

Comparative Architectures of Myocardia in Some Teleost Fishes

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Abstract

Myocardia of teleostean hearts in the pelagic species as the skipjack tuna *Euthynnus pelamis*, the mackerel *Scomber japonicus*, the horse mackerel *Trachurus japonicus* and the sardine *Sardinops melanostictus* were compared to those of the littoral sluggish species as the rock-fish *Sebastes marmoratus*, the gurnard *Satyrichthys amiscus* and the flatfish *Eopsetta grigorjewi*. Architectures of the myocardia were different between the pelagic and sluggish species. The thickened cortex was observed in the ventricle of the pelagic, although the inner trabeculated or spongy layer showed almost the same development as in the sluggish. The development of myocardinal cortex was considered to occur due to a functional increase of the hearts of pelagic fishes.

Teleost fishes show diverse life-styles which are provided with swimming ability. The swimming power is different from species to species. The swimming power of pelagic species is higher than that of the sluggish species. The difference of the ability is related to a positive correlation with the heart weight¹⁾. Fish heart is situated within the pericardinal cavity, and transforms from a primitive linear shape to a developed s-type during its ontogenetic development²⁾. It consists of the sinus venosus, atrium, ventricle, and aortic bulb in the direction of the blood-flow. They are essentially composed of three layers of tissues; epicardium, myocardium and endocardium. The histological studies revealed the difference of architectures in the myocardium of the ventricle between the skipjack tuna and toadfish³⁾. The swimming ability may be supported by the structural development of the ventricle⁴⁾.

The present study was conducted to ascertain the aspects mentioned above, comparing myoarchitectures of the hearts in pelagic and littoral species.

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Materials and Methods

As materials of this study, the hearts of the skipjack tuna *Euthynnus pelamis*, the mackerel *Scomber japonicus*, the horse mackerel *Trachurus japonicus*, and the sardine *Sardinops melanostictus* were used. These species belong to the pelagic swimmer. For comparison, the hearts of littoral sluggish species as the rock-fish *Sebastes marmoratus*, the gurnard *Satyrichthys amiscus*, and the flatfish *Eopsetta grigorjewi* were chosen. After collecting them at fish markets, their hearts were all fixed in 10 % formaline. First the external structure of the hearts was observed to recognize specific differences. Secondly the sinus venosus was cut dorsally and opened to investigate the distribution of inflow-vessel openings and the myoarchitecture of the heart which was longitudinally sectioned. Thirdly respective right-halves of the atrium, ventricle and aortic bulb were sectioned crossly to compare the muscular constructions. For the aortic bulb and ventricle, the cutting level was put at the site of the maximum size. Due to its partial difference of size, the cutting level of the atrium was put at the posterior to the valves between the atrium and ventricle.

Results and Discussion

The aortic bulb sent antero-laterally four paired arteries to respective gill arcs (Fig. 1). These arteries corresponded to the 1st, 2nd, 3rd and 4th afferent branchial arteries. Regarding the 3rd and 4th afferent branchial arteries, a specific difference was observed in their diverging pattern. The origin of both arteries in the sardine was completely separated, differing from the conjugated cases in other species.

The aortic trunk also showed a specific difference of its posture. Except the sardine and gurnard, fishes had the aortic trunk bent dorsally just after deriving from its original site near the aortic bulb, then changed to horizontal condition at the diverging sites of the 3rd and 4th afferent branchial arteries. The aortic trunk in sardine bent ventrally just after deriving from the aortic bulb, then showed slight bending dorsally near the origin of the 2nd afferent branchial artery. The other case was observed in the gurnard. The posture of the aortic trunk was similar to the case in the skipjack tuna until it reached the bases of the 3rd and 4th afferent branchial arteries. It bent ventrally after passing through them.

