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Anatomy of the Branchial Organ of the Prawn, *Penaeus japonicus* BATE

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Abstract

Branchial organ of the prawn consists of the eighteen paired gill units, that is, six wall-gills, five anterior joint-gills, six posterior joint-gills and a foot-gill. Their distribution is as follows: a foot- and two joint-gills on the 2nd maxilliped; a set of a wall- and two joint-gills on each of the 3rd maxilliped, 1st, 2nd and 3rd pereiopods; a wall- and a joint-gill on the 4th pereiopod; a foot-gill on the 5th pereiopod. Branchial unit is classified as a dendrobranchia type, and shows externally a sack-like shape. Its structural components are a central axis, primary gill filaments and finer gill filaments which diverge from the primary ones. Afferent and efferent vessels run in pairs along the central axis, braching out at each entrance of primary gill filaments to those distal ends of still more diverged filaments. At the tips of filaments, each of vascular ducts forms a loop connection between afferent and efferent vessels. Efferent vessels getting out of their proper gills run upwards to the collecting cavity just before a pericardium. Their passages inside the thoracic wall are organized with duct-like gaps which have been formed by the thoracic shell and basal muscles of legs concerned. Arrangement of the paired vessel pores at the branchial attachment shows a certain regularity, that is, as for all of the wall-gills except of the 2nd maxilliped the efferent pores are situated peripherally than the afferent ones, reversely to the foot- and joint-gills. As for the wall-gill of the 2nd maxilliped, it is positioned approximately in parallel with the afferent one.

External respiration of the prawn is taken charge of by gills which locate at the thoracic appendages or their basal thoracic wall, being surrounded by a branchiostegite. In the Decapoda, a foot-gill (podobranchia), two joint-gill (arthrobranchia) and a wall-gill (pleurobranchia) are fundamentally distributed corresponding to their attaching place. Many species lack some of them generally in nature, and there exist significant specific differences in the kind and the number about such gills[1)2)]. Anatomical examinations have dealt here with the branchial arrangements and their constructional structures of gills of the prawn, relating to such a vascular system as branchial afferent and efferent vessels.

Materials and Method

Prawns, *Penaeus japonicus* BATE, used in this study were about 200 g of females in body weight. Cephalo-thoracic regions were fixed with 10% formalin before anat-

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omical observations with the naked eye or under binocular microscope. For the finer structures of gill filaments and recognitions of efferent vessels inside the thoracic wall, methylene blue was used selectively as a weak solution of staining.

Results and Discussion

Gills of the prawn consist of the eighteen units at each side. All of them are situated at the thoracic region, covering themselves with the paired branchiostegite of carapace. Their distribution ranges through the arthropodial membrane at the base of the leg (arthrobranchia or joint-gill) and the neighbouring body wall (pleurobranchia or wall-gill). Four gill series on each segment have been considered to be typical in the Decapoda[1)], however some members of them show a degenerated situation at the prawn (**Fig. 1**). The 7th segment is the most anterior segment possessing gills, which corresponds to the 2nd maxilliped and is provided with three gills. They are two joint-gills and a foot-gill. The latter foot-gill is named as a podobranchia, and only recognized at the coxa of this appendage. The 1st maxilliped which derives from the 6th segment of the prawn lacks entirely such gills as in other species. From the 8th to 11th segments which correspond to the 3rd maxilliped, 1st, 2nd and 3rd pereiopod respectively, branchial arrangement shows a same pattern one another, that is, two joint-gills and a wall-gill are provided as a set at each appendage. At the 4th pereiopod of the 12th segment, one of the joint-gills is lost, so that its combination is a pair of joint- and wall-gill. The most posterior appendage which possesses the gill is the 5th pereiopod of the 13th segment. It is provided only with a wall-gill as in almost other species of the Decapoda. The above mentioned results of branchial arrangements are summarized in **Table 1**, also diagrammed in **Fig. 4.**

Afferent vessels to gills are conducted in the first place by an aorta descendents which comes perpendicularly from the heart to a ventral thoracic artery. The latter lies below the ventral nerve cord, branching out to thoracic legs as shown in **Fig. 2.** In each appendage, such an appendage artery may invade deeply into the distal segment, but its peripheral system especially connecting with the branchial vessels could not be discerned in detail in this experiment. Vessels which enter into the gills have been only traced near inside the thoracic wall like as in **Fig. 3**, by local injection of dyeing. Afferent vessels to the heart make a collecting cavity at each side with a thin membrane which encloses the heart at its dorsal part. Tributaries diverged from the cavity connect themselves to corresponding vessel pores at each attaching site of the gills. The latter is the opening of the efferent branchial vessel. The above mentioned arrangement of appendage gills and their pores of afferent and efferent branchial vessels are diagrammatically shown in **Fig. 4.** As for the 2nd and 3rd maxillipeds, a paired pore of the anterior joint- or wall-gill shows a parallel arrangement which is different from other pairs. In the others, each of pairs is in series. All the wall-gills except this 3rd maxilliped arrange their afferent pores in a proximal

