fig. 5*b*) between which connective tissue exists. The nuclei though fewer in number and scattered are nevertheless detectable.

6. **Clarias batrachus** (Linn.)

(Plate 4, Fig. 6*a*, *b*)

The epithelial cells lining the bladder are pentagonal or hexagonal in shape and possess prominent nuclei. The secretory vesicles are scattered irregularly. The epithelium is three or four cells deep at some places, and eight cells deep at other points. It is not so much vascularised as in the case of *Ophiocephalus*, but a few erythrocytes lie here and there.

The connective tissue below the epithelium follows the course of the epithelium and consequently villi-like projections occur in it. The muscles exist in groups and in bands. Blood capillaries are interspersed between the circular and the longitudinal muscle fibres.

7. **Wallago attu** (Bloch & Schneider)

(Plate 4, Fig. 7*a*, *b*)

The epithelium is six or seven cells thick. The cells are small in size, hexagonal in shape and bear small nuclei. It is slightly uneven in disposition except for elevations at some points. The secretory vesicles are quite numerous and lie irregularly distributed among the epithelial cells. These vesicles burst forth into the lumen (Plate 4, Fig. 7*b*) and discharge their contents. The epithelium is vascularised in this species also, but the capillaries are not so numerous as in *Ophiocephalus*. The submucosa is moderately wide and traversed by muscular strands distributed irregularly in it. This is followed by a circular layer of muscle fibres, next to which are the longitudinal fibres. The former is easily recognized by the manner of its disposition, while the latter is disposed in groups or bundles.

8. **Mystus aor** (Ham.)

(Plate 4, Fig. 8*a*, *b*)

The structure of the wall of the urinary bladder very closely resembles that of *Wallago attu* except for some minor differences. The epithelium is thrown into less prominent folds. It is not vascularised and is only 3-4 cell-deep, excepting where it is elevated. The secretory vesicles are quite numerous and are scattered without any apparent order close to the edge of the epithelium. Some of them are seen bursting into the lumen and discharging their contents.

9. **Eutropiichthys vacha** (Ham. & Buch)

(Plate 4, Fig. 9*a*, *b*)

The structure of the urinary bladder does not differ much from that found in either *Wallago attu* or *Mystus aor*, but the epithelium is slightly thicker and more vascularised. The secretory vesicles are irregularly distributed as in the other two species. The connective tissue and the muscles are not uniformly thick all round.

10. **Notopterus notopterus** (Pallas)

(Plate 5, Fig. 10*a*, *b*)

11. **Notopterus chitala** (Ham.)

(Plate 5, Fig. 11*a*, *b*)

The epithelium is broad and several layers in thickness, and the first two layers of cells are actively concerned in secretion as can be inferred from the presence of vacuoles and secretory granules in them. These cells burst and discharge their contents into the lumen, become spent out and the lower layers of cells take up their place and elaborate secretions (Plate 5, Fig. 10*b* and 11*b*). The epithelium is folded into villi-shaped projections such as are usually found in the intestine.

The submucosa is broad, vascularised possessing something like muscularis mucosa.

The muscles investing the submucosa are distinctly recognisable as consisting of an inner layer of circular and an outer layer of longitudinal muscle fibres.

12. **Mastacembelus armatus** (Lacép.)

(Plate 5, Fig. 12*a*, *b*)

The epithelium is comparatively narrow, being only two or three layers thick. The marginal epithelial cells are studded with secretory vesicles and form a conspicuous feature of the epithelium of *M. armatus*. Blood vessels are distributed under the epithelium abundantly. The cells in the secretory phase stain deeply and therefore stand out prominently to view.

The submucosa is moderately broad and vascularised. " Muscularis mucosa " is absent, but small bundles of muscles lie in the submucosa.

The investing layer of muscle fibres consist of an inner circular and an outer longitudinal layer, the former being somewhat discontinuous.

13. **Catla catla** (Ham.)

(Plate 5, Fig. 13*a*, *b*)

The cavity of the urinary bladder is double. Both are lined by an epithelium that is four or five cells thick. The cells are small in size, hexagonal in shape and bear small nuclei. The secretory vesicles are fewer in number, scattered at intervals and not disposed in groups. The capillaries penetrate up to the surface of the epithelial layer.

The connective tissue lying below is dense vascularised and strewn with strands of muscle fibres.

The investing layer of muscle fibres is thin, fibrous and loosely compact.

14. **Labeo rohita** (Ham.)

