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Morphological Study on the Mandibular Organ of the Prawn *Penaeus japonicus* BATE

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Abstract

The mandible of the prawn *Penaeus japonicus* is provided with two points of articulation. One of them, upper joint, consists of a dorsal tip of the outside of the mandible and a cap-like covering which is a protector named in this experiment as the joint apparatus. The other is a lower joint which is separated into two combinations ; a fist-like process of the ventro-posterior rim of the epistomal plate, articulated with the receptor process of the frontal edge of the gnathal lobe of the mandible and its near part touched with the antero-superior edge of the gnathal lobe. Movement of the paired mandible is restricted to a single plane which lies perpendicular to the hinged line. The planes of movement for two mandibles are orientated at approximately 30° to the sagittal plane. Mandibular muscles can be divided into two groups ; adductors and abductors. Adductors are the major and minor muscle bundles. The major mandibular adductor has its origin on the endophragmal skeleton and attaches to the lateral carapace. The minor mandibular adductor connects the dorsal carapace with the posterior rim of the mandible on which an oar-like apodeme is prepared. The abductor is composed of four members. Each connects superior inside of the gnathal lobe with the lateral carapace. Innervation of mandibular muscles is as follows ; the major and minor mandibular adductors receive respective nerves derived from the circumoesophageal connective, and the mandibular abductors are innervated by two paired nerves derived from the commissural ganglion and circumoesophageal connective.

Although several descriptions of macruran mandible musculature and innervation exist, that of the prawn, *Penaeus japonicus*, is as yet undescribed. The mandible, the most anterior of the crustacean mouth parts, is a feature common to mandibulate arthropod. The crustacean mandible has been the subject of some comparative studies. The mandibles of the nephropsideans, *Astacus fluviatilis*[1][2], *Homarus americanus*[3] and *Cambarus longulus*[4] have received some attention but only the foremost is described in any detail. Recent progress of the prawn culture in Japan yields a number of basic studies related to the rearing technique of larvae or adults and nutritional demands as basic data to research for an ideal diet of the prawn. However a fundamental knowledge of the prawn itself is not as yet well obtained. This report on

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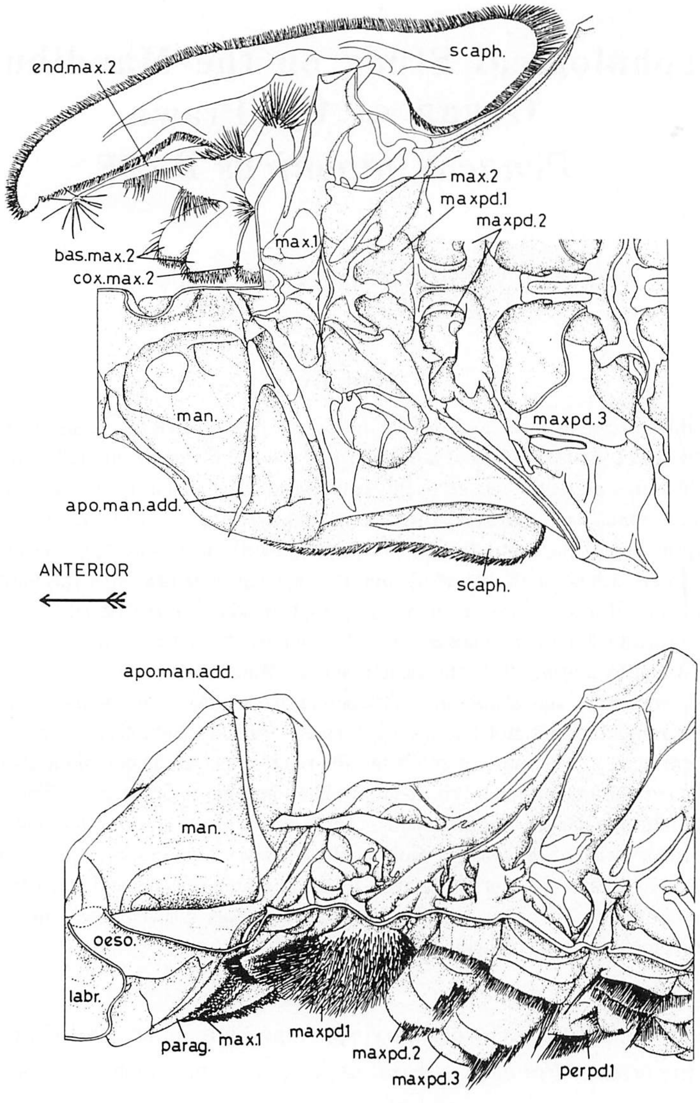