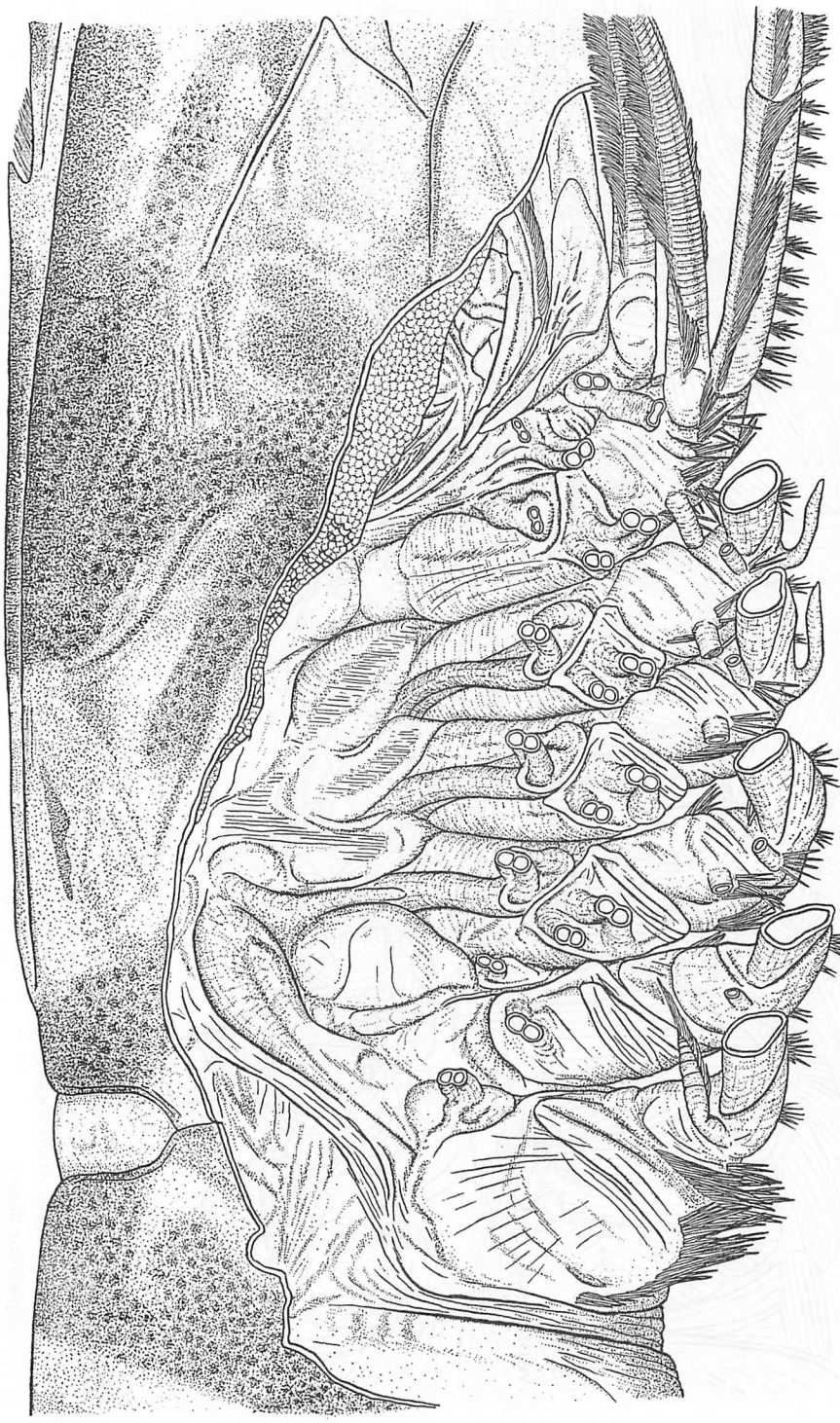


Fig. 1. Outward appearance of the branchial region of carapace, representing the arrangement of gill bases. All of pereiopods are cut off at the level of the ischiopodite. Their epipodites are also removed for simplification.