The sinus venosus received blood anteriorly from the anterior cardinal vein and jugular vein, and posteriorly from the hepatic vein, posterior cardinal vein, preabdominal vein and subclavian vein²⁾. The expanded shape of the sinus venosus was almost rectangular, regardless of the species. Distributions of openings of the inflow vessels on its inner surface are shown in Fig. 2. There were no specific differences of their distribution pattern. Regarding the jugular vein, the caliber of its paired vein was not equal; the right is larger than the left. In the median area of the sinus venosus, semi-lunar valves were located as a paired condition. Their position corresponded to an

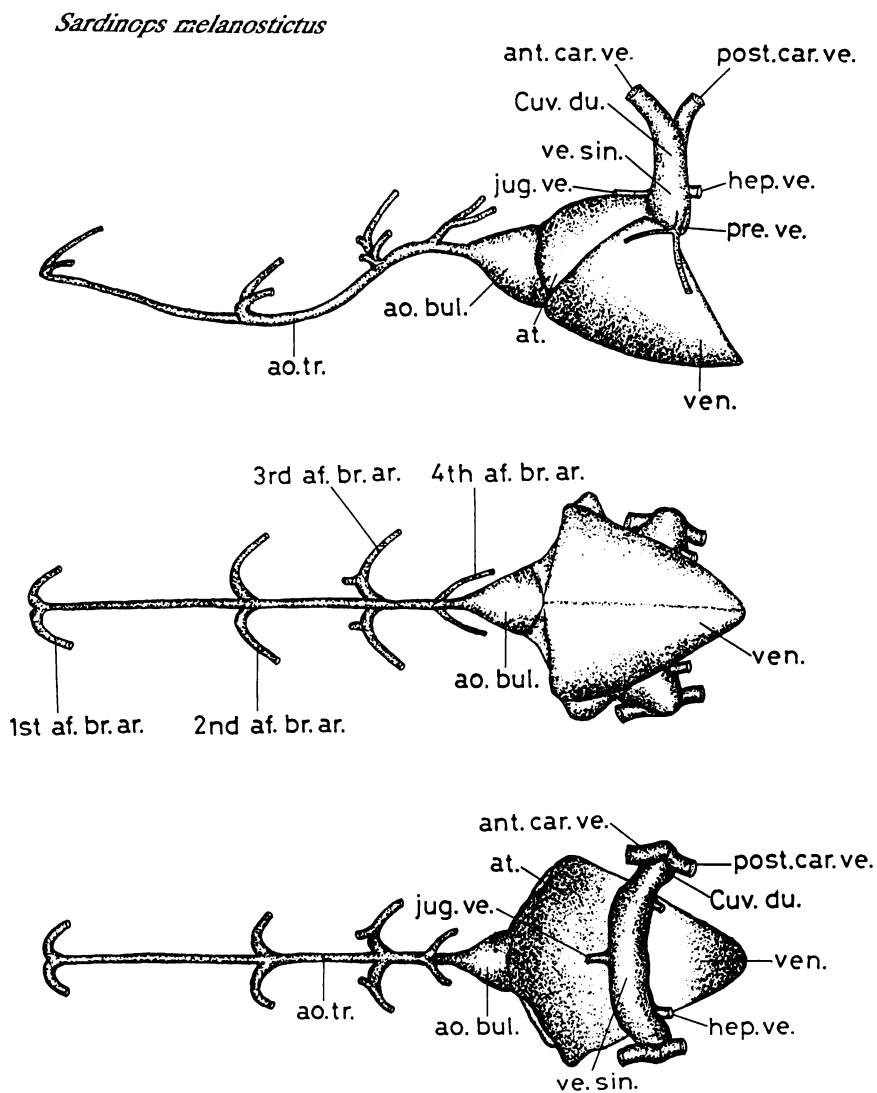


Fig. 1 External structure of the sardine heart. Upper, left lateral; middle, ventral; lower, dorsal. ant. car. ve., anterior cardinal vein; ao. bul., aortic bulb; ao. tr., aortic trunk; at., atrium; Cuv. du., Cuvierian duct; hep. ve., hepatic vein; jug. ve., jugular vein; post. car. ve., posterior cardinal vein; pre. ve., preabdominal vein; ven., ventricle; ve. sin., venous sinus; 1st af. br. ar., 1st afferent branchial artery; 2nd af. br. ar., 2nd afferent branchial artery; 3rd af. br. ar., 3rd afferent branchial artery; 4th af. br. ar., 4th afferent branchial artery.

entrance to the atrium. The same valves were also observed between the ventricle and aortic bulb. Another valves of the different type were bicuspidal valves provided with accessory valves, which were situated between the atrium and ventricle (Fig. 3).