Fig. 1 Dorso-horizontal and left lateral diagrams of the thoracic exuviae, representing the positional relation of the mandible with following appendages. The upper is accompanying with their partly excised bases of right appendages and successive outer wall except an each junction of the 1st and 2nd maxillae to the endoskeleton. The lower shows its median section. Abbrev., apo. man. add.: apodeme of the mandibular adductor, bas. max.2: basipodite of the 2nd maxilla, cox. max.2: coxopodite of the 2nd maxilla, end. max.2: endopodite of the 2nd maxilla, labr.: labrum, man.: mandible, max.1: 1st maxilla, max.2: 2nd maxilla, maxpd.1: 1st maxilliped, maxpd.2: 2nd maxilliped, maxpd.3: 3rd maxilliped, oeso.: oesophagus, parag.: paragnatha, perpd.1: 1st pereiopod, scaph.: scaphognathite.

the mandible would supply the proper understanding of feeding habits of the prawn with useful data of anatomical constructions of skeleton, muscles and nerves.

Materials and Method

The skeletal anatomy of the mandible of *P. japonicus* was examined in exuviae. The muscular morphology and innervation were studied in materials fixed in 10% formalin. The finer nerve bundles were located with methylene blue staining techique.

Results and Discussion

The mandible of *P. japonicus* is similar in gross details to those of other nephropsideans ; *Homarus gammarus*[5], *H. americanus*[3], *Cambarus longulus*[4] and *Astacus fluviatilis*[1][2]. It is a paired organ situated between the labrum and paragnatha. It shows like a hemisphere of Rugby ball (**Fig.1**). The gnathal lobe of the mandible has

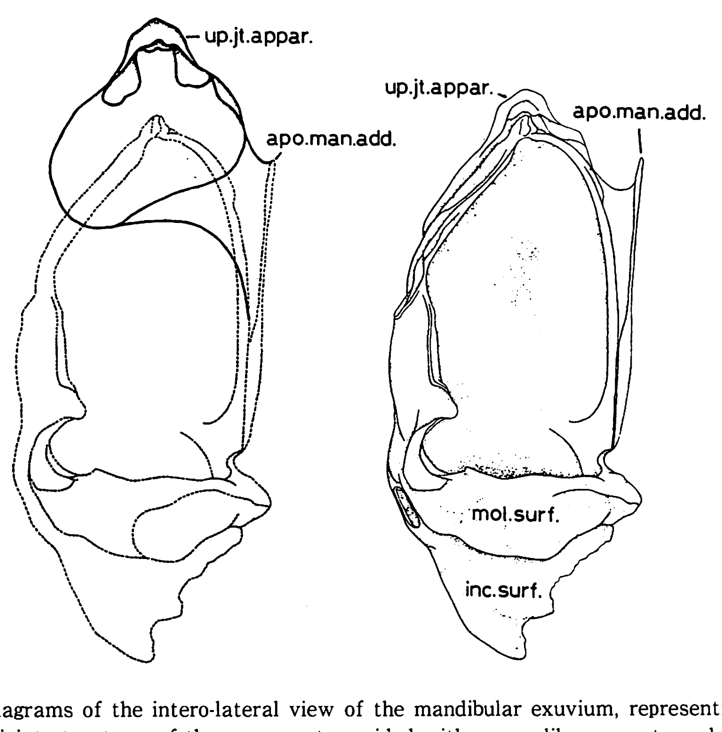

Fig. 2 Diagrams of the intero-lateral view of the mandibular exuvium, representing the joint structure of the upper part provided with a cap-like apparatus which is situated at the upper tip of the mandible. The left shows a pulled condition of the apparatus opposed to the natural right. Abbrev., apo. man. add. : apodeme of the mandibular adductor, inc. surf. : incisor surface, mol. surf. : molar surface, up. jt. appar. : upper joint apparatus.