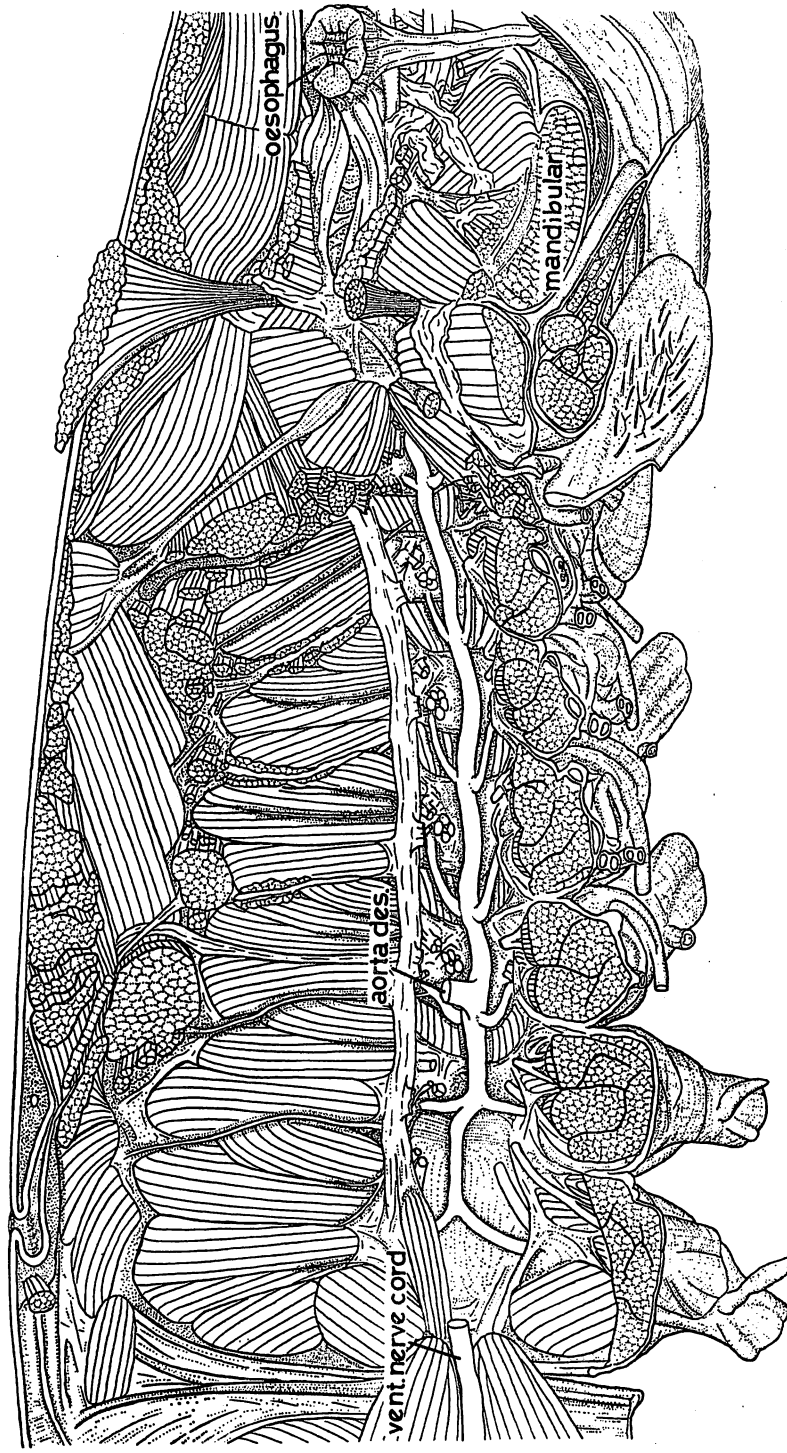


Fig. 2. Ventral thoracic artery and its brachings to each pereiopod. Such internal organs as a stomach, a midgut gland and a gonad are removed accompanying with some of dorsal and lateral muscles. An upper-lying ventral nerve cord is also taken off. The artery sends its vascular ducts symmetrically to each pereiopod and maxilliped, and its trunk runs sagittally along a ventral midline between an anterior and a posterior thorax.

Table 1. Branchial formula of the prawn, *Penaeus japonicus*.

The 1st maxilliped corresponds to the segment of VI, and has no gills. Foot-gill is recognized only at the 2nd maxilliped. The 4th and 5th pereiopods (seg. XII and seg. XIII) have no epipodite.

Segment / Gill	VI	VII	VIII	IX	X	XI	XII	XIII	Total
Foot-gill	0	1	0	0	0	0	0	0	1
Anterior joint-gill	0	1	1	1	1	1	0	0	5
Posterior joint-gill	0	1	1	1	1	1	1	0	6
Wall-gill	0	0	1	1	1	1	1	1	6
Epipodite	1	1	1	1	1	1	0	0	6
Total	1e	3+1e	3+1e	3+1e	3+1e	3+1e	2	1	18+6e

