STUDIES ON THE HEART OF HETEROPNEUSTES FOSSILIS (BLOCH)

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ABSTRACT

The minute anatomy of the heart of Heteropneustes fossilis has been described. The anteriormost chamber of the heart is a bulbus arteriosus with an appendant pouch-like structure. As for the cardiac-valves, there are a pair of sinu-atrial valves, two pairs of atrio-ventricular valves and a pair of ventriculo-bulbar valves. The conducting tissues are absent in the heart.

INTRODUCTION

PRAKASH (1953) has described the conducting tissues in the heart of Heteropneustes fossilis and has put forth the claim that contrary to the previous belief that the cardiac conducting tissues in birds and mammals are neomorphic structures, they occur in a less specialised condition even in the fishes. I have made anatomical and embryological studies of the heart of a few fresh-water teleostean fishes in connection with a research project under the auspices of the University Grants Commission, New Delhi. Although I have tried to trace the conducting tissues of the heart of these fishes, I did not, however, come across the same in any of them. Under the circumstance, I was constrained to investigate into the minute anatomy of the heart of Heteropneustes fossilis with a view to determining the tenability of Prakash's (1953) claim on the occurrence of the cardiac conducting tissues in this fish.

HISTORICAL RESUME

Gegenbaur (1891) observed that the conus arteriosus in teleosts was reduced considerably and represented by the portion of the myocardium adjacent to the aortic valves. Parsons (1929) made an extensive study of
the heart of Raia, Acanthias, Pristiurus, Lepidosteus, Polypterus, Ceratodus, Protopterus, Acipenser, Amia, Megalops, Symbranchus, Gymnarchus and Loricaria, and concluded that the bulbus arteriosus in the teleostean heart was a part of the original conus arteriosus. Goodrich (1930) noted the disappearance of the conus arteriosus in typical teleosts. Awati and Bal (1934) described the structure of the heart of Tetradon oblongus. Mott (1950) gave a general description of the heart of Anguilla anguilla. Prakash (1953) described the heart of Heteroneustes fossilis with special reference to its conducting system. Karandikar and Thakur (1954) studied the anatomy of the heart of Sciaenoides Brunneus (Day). Singh (1960) probed into the structure of the heart of Mystus aor, Wallago attu, Hilsa ilisha, Labeo rohita, Ophiocephalus striatus and Mastacembalus armatus. Thomas (1963 and 1967) studied the minute structure of the heart of Clarias magur and Ophiocephalus striatus respectively. Khanna and Goswami (1965) observed the structural variations and their functional significance of the heart of Tor tor, Orienus sinuatus, Clarias batrachus and Notopterus notopterus.

MATERIAL AND TECHNIQUE

Live specimens of Heteropneustes fossilis for the present investigation were collected from the fish-ponds of Mr. Prince K. Zacharias at Chennamkary near Alleppey. After slitting open the ventral body wall some of the fish were preserved in 10% formalin for about four days and the heart was carefully dissected out under the powerful Binocular Microscope. Thick hand-cut sections of the heart hardened in formalin were prepared in the various planes. The heart from live specimens dissected under 1% saline solution was fixed in Bouin’s picroformol after the blood being completely squeezed out of it. It was then dehydrated in graded alcohols, and serial sections 8–10 microns thick were cut in transverse and sagittal planes by the paraffin embedding process. These were stained either with Eosin and Delafield’s Haematoxylin or with Mallory’s Triple Stain.

THE HEART

(a) General Account

The heart is situated immediately in front of the septum transversum and in close proximity with the gills. The two coracoids meeting mid-ventrally afford sound protection to the heart on its ventral side. The heart consisting of four chambers, viz., the sinus venosus, the atrium, the ventricle, and the bulbus arteriosus is enclosed within the pericardium.
(b) **The Pericardium**

The pericardium is a thin-walled membranous conical structure with a narrow anterior region posteriorly getting steadily wider.

(c) **The Chambers of the Heart**

1. *The sinus venosus.*—The sinus venosus (Fig. 1), the posteriormost chamber of the heart, is situated immediately anterior to the septum transversum. It encloses a spacious lumen. Its wall is made up of compactly disposed fibres and devoid of any trabecula projecting into the lumen of the sinus venosus. The anterior narrow region of the sinus venosus communicates with the posterior region of the atrium through the sinu-atrial aperture guarded by a pair of asymmetrically disposed sinu-atrial valves (Fig. 2).