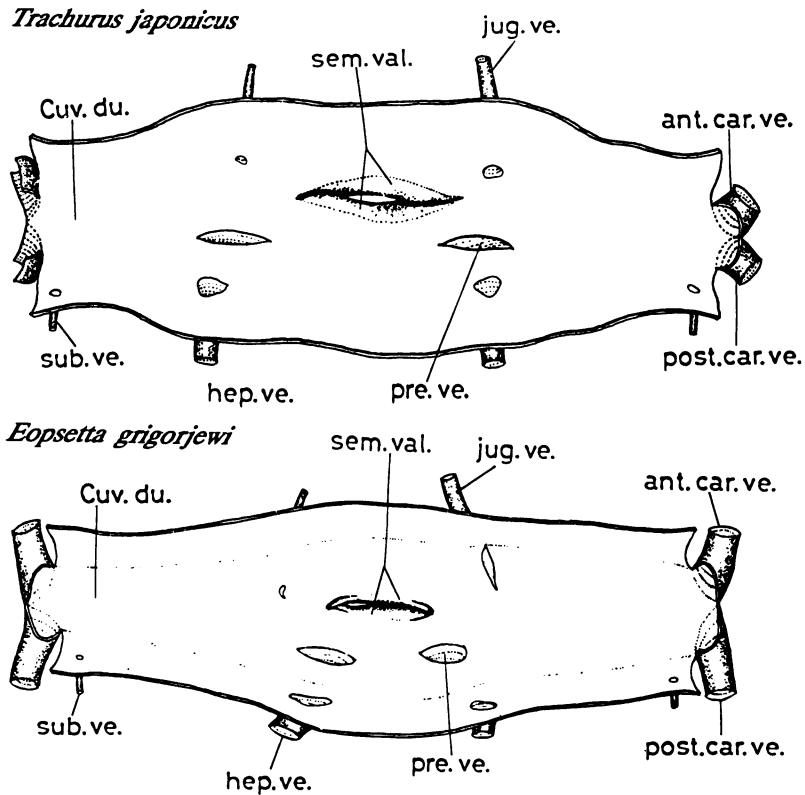


Fig. 2 Inside views of the sinus venosus, showing the distribution of opening sites of inflow blood.

ant. car. ve., anterior cardinal vein; Cuv. du., Cuvierian duct; hep. ve., hepatic vein; jug. ve., jugular vein; post. car. ve., posterior cardinal vein; pre. ve., pre-abdominal vein; sem. val., semilunar valves; sub. ve., subclavian vein.

The heart showed a triangular shape with its anterior apical. However, in sardine and mackerel, the hearts were contra-triangular. The size proportions of the aortic bulb, ventricle or atrium were varied according to species. For examples, skipjack tuna and sardine showed a small atrium compared to the ventricle (Figs. 1 and 3). The atria in horse mackerel, rock-fish and gurnard were large on the contrary. In flatfish, the aortic bulb was comparatively smaller than the atrium and ventricle. However, there were some significant relations between the component proportion of the heart and the swimming capacity of the fishes.