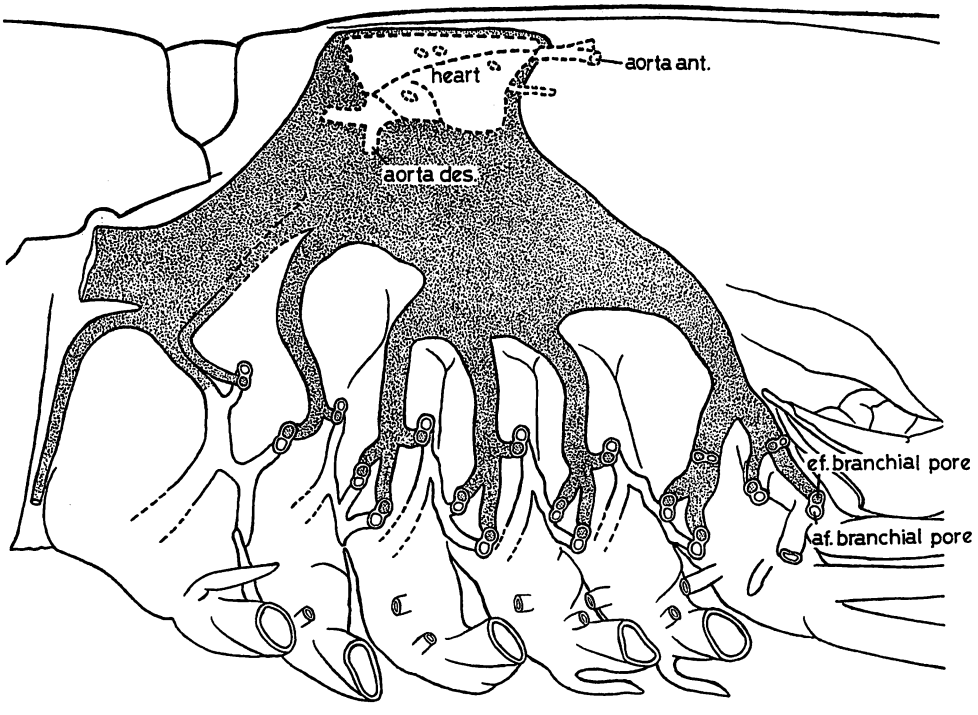


Fig. 3. Diagram of the efferent vessel (Vasa branchiocardiaca) system of the prawn, *Penaeus japonicus*. Vascular ducts are not so well developed distally as arteries, and their vessel walls borrow generally from the proper gaps of shell and musculatures which are corresponding to the passages. However, their proximal collecting area near the pericardium forms a comparatively large space surrounded by a characteristic thin membrane. At the bases of gills, their efferent pores are arranged in a certain regularity. Especially concerning with the pereiopods, wall-gills situate their efferent openings away from the heart than the afferent. On the other hand, each pore of joint-gills shows its location nearer the heart than the latter.

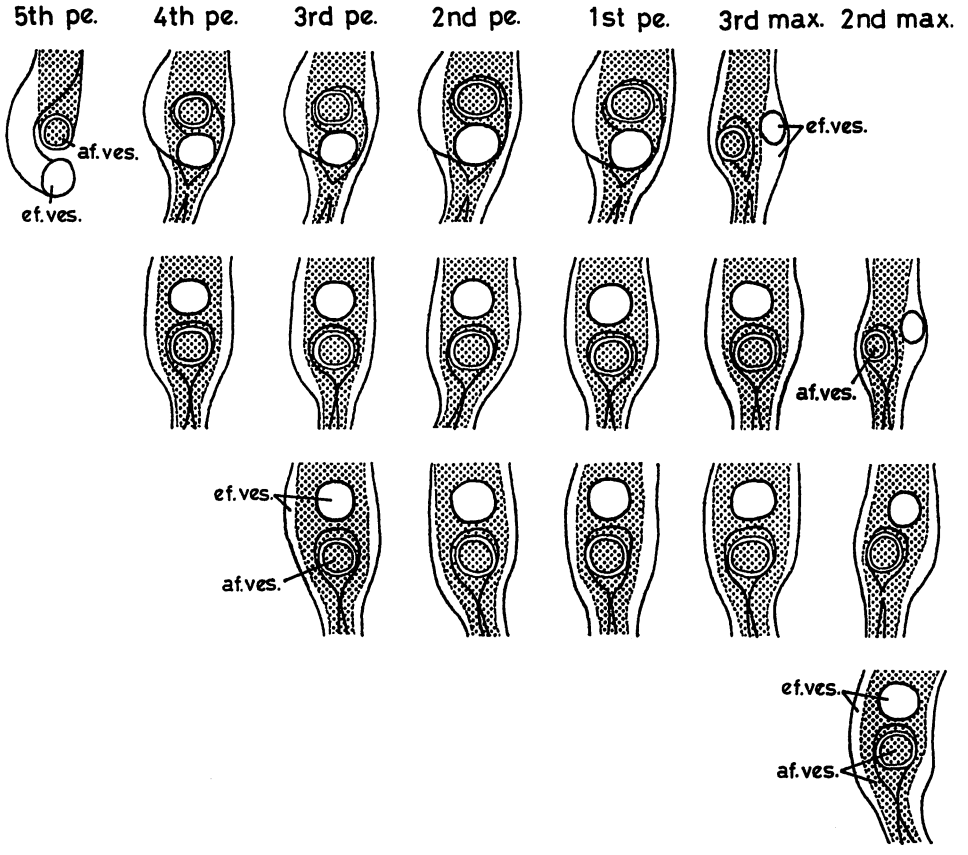
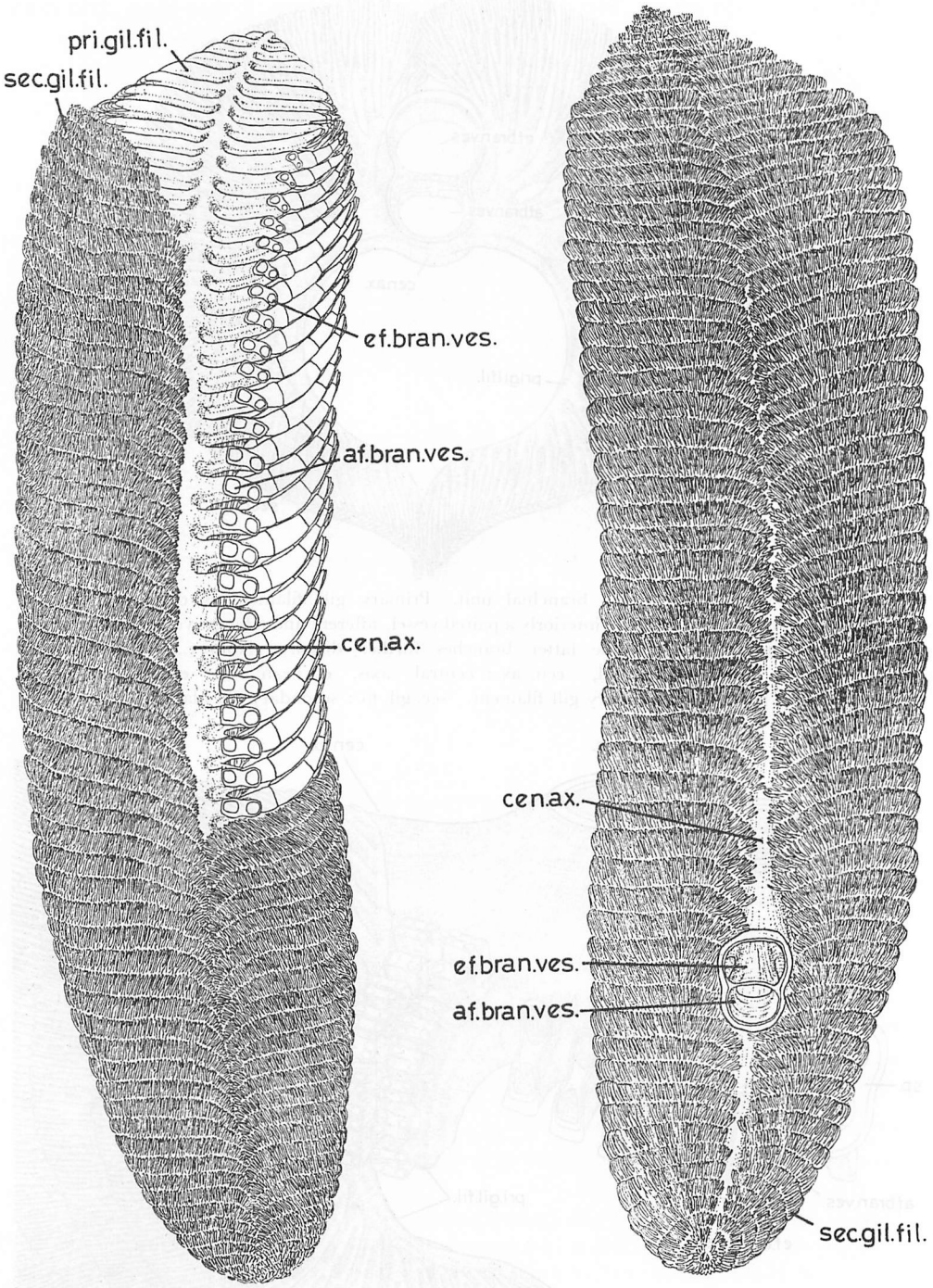