2. *The Atrium.*—The atrium (Fig. 1) is situated anterior to the sinus venosus and dorsal to the ventricle. It is almost conical with its narrow anterior end reaching the base of the bulbus arteriosus while its posterior wide region extends a little beyond the apex of the ventricle. The atrial wall is spongy due to the criss-cross disposition of the cardiac muscle fibres. The atrium opens into the middle of the ventricle through the atrio-ventricular aperture guarded by four valves. Two of these valves are larger than the
other two. The larger valves may be termed the major valves and the smaller valves the minor valves. As for the disposition of these valves, one of the major valves is anterior and the other is posterior while there is a right and a left minor valve (Fig. 3).

Fig. 3. Sagittal section of the Heart of *Heteropneustes fossilis* through the atrio-ventricular valves, ×100.

3. The ventricle.—The thick and elongated ventricle (Fig. 1) is reniform. There is a distinct circular layer of muscle fibres surrounding the ventricle. The ventricular wall is thick, the fibres crossing and recrossing each other in various directions. Besides the numerous small lacunae among the ventricular muscle bundles, there is a central fairly spacious ventricular lumen communicating with that of the bulbus arteriosus.

4. The Bulbus arteriosus.—The bulbus arteriosus, (Fig. 1), the anterior-most chamber of the heart, has a proximal tubular region extending into a distal bulb-like dilatation. In serial transverse sections anteriorly the bulbus arteriosus is oval with a fairly thick circular layer of muscle fibres invested by a thin layer of loose connective tissue fibres. Posteriorly two prominent inpushings facing each other and projecting into the lumen of the bulbus arteriosus develop from its wall (Fig. 4). In the subsequent posterior sections these two inpushings of the wall of the bulbus arteriosus gradually approach each other until at last they get coalesced with each other. Consequently the lumen of the bulbus arteriosus becomes divided into a left and a right compartment, the latter opening into the ventricle through the ventriculo-bulbar aperture (Fig. 5).
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Fig. 4. Transverse section of the Heart of *Heteropneustes fossilis* through the anterior region of the ventriculo-bulbar valves, ×100.

Fig. 5. Transverse section of the Heart of *Heteropneustes fossilis* through the complete median partition of the bulbus arteriosus, ×100.

The ventriculo-bulbar aperture is guarded by a pair of ribbon-shaped ventriculo-bulbar valves. In transverse sections passing through the anterior-most region of these valves, they appear as a pair of elongated digitate structures guarding the ventriculo-bulbar aperture and projecting into the lumen of the bulbus arteriosus (Fig. 4). Posteriorly in addition to these elongated digitate structures and opposite to them a pair of small digitate structures appear and they project from the wall of the bulbus arteriosus.
into its lumen (Fig. 5). In the subsequent posterior sections these two pairs of digitate structures become steadily longer (Fig. 6) and ultimately get united with each other in such a way as to form a left and a right ventriculo-bulbar valve dividing the lumen of the right compartment of the bulbus arteriosus into a narrow middle sector on either side of which is the more spacious sector bounded by the respective valve of the side and the wall of the bulbus arteriosus (Fig. 7).

**Fig. 6.** Transverse section of the Heart of *Heteropneustes fossilis* through the posteriorly closed appendant pouch-like structure of the bulbus arteriosus, ×100.

**Fig. 7.** Transverse section of the Heart of *Heteropneustes fossilis* through the posterior region of the bulbus arteriosus and the two ventriculo-bulbar valves, ×100.

The left compartment of the bulbus arteriosus gradually gets diminished in size posteriorly and it becomes a closed structure at its posterior end and it does not negotiate with the ventricular lumen (Fig. 6).
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THE WORKING OF THE HEART

When the sinus venosus is filled with blood, it contracts. The blood then flows into the atrium, the reflux of the blood into the sinus venosus being prevented by the two sinu-atrial valves. On the contraction of the atrium the blood flows into the ventricle through the atrio-ventricular aperture, the regurgitation of the blood into the atrium being prevented by the four atrio-ventricular valves. The powerful contraction of the ventricle results in the forcing of the blood into the bulbus arteriosus, the backward flow of the blood into the ventricle being checked by the two ventriculo-bulbar valves.

If a large quantity of blood enters the bulbus arteriosus from the ventricle, presumably the pressure would have increased to a great extent within the ventral aorta. This, however, does not happen. The excess of the blood would then flow into the pouch-like structure of the bulbus arteriosus, thus facilitating to maintain the optimum pressure within the ventral aorta.

