The Skeletal Musculature of the Blue Crab

Callinectes sapidus Rathbun

By

Doris Mable Cochran

Thesis submitted to the Faculty of the Graduate School of the University of Maryland in partial fulfillment of the requirements for the degree of Doctor of Philosophy
1933

Index

Introduction

The need for detailed morphologic study of the muscles of crustaceans is apparent upon making a survey of the very scanty literature dealing with the myology of so diverse and important a suborder. The taxomomy and the concurrent analysis of the external antomy of crustaceans have received a great deal of attention, while their physiologic reactions to stimuli have likewise been given a comparatively large amount of study. The internal structure and particularly the myology have been surprisingly neglected.

Huxley (1880) made a now historic contribution in his book on the crayfish, and his masterly dissections were unequalled for over a quarter of a century. Then the German school of zoology at Leipzig began a symposium on the crayfish, and the re-checking of the musculature was undertaken by Walter Schmidt, who did a most thorough and scholarly revision, in which he came upon several important points which Huxley had failed to emphasize.

The next complete myological study of a crustacean was published by Alfreda Berkeley in 1928. Her study of the shrimp Pandalus danae was executed in the general manner of Schmidt's treatment, so that their two papers are readily comparable.

Several short papers have since appeared dealing with the very complicated abdominal musculature of shrimps, but these papers have little bearing upon the following study, because the shrimp and the crab are structurally dissimilar in regard to their abdominal organization.

I am particularly indebted to Mr. R. E. Snodgrass of the Bureau of Entomology of the United States Department of Agriculture for his invaluable assistance and advice in interpreting, describing and figuring the muscles of the blue crab, and in comparing them to those of other orthropods.

I am likewise indebted to Professor C. J. Pierson of the Department of Zoology of the University of Maryland for outlining the present study, and to Dr. R. V. Truitt of the same department for directing my preliminary survey of other anatomical features of the blue crab.

My sincere thanks are due also to Dr. Waldo L. Schmitt, Curator of the Division of Marine Invertebrates of the United States National Museum for donating comparative material for dissection and for making available much of the literature dealing with crustaceans.

The trunk

The complete fusion of the segments of head and body in the blue crab has resulted in the disappearance of those intersegmental muscles which in crustaceans like the shrimp and the crayfish give a high degree of flexibility to the movements of the body.

The crab's head and body are encased in a hard, unjointed covering which shows no trace whatever of segmentation on its dorsal surface, although ventrally the sternal thoracic segments on which the upper leg muscles originate are quite well marked. Of all the extremely complex and numerous body muscles which one encounters in the shrimp and crayfish, there is but one, the attractor of the epimera, which finds a counterpart in the blue crab, where it performs the same function of holding the gill chamber in its proper relation to the carapace.

While the abdomen of the crayfish and shrimp is extremely pliable and is much used in swimming, the abdomen of the blue crab, in the male at least, is apparently progressing towards a condition of partial rigidity, as the third, fourth and fifth segments are immovably fused in that sex. This fusion is not yet completely established, however, as the former segmentation is still partly maintained in its musculature. The female's abdomen has six distinct segments, all of which have the muscles quite well developed. The structure of the hard parts of the abdomen of the male is such that it can not be extended behind the body in line with the back, but at most can assume a position at right angles to the dorsal surface of the body. The abdomen in both sexes normally lies closely adpressed against the posterior region of the thorax. In this position, the dorsal part of the abdomen is underneath the body and actually ventral in position. In the text, however, it is described with the term "dorsal" applied to that part which would be uppermost in a normal crustacean abdomen extending backwards behind the thorax.

1. Musculus ventralis superficialis thoraco-abdominalis (fig. 1B).

It arises on the outer posterior surface of the last segment of the thorax and is inserted on the anterior border of the first abdominal segment near the midline, where it helps to pull the abdomen towards the thorax. This is the only trace in the blue crab of the ventral superficial thoracic muscles which are so prominent between the highly movable body segments in both Astacus and Pandalus. Although this muscle as well as all the other abdominal muscles are paired, the members of the pair are so closely crowded towards the middle line that they appear as one median bundle of muscle fibre.

2-6. Musculi ventrales superficiales abdominis (fig. 1B).

These muscles are arranged regularly in accord with the original segmentation of the abdomen in the male, and the fusion of the third, fourth and fifth abdominal somites in this sex has evidently not affected the ventral musculature at all, since the latter is similar in both sexes. The muscles of the first pair (2) arise on the membrane of the anterior border of the first segment, and are inserted on the heavy sclerotized ridge marking the second segment. Each muscle of the pair splits into several diverging branches, the two inner ones being practically confluent on the midline. The second (3) and third (4) pairs are similar to the first. Each muscle of the fourth (5) is definitely in a single piece, however, and its posterior attachment is made upon an arrow-shaped cartilage-like thickening of the membrane in the middle of the segment. The muscles of the fifth and last pair (6) are likewise undivided, the two muscles lying very close together at their origin but diverging towards their insertion upon the outer walls in the middle of the sixth segment. There is no ventral muscle connecting the sixth segment with the telson in either sex. The ventral superficial muscles are much heavier in the female than in the male, owing no doubt to the fact that the "locking" device for the male's abdomen precludes the necessity for any strong contraction towards the body. The female, on the other hand, has no such locking device, but must hold the abdomen bent forward under the body or curled around the egg-mass, this position of the abdomen necessitating heavier muscles.