Fig. 4. Diagram of the basal pore arrangement of gills, refering to the afferent and efferent vessel system. Each drawing represents roughly to be situated on its proper position as seen in nature. The 2nd maxilliped has a foot-gill but no wall-gill contrary to the others. The 4th pereiopod lacks both anterior joint-gill and foot-gill. The 5th pereiopod has only a wall-gill. All the wall-gills show each arrangement of the efferent pore inferior to the afferent one, reversely to the foot- and joint-gills. Abbrev., af. ves.: afferent vessel, ef. ves: efferent vessel, max.: maxilliped, pe.: pereiopod.

row against efferent ones. Reversely all the joint- and foot-gills arrange their afferent pores in distal rows against efferent ones.

Gills of the prawn are classified as a dendrobranchial type, and the external structure of their unit shows a sack-like shape (**Fig. 5**). Its upper part is open, and lateral parallels are formed by loop- or crescent-shaped primary gill filaments accompanying

Fig. 5. Branchial unit of the prawn, *Penaeus japonicus*. Left is an exterior view, representing partially the central axis and primary gill filaments. Right is an interior view, that is the attaching side to the thoracic wall of a gill chamber. Abbrev., af. bran. ves.: afferent branchial vessel, cen. ax.: central axis, ef. bran. ves.: efferent branchial vessel, pri. gil. fil.: primary gill filament, sec. gil. fil.: secondary gill filament.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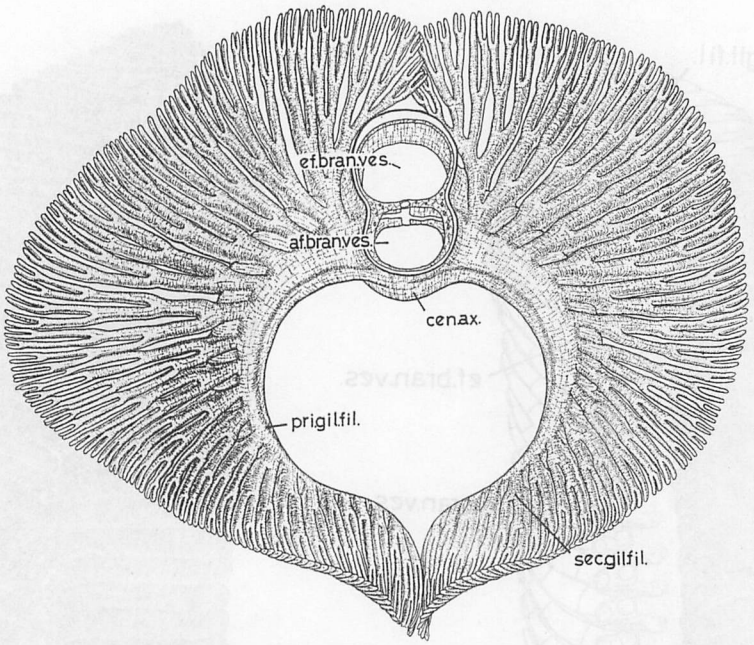

Fig. 6. Transversal slice of the branchial unit. Primary gill filament is derived from the central axis which possesses interiorly a paired vessel, afferent and efferent vessels, sending off many gill filaments. The latter branches further distally. Abbrev., af. bran. ves.: afferent branchial vessel, cen. ax.: central axis, ef. bran. ves.: efferent branchial vessel, pri. gil. fil.: primary gill filament, sec. gil. fil.: secondary gill filament.