(Plate 6, Fig. 14*a*, *b*)

The lumen is single and lined by epithelium four or five cells deep. The cells are small but their nuclei are prominent (Plate 6, Fig. 14*b*). At certain places the epithelium is folded and not vascularised. The secretory vesicles occur in the marginal epithelium at varying levels.

There is a distinct strand of " muscularis mucosa " in the submucosa under the epithelium. The connective tissue is traversed by thin strands of muscle fibres and blood vessels.

The muscles lying below the submucosa are often in the form of small bundles, but they are not arranged as regularly as in some of the species decribed before. The longitudinal layer is inconspicuously thin.

15. **Cirrhtna mrigala** (Ham.)

(Plate 6, Fig. 15)

The epithelial folds are more prominently disposed than in *Labeo rohita*. In other respects, the structure of the urinary bladder of *Cirrhina mrigala* resembles that of *Labeo rohita*. The secretory vesicles are however less numerous.

The circular layer of muscle fibres is thick, but the longitudinal layer is less prominent to view.

16. **Rasbora rasbora** (Ham.)

(Plate 6, Fig. 16*a*, *b*)

The structure of the urinary bladder of this species is almost similar to that of *Cirrhina mrigala* but the secretory vesicles are not prominent as in other cases but some secretory material is found adhering to the free edge of the epithelium.

The submucosa is moderately broad with a distinct muscularis mucosa in it. The layer of circular muscle fibres is thick. The longitudinal muscle fibres are fairly well represented.

V—Discussion and Conclusion

(*a*) A short survey of the previous work

Conflicting views have been expressed in the past in regard to the homology, analogy, embryology and morphology of the urinary bladder of fishes in generai. Sedgwick (1905) casually mentions the bladder opening either into the rectum or on the summit of a papilla without referring to its structure in detail. Some excerpts from Goodrich (1931) will indicate the position obtaining to-day : " The morphology of the Teleostean ducts is very difficult to interpret, and the homology of the parts by no means yet established. " " The exact relation of the testicular canals and marginal canal to the mesonephric tubules and peritoneal funnels has not yet been satisfactorily described in various groups of Pisces "

Goodrich opines that " from the combined, terminal ends of the ureters arises another diverticulum (urinary bladder) which becomes a receptacle for urine "

Parker and Haswell (1940) mention the occurrence in many fishes of a dilatation of the mesonephric duct *serving as a receptacle for urine*, thus becoming analogous to the allantoic bladder of the higher vertebrates.

Kingsley (1926) writes that " in most of the fishes, *the bladder arises by a fusion of the hinder ends of the wolffian ducts plus a part derived from the hinder end of the digestive tract* (*cloaca*), the wolffian ducts emptying into it and the whole opening to the exterior, usually dorsal and posterior to the anus. In the Dipnoi there is a diverticulum from the dorsal wall of the cloaca, anterior to the openings of the Wolffian ducts. This is usually called the urinary bladder but it may be homologous with the rectal gland of the Elasmobranchs "

According to Pfeiffer (1933), in the male of *Lepidosteus*, the vasa efferentia enter the kidney and join the malpighian bodies, then through the urinary tubules, they open into the Wolffian duct. From the Wolffian duct, the sperms pass into the " bladder " which opens on a small papilla posterior to the anus. He further describes that along the dorsal " horns" of the bladder are small " pockets" where the urinary ducts enter. The Wolffian duct begins in a group of urinary tubules at the anterior end of the kidney, traverses the entire length on the outer, ventral border and posteriorly it joins with its mate to form an unpaired dilatation. This dilatation, he says, has been termed the ' Urinary bladder ' by Balfour and Parker (1882), a wrong terminology to be used for a structure which is embryologically derived from the Wolffian duct.

In the female of *Lepidosteus*, Pfeiffer finds the eggs passing directly into the oviduct which opens into the bladder on the summit of a papilla. *He asserts that this is the condition found in most teleosts.*

Owen (1938) describes the *Cyclothone* kidney as consisting of two parallel tubules, each starting from a Bowman's capsule, running backwards and posteriorly uniting together into a bladder which opens behind the anus. In the males, the testes possess no separate ducts and so Owen (1938) infers that *the semen is discharged through the bladder.* To describe the structure of the tubule and the bladder in his own words " Some portions have a droplet-like appearance as if to be pinched off into the lumen which suggests that these cells are engaged in some sort of apocrine secretion. The bladder is lined with a low cuboidal epithelium in which the curved tops of the cells give a characteristic biscuit-like appearance. A very thin coat of smooth muscles completes the structure "