Muscular constructions of the heart were partially variable. The muscle of the atrium was diverged irregularly and called pecten muscle. That of the ventricle is spongy and called papillary muscle. The wall of the heart consisted of outer epicardium, middle myocardium and inner endocardium^{2,4)}. The epicardium connected with the pericardial membrane in junction of the sinus venosus and atrium. The endocar-

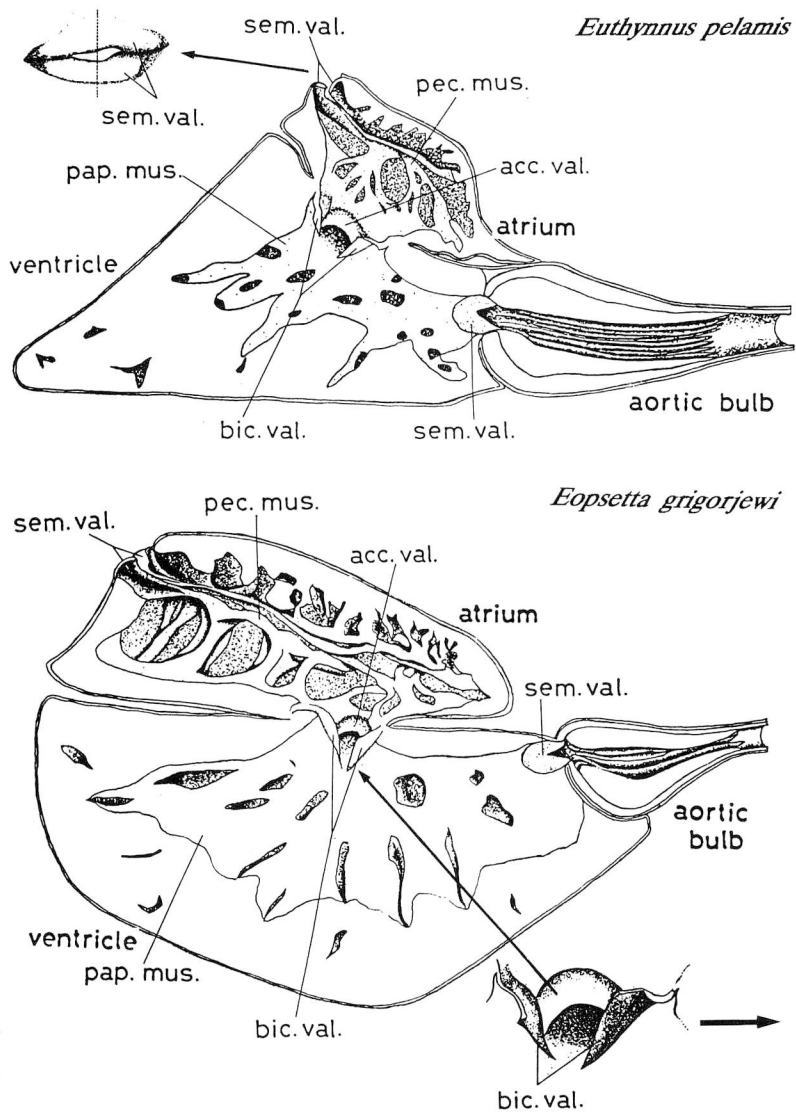


Fig. 3 Longitudinal sections of the heart, representing the arrangement of the atrium, ventricle and aortic bulb. The sinus venosus is removed in this figure. acc. val., accessory valves; bic. val., bicuspidal valves; pap. mus., papillary muscle; pec. mus., pecten muscle; sem. val., semilunar valves.

dium contained the epithelial and connective tissues, being directly exposed to in-flow blood. The myocardium consisted of the outer cortex layer and inner pecten or papillary muscle layer⁴⁾. This construction of the myocardium seemed to relate to a specific ability of the swimming behaviour. That is, a certain regularity was detected in the thickness ratio of the cortex to the inner layer mass between two different categories