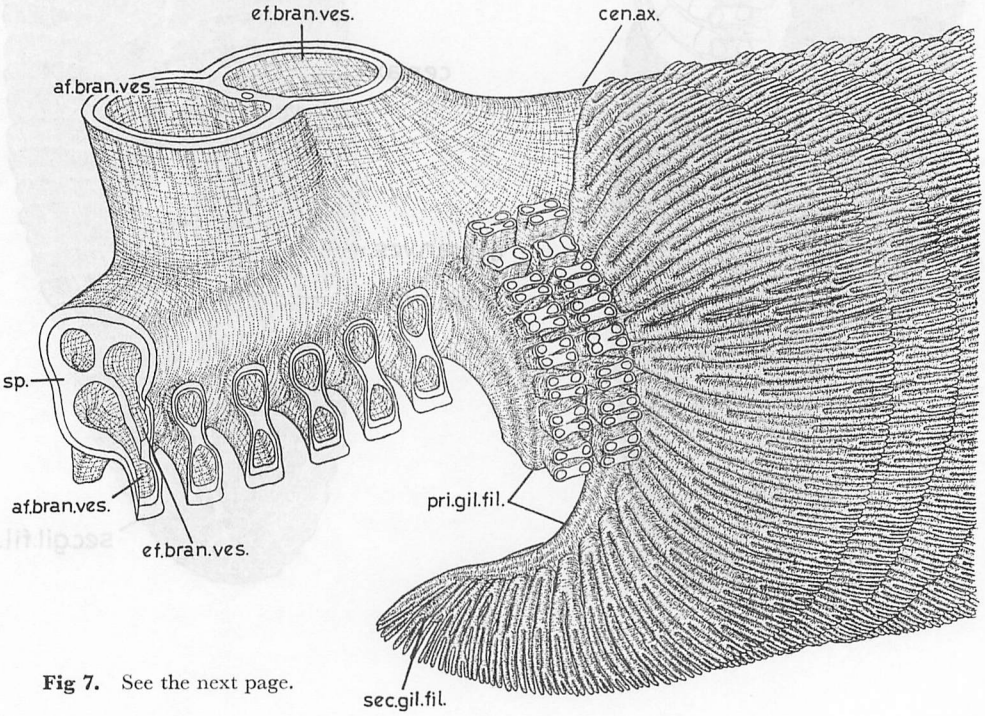

Fig 7. See the next page.

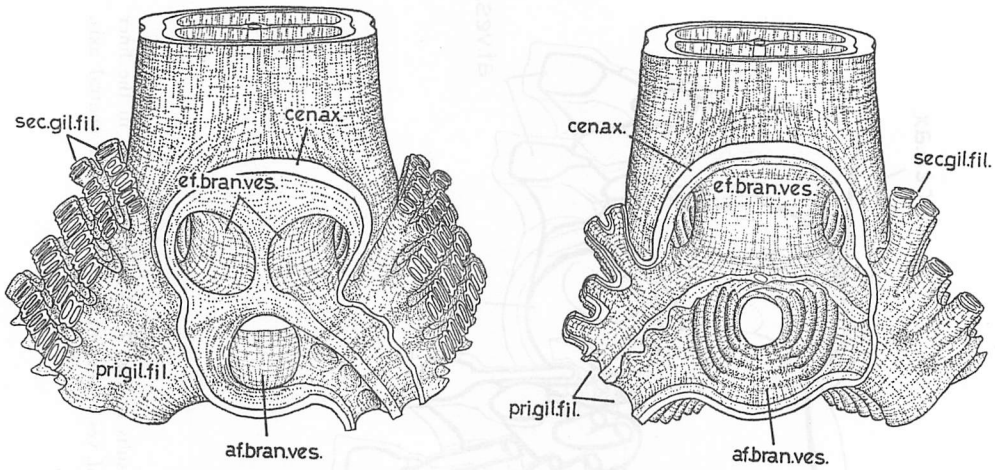

Fig. 8. Area of the branchial base attaching to the joint membrane, showing a divergence pattern of the afferent and efferent vessels. Left is an inferior view, and right is a superior (dorsal). In the former, the efferent vessel shows a paired condition at this basal part, holding the afferent trunk between its boughs. In the latter drawing, both of the afferent and efferent cavities expand a little at this side, and so each of vessel entrances to primary filaments are glanced. Abbrev., af. bran. ves.: afferent branchial vessel, cen. ax.: central axis, ef. bran. ves.: efferent branchial vessel, pri. gil. fil.: primary gill filament, sec. gil. fil.: secondary gill filament.