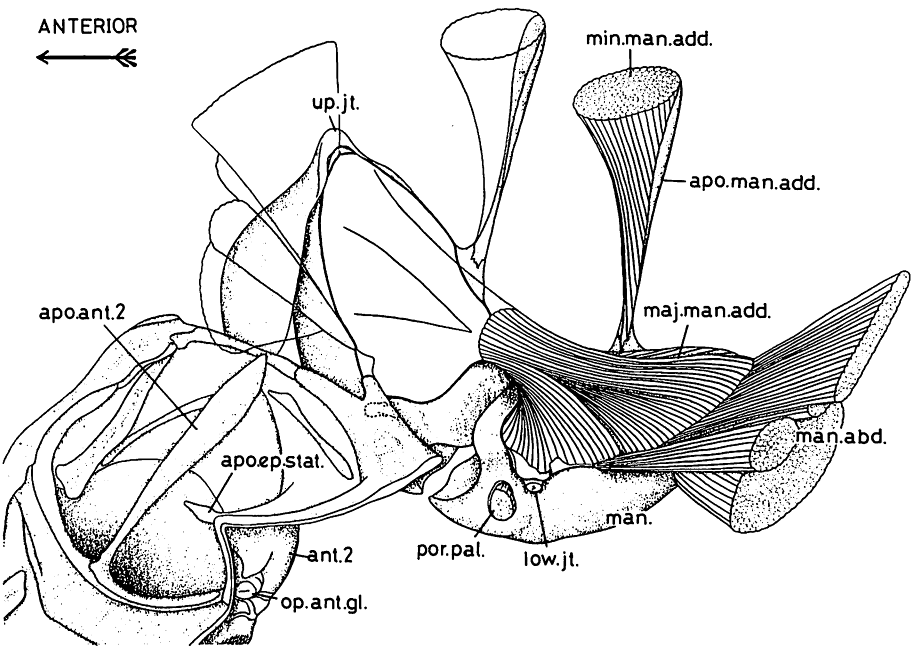

Fig. 3 Diagram of the antero-dorsal view of the basal of the 2nd antenna and mandibular exuviae added relating muscles as four abductors and two adductors. Mandible has two junctions as the lower and upper. The former is situated at the frontal edge superior to the pore of the palpus, connecting with the process of the posterior epistome which forms a posterior basal brim of the 2nd antenna. The structure of the latter is shown in **Fig. 2**. Abbrev., ant.2 : 2nd antenna, apo. ant.2 : apodeme of the 2nd antenna, apo. ep. stat. : apodeme of the epistomal stator, apo. man. add. : apodeme of the mandibular adductor, low. jt. : lower joint, maj. man. add. : major mandibular adductor, man. : mandible, man. abd. : mandibular abductor, min. man. add. : minor mandibular adductor, op. ant. gl. : opening of the antennal gland, por. pal. : pore of the palpus, up. jt. : upper joint.