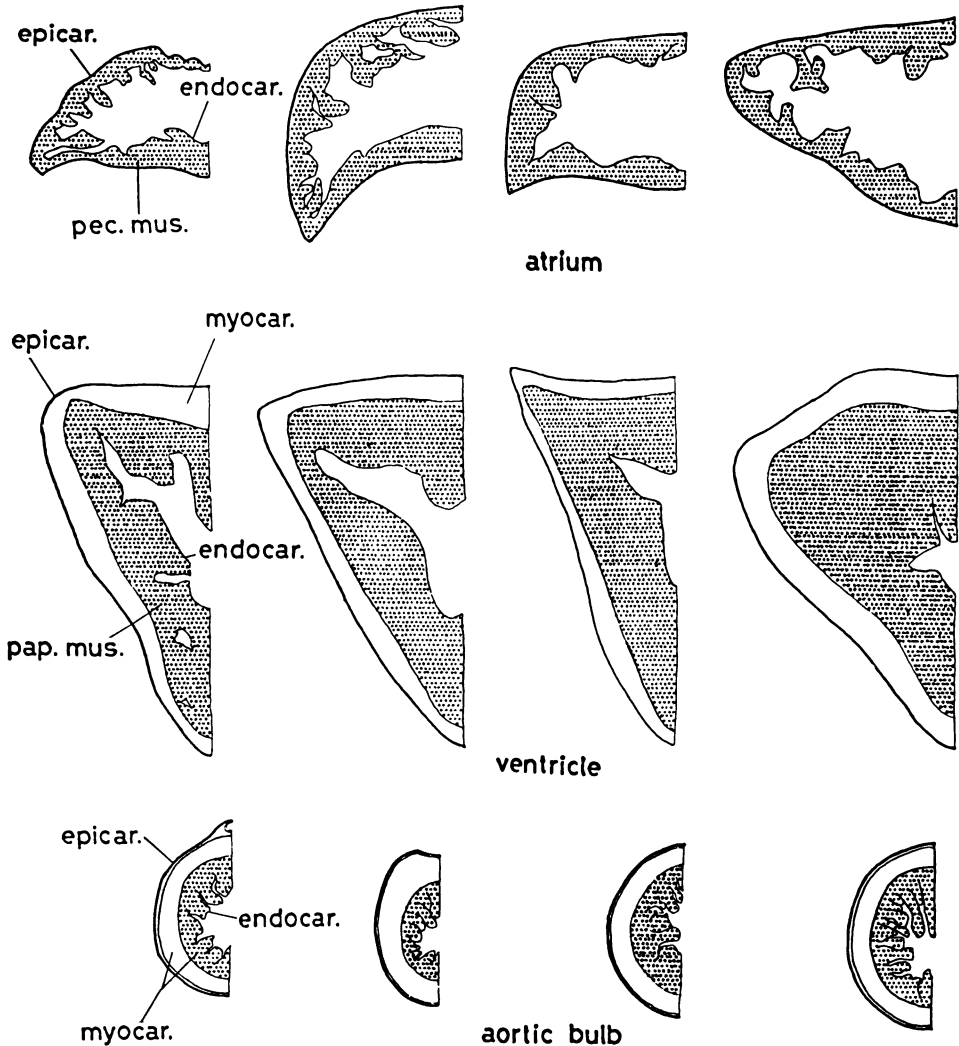
Euthynnus pelamis *Scomber japonicus* *Trachurus japonicus* *Sardinops melanostictus*

Fig. 4 Diagrams of the cross-sectioned halves of the atrium, ventricle and aortic bulb in the pelagic swimmers. endocar., endocardium; epicar., epicardium; myocar., myocardium; pap. mus., papillary muscle; pec. mus., pectenal muscle.

of the species as the previously indicated pelagic tuna *Katsuwonus pelamis* and sluggish toadfish *Opsanus tau*³⁾. In skipjack tuna, mackerel, horse mackerel, sardine and flatfish, the myocardium was composed of two layers (Figs. 4 and 5). The outer layer of the myocardium in flatfish was, however, extremely thin, as compared to those in the other fishes. The myocardia of rockfish and gurnard had the inner layer, papillary muscle. Such a disappearance of the myocardium cortex has also been reported in