their finer derivatives. Its lower part is almost closed by gradually shortening loops of filaments (**Fig. 6** and **7**). Such a branchial unit is mainly composed of three parts, that is, a central axis which possesses interiorly a pair of afferent and efferent vessels, primary gill filaments which are branches of the former and secondary gill filaments deriving from the latter. Branchial vascular system develops up to finer filaments, forming a loop-connection between afferent and efferent vessels at each tip of peripheral filaments (**Fig. 10**). After entering into the branchial unit hemolymph flows at first in the afferent branchial vessel along the central axis, sending its tributaries at each duct in primary filaments. It goes repeatedly diverging to the

Fig. 7. Stereogram of the branchial unit of the joint-gill, partially taken off its components. Afferent branchial vessel enters into the central axis, then runs along its axis sending out many vascular ducts at each branching point of primary gill filaments. The central axis possesses also the efferent branchial vessel superiorly in case of this drawing to the afferent one along its axis. The former is provided with many branches as the latter. In such all filaments as primary, secondary and more finer ones, these vessels run in pairs distally to their end areas. At the terminal, each of them forms a loop connection as shown in **Fig. 10.** Abbrev., af. bran. ves.: afferent branchial vessel, cen. ax.: central axis, ef. bran. ves.: efferent branchial vessel, pri. gil. fil.: primary gill filament, sec. gil. fil.: secondary gill filament, sp.: sponge structure.

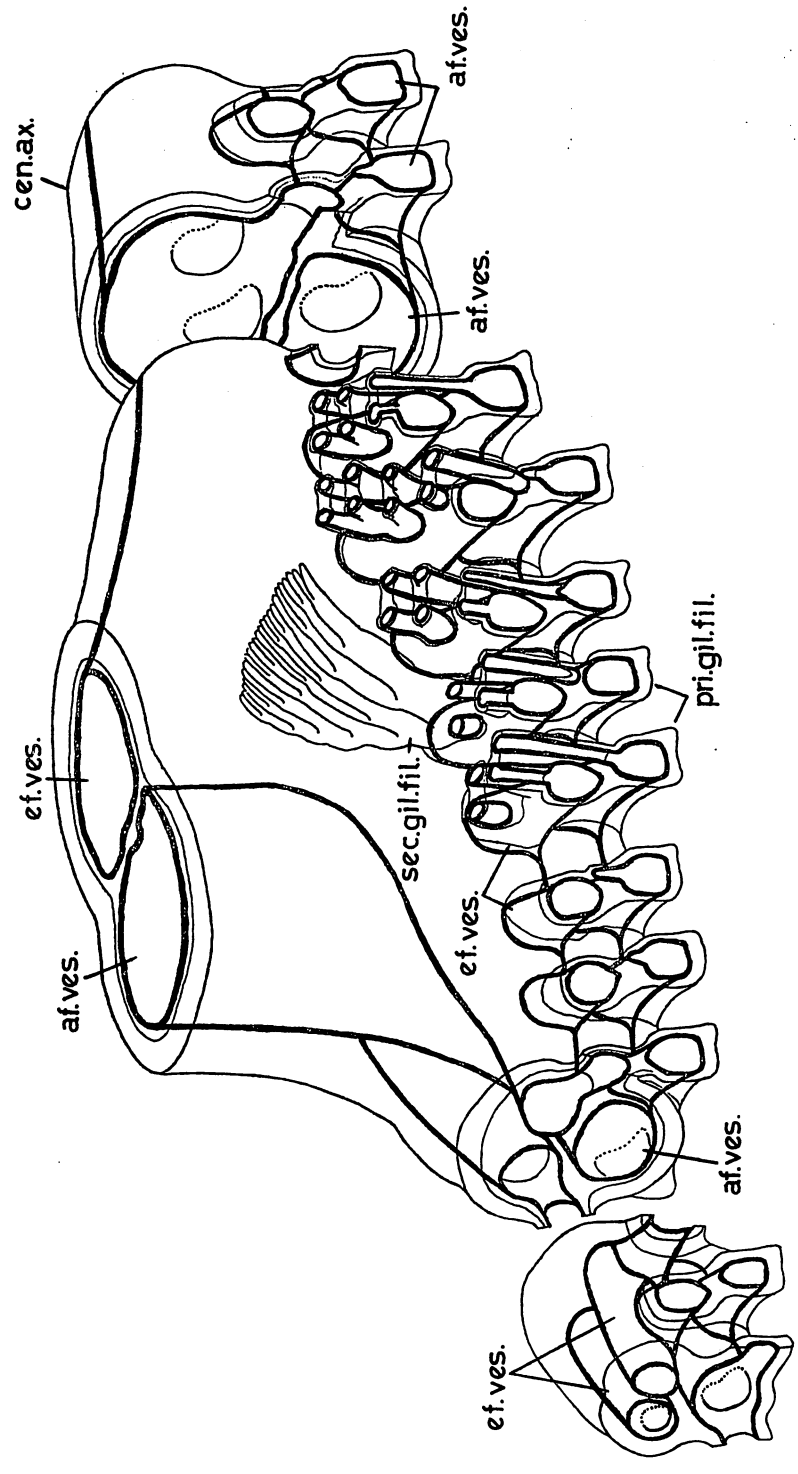

Fig. 9. Diagram of the fundamental construction of the branchial unit, conducted from the results of **Fig. 7.** Vascular systems in the finer components more than secondary gill filaments are excluded for simplification. Abbrev., af. ves.: afferent vessel, cen. ax.: central axis, ef. ves.: efferent vessel, pri. gil. fil.: primary gill filament, sec. gil. fil.: secondary gill filament.