two processes ; a dorsal molar process of calcified cuticle and a ventral incisor process with a chitin-like cutting edge. The molar process is a partially protruded area of the lateral surface of the mandible toward the oral cavity, and shows an elliptical shape smoothed compared to the incisor. Although anterior edge of the latter process shows a smoothly curved surface, its posterior margin has a rugged surface and in closing of mandibles whole areas and posterior edges of them come in contact respectively (**Fig.2**). Endopodite, mandibular palpus, is derived from a small pore prepared inferiorly at the front of the gnathal lobe. Labrum is held between these paired palpus. Postero-superior edge of the mandible is provided a little to the midline with an oar-like apodeme to which the muscle of mandibular adductor adheres (**Fig.3**). Contraction of this muscle will produce an inside swing of the mandible. The mandible is hinged along its anterior margin with the epistomal plate and has two points of articulation. These are named in this experiment an upper joint and a lower joint as shown in **Fig.3**. The former consists of a dorsal tip of outside edge of the mandible and a cap-like covering named in this experiment as the joint apparatus which is the protector made with a definitely thick chitin and its inferior margin becomes gradually to be a thin membrane. The membrane extends superiorly extero-lateral of the mandible and connects with the above mentioned apodeme. As for the lower joint, it is located near the midline at the frontal margin of the gnathal lobe and is separated into two parts in detail. A fist-like process of the ventro-posterior rim of the epistomal plate articulates with the receptor process, of which tip shows a hollow disc, prepared at the frontal edge of the gnathal lobe on a level with the moral process. The other combination of the lower joint corresponds to the part of ventro-posterior rim of the epistomal plate and comparatively thick area of antero-superior edge of the gnathal lobe on a level superior to the molar process. The lower joint has not been recognized in *P. setiferus*[6)] but it seems to be one of fulcra which form with the upper joint an axis of the mandibular movement in *P. japonicus* like as *H. gammarus*[5)]. Movement of each mandible is restricted to a single plane which lies perpendicular to the hinged line. The planes of movement for two mandibles are orientated at approximately 30° to the sagittal plane and hence do not directly oppose one another. In opening, the mandibles swing ventro-laterally and in closing they move dorso-medially. And also mandibular opening seems to receive some restriction on the movable range compared to the closing.

Mandibular muscles can be divided into two groups; adductors and abductors. These terms are used to indicate whether the disposition of the muscle is such that it will tend to close or open the mandible but not that this is necessarily their main function. Adductors are easily divided into two main bundles like in *P. setiferus*[6)]. Major mandibular adductor arises from the anterior-most lip of the endophragmal skeleton posterior to the mandible and goes radially to the almost area of the inner surface of the gnathal lobe. Each of paired minor mandibular abductor has its origin on the pylorus area of the dorsal carapace and attaches showing a retro-conical shape to the posterior rim of the mandible by means of a single oar-like apodeme. These muscles have been named by YOUNG[6)] the anterior and posterior mandibular adductors, respectively. However in *P. japonicus* the anterior mandibular adductor shows a considerably large size compared to the posterior one, then is suitably named in this experiment the major mandibular adductor. In *H. gammarus*, WALES et al. have distinguished seven adductors and the above mentioned major and minor mandibular adductors correspond respectively to the Muscles M1-M6 and Muscle M9. The Muscle M9 has been regarded as the largest muscle by far among seven adductors. Such numerical and size differences of adductors between species would provide an interesting problem to the comparative study of crustacean feeding mechanism. Abductors of the mandible in *P. japonicus* consist of four muscles contrary to YOUNG who has shown only one abductor in *P. setiferus*. These muscles have their converged origin on the superior inside of the gnathal lobe and attach separately each other to the lateral carapace (**Fig. 3**). They are two superior muscles, an inferior one and a middle one. The superior muscles are separated to the anterior conical and posterior flat members. The inferior muscle shows the most large and conical shape, and the middle muscle slenderly conical shaped is situated closely inferior to the postero-superior muscle. In *H. gammarus*, abductors have been counted two, each of which showed an entirely different distribution. It seems that the closing of the mandible is more powerful than the opening because of the dominant occupancy of adductors in the inner surface of the gnathal lobe compared to the abductors in *P. japonicus*.

As described for *A. fluviatilis*[7], *C. affinis*[8] and *H. gammarus*[5], the mandible of *P. japonicus* is innervated by two nerve trunks. These are the major mandibular adductor nerve derived from the ventral swelling of the circumoesophageal connective just before the suboesophageal ganglion and the mandibular abductor nerve composed of two members which arise from the commissural ganglion and circumoesophageal connective at the site a little posterior to the commissural ganglion (**Fig.4** and **5**). The major mandibular adductor nerve enters dorso-posteriorly into the gnathal lobe crawling along the inner surface of the molar process, then diverges there to three branches. One of them lengthens forward considerably and after sending off some branches to the major mandibular adductor becomes to be the mandibular palpus nerve. The other two branches diverge repeatedly and go to the major mandibular adductor. One of two branches goes downward in the major mandibular adductor along the inside of the molar process. Another branch advances in the major mandibular adductor toward the lateral carapace, then changes its direction downward. The minor mandibular adductor nerve derived dorsally from the proximal trunk of the major mandibular adductor nerve at its starting site goes upward along the surface of the minor mandibular adductor and sends off many branches to the adductor. However only a branch derived firstly from the most proximal trunk of the minor mandibular adductor nerve innervates the major mandibular adductor. By the way, the paragnathal nerve is derived inferiorly from the starting site of the major mandibular adductor nerve. The 1st maxilla nerve arises from the site of the circumoesophageal connective, posterior to the deriving site of the paragnathal nerve and just anterior to the suboesophageal ganglion. In *P. setiferus*, the paragnathal nerve is derived superiorly from the mandibular nerve which is only identified as a related nerve to the mandible by YOUNG. As for abductor nerves, two pairs arise from the circumoesophageal connective as previously mentioned. Anterior pair derived from the commissural ganglion shows a little thick compared to the posterior one and after advancing slightly it crawls along the frontal area of the gnathal lobe