(*b*) *Discussion*

A critical survey of the views expressed by the previous workers, together with the actual findings in several fishes belonging to different families results in the following conclusions :

If the " Urinary bladder " is a mere dilatation of the mesonephric duct, as expressed by Goodrich, Parker and Balfour, then the actual structure of it, as seen in the cases described above, does not justify such a belief because of the presence of the stratified epithelium with the secretory cells, submucosa and muscular layers in it. The actual findings are more in conformity with Kingsley's point of view that the " urinary bladder " is partly formed from the posterior end of the rectum, or as he himself puts it, " the cloaca " It would be more appropriate to regard it as having been derived from the terminal end of the rectum, because, the cloaca is not universally present in all the teleosts as assumed by Kingsley and shown here. The studies by the present author on the urino-genital organs of several species of freshwater teleostean fishes tend to disprove the assumption of Kingsley. Moreover, cloaca represents a part of the external world into which the urinary, genital and anal openings lie. Judging from his own statement, it becomes doubtful whether the dilatation of the bladder is formed partly from the Wolffian duct (or the mesonephric duct) and partly from the cloaca. Kingsley has expressed the view that in teleosteans, the pronephric (archinephric) duct does not split into the Wolffian and the Mullerian ducts. If so, then Goodrich's view that it is a dilatation of the mesonephric duct becomes more plausible. But to call it an " urinary bladder " looks like a terminological inexactitude as Pfeiffer has pointed it out, for, embryologically this structure is not the same as that found in higher vertebrates. In the Amniotes, the allantois forms the bladder and the ureters are not direct descendents of the pronephric ducts. In Amphibia, the bladder is an inpushing from the ventral wall of the cloaca, and there is a striking resemblance between the structure of this organ as found in the Amphibia and that in the Teleostean fishes described here. But in the former, the ureters do not directly open into the bladder, while in the latter there is a direct connection between the two. Moreover, in some species like *Hilsa ilisha*, the bladder is a continuation of the ureters. The important point to bear in mind is that all Teleostean fishes do not possess a cloaca. Therefore, it can be safely asserted that this structure that is found in all the Teleosteans may be an inpushing for aught we know from the terminal, ventral portion of the rectum, which acquires connexion with the ureters. This conclusion will be in harmony with what Sedgwick wrote that in some fishes, the ureters open into the rectum. The strong point in support of the urinary bladder being an outgrowth from the wall of the rectum lies in the fact that there is a strong resemblance between the histological appearance of the rectum and the urinary bladder. Histologically the structure of the *ureter* or the *cloaca* is not in concord with the histological picture of the urinary bladder. Therefore, the urinary bladder cannot be regarded as having been derived from the ureter or the cloacal wall. The presence of secretory granules and goblet cells strongly suggest that far from being merely a " receptacle for urine " as stated by Parker and Haswell, it may be concerned in some kind of secretory and absorptive activities also. The presence of a stratified epithelium with abundant secretory cells in the urinary bladders of the species investigated shows that this structure is not merely a receptacle for holding urine. Moreover, sections show the haze of the secretions in the lumen, (*e.g.*, *Notopterus notopterus* and *N. chitala*) (Plate 5, Figs. 10 *a* and *b* ; 11 *a* and *b*), and in some cases, even proof of holocrine secretion exists as testified by the discharge of cells, nuclei and erythrocytes into the lumen (*e.g.*, *Hilsa ilisha* and *Mystus aor*) (Plate 3, Fig. 4*b*; Plate 4, Fig. 7*b*). The signs of secretory activity as well as the high degree of vascularization of the epithelium lead us to infer that the bladder is more than a mere reservoir for the storage of urine, but concerned in secretory and absorptive activities also.

In the migration of fishes from the sea to the fresh-waters or vice-versa, it is the urino-genital organs, especially the renal organs, that have suffered change because they are osmo-regulatory in function. Thus, the kidney has been subjected to a lot of strain. In order to minimize this, the bladder may have taken on itself part of the osmo-regulatory function. The fact that its epithelium is highly vascularised and the cells are engaged in apocrine and holocrine secretory activities is a pointer in this direction. It may serve as a receptacle for urine but it may also be eliminating certain salts and absorbing water from the urine. It may not be out of place to mention here that a rounded mass of highly vascular tissue is found in close association with the inner epithelium of the urinary bladder in *Ophiocephalus gachua* (Plate 3, Fig. 1*a*).