DISCUSSION

Goodrich (1930), Singh (1960), Thomas (1963) and Khanna and Goswami (1965) have reported the occurrence of a pair of sinu-atrial valves in the heart of the various teleostean fishes they have examined. Prakash (1953) has described a single sinu-atrial valve in the heart of *Heteropneustes fossilis*. According to him the single sinu-atrial valve does not communicate with the fibres of either the sinus venosus or the atrium. I have, however, observed that the sinu-atrial aperture in *Heteropneustes fossilis* is guarded by a pair of sinu-atrial valves which are asymmetrically disposed. The proximal ends of these valves are inserted on the wall of the sinus venosus while their distal ends project freely into the atrial lumen.

Goodrich (1930), Thomas (1963) and (1967) and Khanna and Goswami (1965) have noted the presence of a pair of atrio-ventricular valves in the heart of the various teleostean fishes they have studied. Prakash (1953) has observed a single pair of atrio-ventricular valves in the heart of *Heteropneustes fossilis*.

*striatus* and *Mastacembalus armatus* have described the presence of four atrio-ventricular valves.

I have noted that the atrio-ventricular aperture in the heart of *Heteropneustes fossilis* is guarded by four atrio-ventricular valves, two of which are larger than the other two, thus constituting a pair of major valves and a pair of minor valves. Of the major valves, one is anterior and the other is posterior while there is a right and a left minor valve.

Prakash (1953) has noted only the minor right and left valves; evidently he has failed to take cognizance of the anterior and posterior major valves.

Prakash (1953) says that the anteriormost chamber of the heart of *Heteropneustes fossilis* is a conus arteriosus and not a bulbus arteriosus because of its muscular and contractile nature. Further, he adds that this chamber has four valves in its posterior region and it communicates through these valves with two separate channels present inside the ventricle (p. 115).

I have observed that the anteriormost chamber of the heart of *Heteropneustes fossilis*, however, does not contract and expand as in the case of the conus arteriosus of elasmobranch fishes. Prakash (1953) has erroneously interpreted the structure and the disposition of the ventriculo-bulbar valves. In transverse sections passing through the anterior region of the ventriculo-bulbar valves, admittedly they appear as two pairs of valves. But in the subsequent posterior sections these two pairs of valves coalesce so as to form only a single pair of the ventriculo-bulbar valves.

Prakash (1953) observes “the two depressions formed in the ventricle run anteriorly in the form of two tube-like structures. The walls of these two tubes approach each other and the enlarged conus arteriosus is formed by their confluence.” Although the bulbus arteriosus appears to be a single structure to the naked eye, study of serial transverse sections shows that it is formed of two tube-like structures of which one is rather short, devoid of any valves and without any communication with the ventricular lumen. The larger tube opens into the ventricular lumen by the ventriculo-bulbar aperture guarded by the ventriculo-bulbar valves.

Thus there is, however, absolutely no justification in considering the anteriormost chamber of the heart of *Heteropneustes fossilis* as the conus arteriosus. It is evidently a bulbus arteriosus. All the same, it is a modified bulbus arteriosus, the modification being the occurrence of a small appendant pouch-like structure along with the normal bulbus arteriosus.
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CONDUCTING TISSUES OF THE HEART

Prakash (1953) has claimed to have discovered a rectangular sinus-atrial plug on the dorsal side of the sinus-atrial opening, and an atrio-ventricular plug dorsal and anterior in position to the atrio-ventricular valves. Although I have carefully examined numerous serial transverse and sagittal sections of the heart of Heteropneustes fossilis I have not been able to observe the sinu-atrial plug and the atrio-ventricular plug described by Prakash (1953). From Prakash's (1953) descriptions and photomicrographs of the conducting tissues of the heart of Heteropneustes fossilis, I am constrained to believe that presumably a distorted configuration of the sinu-atrial valve and the major anterior and posterior atrio-ventricular valves has led him to claim the occurrence of the conducting tissues in the heart of this fish. In the light of the present investigation, Prakash's (1953) claim on the occurrence of the conducting tissues in the heart of Heteropneustes fossilis is untenable.

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REFERENCES


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ABBREVIATIONS USED IN THE FIGURES

A. . . Atrium.
A.V.V.I. . . Major atrio-ventricular valve.
A.V.V.II. . . Minor atrio-ventricular valve.
C.D. . . Cuvierian duct.
I.L. . . Inner circular muscle layer of the bulbus arteriosus.
I.P. . . Impushing of the wall of the bulbus arteriosus.
M.P. . . Median partition of the bulbus arteriosus.
O.L. . . Outer loose connective tissue layer of the bulbus arteriosus.
S.A.V. . . Sinu-atrial valve.
S.V. . . Sinus venosus.
V.B.V. . . Ventriculo-bulbar valve.