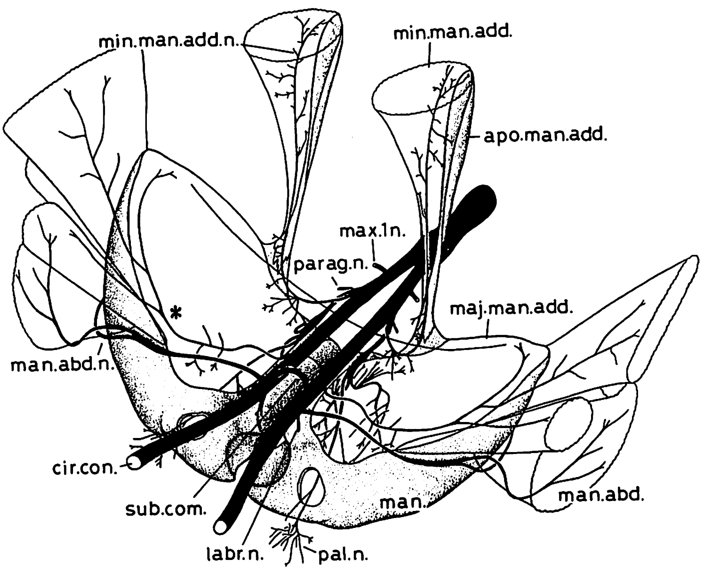

Fig. 4 Diagram of the mandibular innervation. Muscles as the abductor and adductor are drawn roughly to show the complicated distribution of the nerves derived from the circumoesophageal connectives. One of the nerves (*) controls especially both of the abductor and adductor. Abbrev., apo. man. add. : apodeme of the mandibular adductor, cir. con. : circumoesophageal connective, labr. n. : labral nerve, maj. man. add. : major mandibular adductor, man. : mandible, man. abd. : mandibular abductor, man. abd. n. : mandibular abductor nerve, max.1 n. : 1st maxilla nerve, min. man. add. : minor mandibular adductor, min. man. add. n. : minor mandibular adductor nerve, pal. n. : palpus nerve, parag. n. : paragnathal nerve, sub. com. : suboesophageal commissure.

following the anterior surface of the major mandibular adductor. It is hence divided into two branches which go backward to the inferior mandibular abductor. Posterior pair advances along the anterior surface of the major mandibular adductor, sending off four branches to the major mandibular adductor and at the periphery it divides itself repeatedly into three branches. Two branches of them reach the superior and middle abductors ; the first branch innervates the antero-superior abductor and another goes both postero-superior and middle muscles of abductors. The remnant branch only innervates the major mandibular adductor. According to WALES et al., the mandibular palpus, major and minor mandibular adductor nerves in this experiment are considered to correspond to such members of the inner mandibular nerve (imn) as the imn2, imn4 and imn5, respectively. The inner mandibular nerve contains further a tegumentary nerve to the epistomal hypodermis (imn3) in *H. gammarus*. As for abductors, the mandibular abductor nerve in this experiment is similarly regarded as the outer mandibular nerve (omn)3. The other nerve as the omn1 functions as the mandibular