The evolution of this osmo-regulatory mechanism may have taken place in more than one step. In the first place, it was necessary to increase the blood supply to the urinary bladder. Unless this happened, the mechanism of elimination of salts and the absorption of water from the urine could not have been perfected. So the Ophiocephalidae represent the first step in this direction. In them, the epithelium is several layers thick, traversed by numerous capillaries that reach almost the free edge and even islands of blood cells are formed (Plate 3, Figs. 1*a*, *b*, and 2*b*). The next step in the evolution of this mechanism is represented by *Hilsa ilisha* (Plate 3, Fig. 4*a*, *b*) where several of the cells of the epithelium are engaged in apocrine secretion or both holocrine and apocrine secretion (Plate 4, Fig. 9*b*) as seen in *Eutropiichthys vacha*. Recent work in cyto-histology have shown that secretory and absorptive cells belonging to a common epithelium may exist side by side but may be demarcated from one another by physiological functions. Hence, it may notbe wrong to infer that some of the cells of the epithelium are serving for absorbing water from the urine stored in the urinary bladder.

VI—SUMMARY

1. The structure of the urinary bladder as found in sixteen species of fresh-water fishes is given.

2. The histology of the urinary bladder of these fishes has been described for the first time.

3. Comparisons have been made between the structure of the urinary bladder as found in the sixteen species and the difference brought out.

4. It has been shown that the histology of the urinary bladder resembles that of the rectum.

5. Facts have been brought to light disproving that it had been derived from the cloaca or the urinary ducts.

6. Lastly, it has been suggested that this structure may be performing osmo-regulatory functions, besides being a receptacle for urine.

VII—REFERENCES

BALFOUR, F. M. and PARKER, W. K. 1882. On the structure and development of *Lepidosteus*.—*Phil. Trans.*, London, **173**, pt. 2, p. 359.

BUJOR, P. 1891. Metamorphose de l'*Ammocoetes branchialis*.—*Rev. Biol. Nord.*, France, **4**, p. 41.

ONEL, J. LE ROY, 1917. The Urogenital system of Myxinoids.—*J. Morph.*, Philadelphia, **29**, pp. 75-163.

OODRICH, E. S. 1931. Studies on the structure and development of Vertebrates, pp. 657-715.—London (Macmillan and Co.).

HATTA, S. 1900. Development of pronephros etc. in *Petromyzon*.—*J. Coll. Sc. Imp. Unvi. Tokyo*, **13**, pp. 1-44.

KAMALAVENI, S. 1962. Morphology of the urino-genital system in some Indian Teleostean fishes.—*Rec. Indian Mus.*, Delhi, **59** [1961]., pp. 83-118.

KINGSLEY, J. S. 1926. Comparative Anatomy of Vertebrates, pp. 340-435.—Philadelphia (P. Blakiston's and Co.).

KROUGH, A. 1939. Osmotic Regulation in Aquatic Animals, pp. 1-242. Cambridge (Univ. Press).

MÜLLER, J. 1875. Urogenital system des *Amphioxus* und der *Cyclostomen.—Jena. Z. Naturw.*, Jena, **9**, p. 101.

OWEN, B. B. 1938. A simple Teleost kidney in the genus *Cyclothone.—Biol. Bull. Woods Hole*, Woods Hole, **74**, pp. 349-365.

PARKER T. J. and HASWELL, W. A. 1940. A Text-Book of Zoology, **2**, pp. 154-306. London (Macmillan and Co.).

PFEIFFER, C. A. 1933. The anatomy and blood-supply of the urinogenital system of *Lepidosteus platystomus* Refinesque.—*J. Morph.*, Philadelphia, **54**, pp. 459-472.

PRICE, G. C. 1904. Development of excretory organs in *Bdellostoma.—Zool. Jb.*, Jena, (Anat.), **10**, p. 207.

RATHKE and SCOTT, W B., 1827. Beiträge zur Entwicklungsgeschichte der Petromyzonten.—*Morph. Jb.*, Leipzig, **7**, p. 101.

SEDGWICK, ADAM. 1905. A Student's Text Book of Zoology, **2**, pp. 95-216.—London (Swan Sonnenschein and Co. Ltd.).

SCHNEIDER, A. 1879. In : A Student's Text Book of Zoology, **2**, pp. 97-103, by Sedgwick 1905.—London (Swan Sonnenschein and Co. Ltd.).