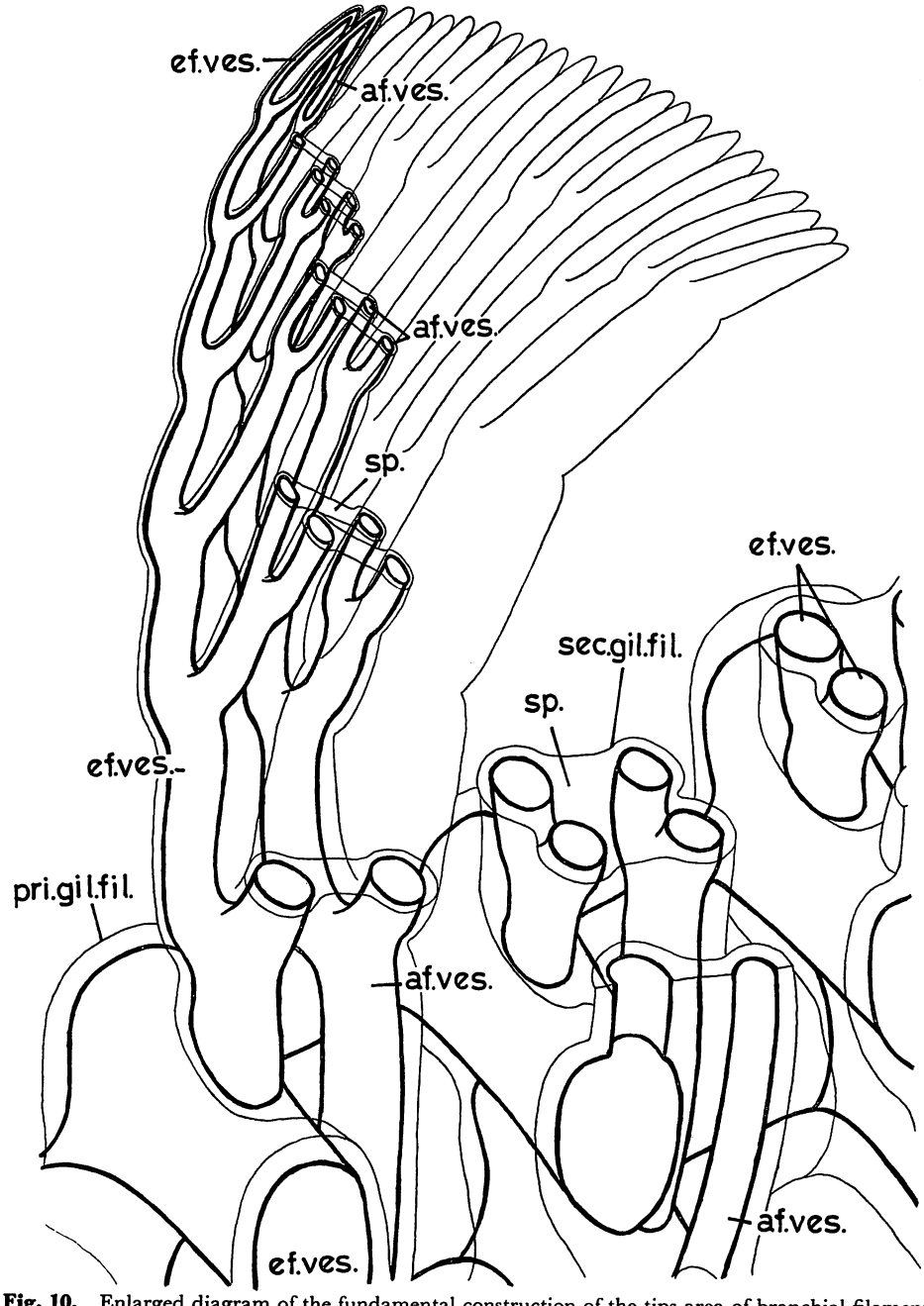

Fig. 10. Enlarged diagram of the fundamental construction of the tips area of branchial filaments, representing inner vascular systems. Distal filaments diverge repeatedly with inner paired vessels. At the terminal end, each of these vascular components forms a loop connection between the afferent and efferent ones. After reaching that turning point, afferent hemolymph becomes to have an efferent character. Abbrev., af. ves.: afferent vessel, ef. ves.: efferent vessel, pri. gil. fil.: primary gill filament, sec. gil. fil.: secondary gill filament, sp.: sponge structure.

terminal ends of peripheral ones. Following turning at the tips of peripheral filaments, hemolymph becomes to have an efferent character and converging repeatedly at each branching point it returns to the central axis. Then, it flows through the efferent pore from the branchial unit.

The above mentioned structure of the vascular system is diagrammatically drawn in **Fig. 9** and **10**. It seems that the characteristic construction is based on the situation of the efferent branchial vessel, that is, the trunk of the afferent vessel is enclosed partly by the crooked trunk of the efferent one or held between the halves of the divided latter at the basal area of the branchial unit.

References

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