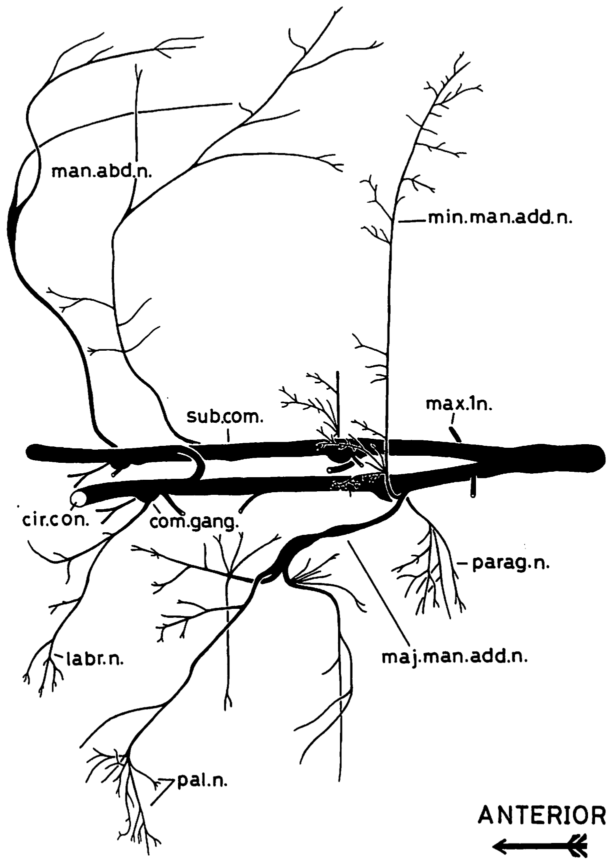

Fig. 5 Diagrammatical ground plan of the diverging pattern of the mandibular nerves. Abbrev., cir. con. : circumoesophageal connective, com. gang. : commissural ganglion, labr. n. : labral nerve, maj. man. add. n. : major mandibular adductor nerve, man. abd. n. : mandibular abductor nerve, min. man. add. n. : minor mandibular adductor nerve, max.1 n. : lst maxilla nerve, pal. n. : palpus nerve, parag. n. : paragnathal nerve, sub. com. : suboesophageal commissure.

adductor, and the omn2 as the tegumentary nerve goes to the lateral carapace. The omn4 has been named the posterior stomach nerve which goes to the mandibular muscle receptor in *H. gammarus*. Such complicated distributions of the inner and outer mandibular nerves in *H. gammarus* could not be recognized in this experiment. As metioned previously, specific differences of the number, size and distribution pattern of the mandibular muscles and nerves seem to indicate a reflection of diverse feeding habits prepared for each species during geologic times. In addition as being considered by WALES et al., the pattern of muscles may be largely due to the morphology of primitive limb from which the mandibular with some functional modifications has developed.

References

1) MANTON, S. M. (1964): Mandibular mechanisms and the evolution of arthropods. *Phil. Trans.*, **B247**, 1-184.
2) SCHMIDT, W. (1915): Die Muskulatur von *Astacus fluviatilis* (*Potamobius astacus*). *Z. Wiss. Zool.*, **113**, 165-251.
3) SNODGRASS, R. E. (1950): Comparative studies on the jaws of mandibulate arthropods. *Smithson. misc. Collns.*, **116**. 1-85.
4) SNODGRASS, R. E. (1965): VI. The crustacea; the crayfish, *Cambarus*. in "A Textbook of Arthropod Anatomy", Hafner publishing company, New York and London, 142-179.
5) WALES, W., MACMILLAN, D, L., and M. S. LAVERACK (1976): Mandibular movements and their control in *Homarus gammarus*. I. Mandible morphology. *J. comp. Physiol.*, **106**, 177-191.
6) YOUNG, J. H. (1959): Morphology of the white shrimp *Penaeus setiferus* (Linnaeus 1758). *Fishery Bulletin*, **145**, 1-168.
7) KEIM, M. (1915): Das Nervensytem von *Astacus fluviatilis* (L.) (*Potamobius astacus* LEACH.). *Z. Wiss. Zool.*, **113**, 485-545.
8) CHAUDONNERET, J. (1956) : Le systéme nerveux de la région gnathale de l'écrevisse *Cambarus affinis* (say). *Ann. Sci. nat. Zool.*, *sér.*11, **18**, 33-61.