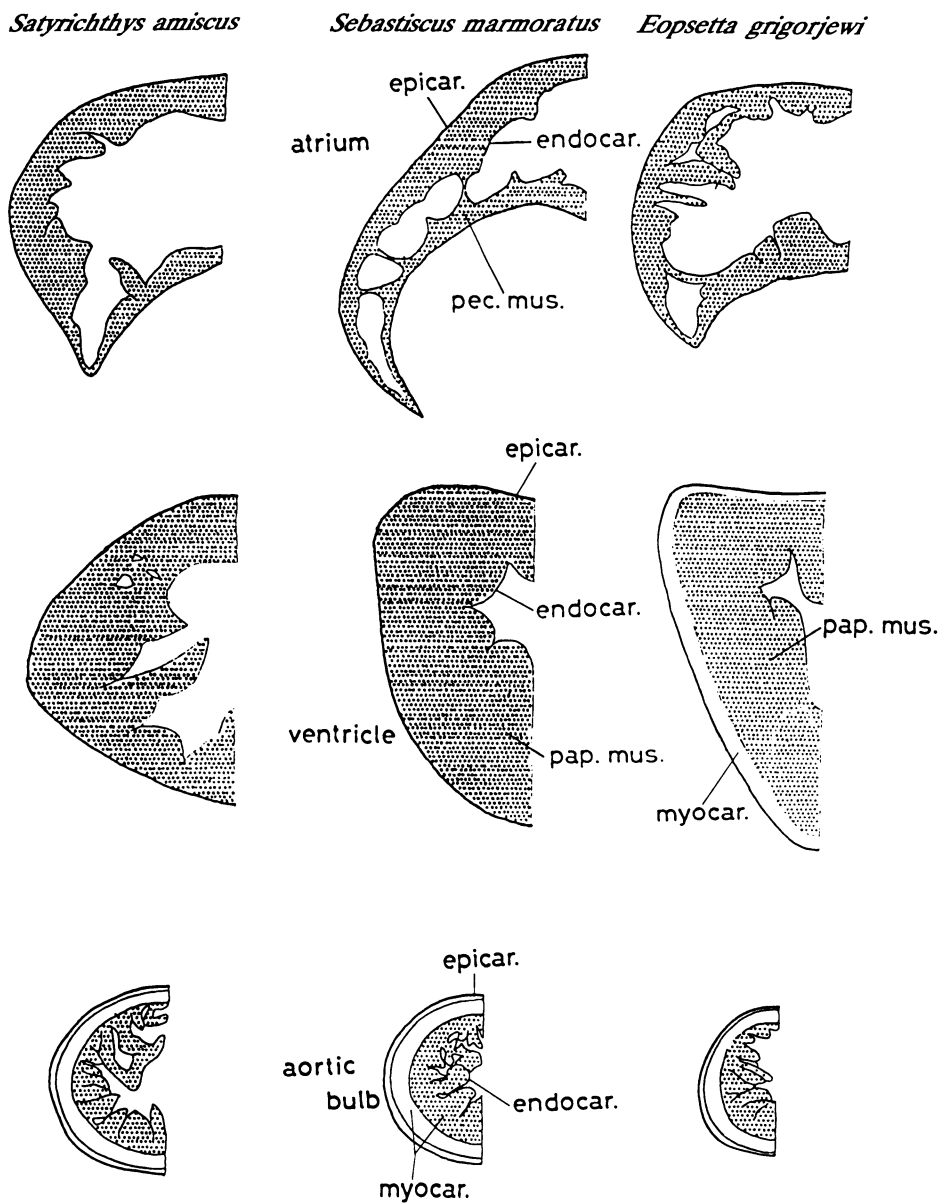


Fig. 5 Diagrams of the cross-sectioned halves of the atrium, ventricle and aortic bulb in the sluggish species. endocar., endocardium; epicar., epicardium; myocar., myocardium; pap. mus., papillary muscle; pec. mus., pectinal muscle.

Gadus species²⁾. The ventricle functions as a primo-pump of the blood circulation, producing successive strokes by cyclic contractions of the myogenic muscles²⁾. In higher vertebrates, the myocardial cortex became to develop further and possessed a coronary supply derived from the efferent branchial vessels⁴⁾. Thus among the heart com-

ponents, the ventricle might reflect the most distinct proportional development of the cortical structure according to functional necessity.

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