7a and 7b. Musculus dilator ani (fig. 1A, B).

The main part of this muscle arises on a triangular cartilage-like thickening on the ventral membrane laying between the posterior border of the sixth somite and the anterior border of the telson. It is inserted ventro-medially by the side of the anal opening. The small second part arises in the same cartilage-like thickening on the ventral membrane, and is inserted on the anterior dorsal wall of the telson. By the contractions of the two muscles the anus is opened and widened, while the elasticity of the membrane around the anus opposes them.

8-13. Musculi dorsales superficiales (fig. 1A).

While Astacus has its first superficial dorsal muscle connecting the thorax with the abdomen, this muscle does not occur either in Pandalus or in Callinectes. A very heavy U-shaped membrane connects the first abdominal segment with the thorax in Callinectes, and at the base of this membrane arises the first pair of dorsal superficial muscles (8), which thus corresponds to the second pair in Astacus. Each muscle of this pair is in several parts lying side by side. The next pair (9) arises near the middle of the second segment behind a heavy sclerotized ridge, and is inserted on the anterior border of the following segment, which in the male crab represents the complete fusion of the third, fourth and fifth abdominal somites. In the center of this fused section there is still, strange to say, a pair of definite patches of muscle tissue arising on a heavy ridge, the marks of attachment of which may be seen going through to the dorsal integument as two slight shallow depressions. This pair of muscles (numbered "10 or 11" in the figure) probably represents either the fourth or fifth pair of dorsal superficial muscles. It appears to have no function, as the hinge to its somite is entirely immovable. The adjacent pair of muscles has completely disappeared in the male. The sixth pair arises some distance within the fused segment and is inserted on a cartilage-like outgrowth from the anterior border of the sixth segment. The seventh pair is long and very slender, to correspond to the shape of the male's abdomen, and is inserted on cartilage-like outgrowths emanating from the anterior border of the telson, which receives all of its power of motion from this muscle, as no flexors of the telson exist in either sex. The female's dorsal superficial muscles are like those of the male, except that all six abdominal segments are distinct, and hence the full complement of six pairs of muscles is present and functional. The dorsal muscles serve to extend the abdomen backwards, but as this position of the abdomen is not habitual in the blue crab, occurring only at the time of mating, the muscles are very weakly developed.

14. Musculus attractor epimeralis (fig. 13B).

All that remains of this muscle, extensive in both Astacus and Pandalus, is a small patch of short muscle fibres uniting the epimeral plates and the carapace, between the metabranchial and the cardiac regions. It extends only for a short distance from the posterior angle of the first epimeral plate. It holds the gill chamber in place in the body, beneath the branchial lobe and the posterior part of the protogastric region, on which the muscle originates.

The eye

The eye of the blue crab is a highly complex organ which presents many specializations in its structure and musculature. The shortening and broadening of the body contour have also been repeated in the changes which have taken place in the eyes. The crayfish and shrimp, both with elongate, narrow bodies, have the eyes close together on short stalks which project forwards in front of the head. The blue crab, on the other hand, has eyes which project on very long stalks at right angles to the axis of the body. The middle cylinder (I in the figure) quite distinct and having its own muscles in the crayfish and shrimp, is completely fused* to the chitinous middle ring in the blue crab, and the muscles of these parts, formerly separated, are now forced to interlace in a very constricted area. The second segment, on the contrary, is immensely elongated in the blue crab. Its proximal part contains no muscles, but only a deep groove in which lie the blood-vessels feeding the eye. Ventrally this part of the segment is separated from the head by a thin membrane. This membrane thickens considerably towards its distal boundary, and on this membrane the adductor muscle arises, which is not the case in either the crayfish or the shrimp. The muscles arising on the distal border of the second segment, or on the heavy tendinous outgrowths from it, bear much the same relations to one another as in the crayfish and shrimp. There are two branches to the abductor and three to the dorsal retractor, the result being that the blue crab has excellent control of its eye movements.

*The entire fused structure will hereafter be spoken of as the middle cylinder.

15. Musculus oculi basalis anterior (fig. 2).

It arises medially on the epistome from a short, curved, movable rod which projects first at right angles from the center of the epistome and then slopes downwards and backwards over the aesophagus and enlarges to a button-like knob. From this knob the muscle runs dorsally and soon divides into two short but relatively thick branches which find attachment side by side below the proximal edge of the chitinous middle cylinder which unites the optic peduncles. The distal part of each peduncle, bearing the retina, is thereby moved forward in a horizontal plane, so that the eyes are brought slightly nearer together. At the same time the second joint may be rotated slightly.

16. Musculus oculi basalis posterior (fig. 2).

This muscle arises on the knob-like part of the supporting rod of the preceding muscle. It runs unpaired dorsally for a short distance, closely adherent to the dorsally directed part of the preceding. Then it divides into two very fine but exceedingly strong branches which diverge slightly as they continue dorsally between the branches of the anterior basal muscle to their attachment on the frontal region of the carapace of the head, where their presence is marked usually by two small indentations.

17. Musculus oculi attractor (fig. 2).

This short compact muscle arises on the head carapace near its junction with the middle cylinder. The muscles of this pair converge slightly before reaching their insertions on a T-shaped infolding of the ventral part of the middle cylinder, in front of the attachment of the anterior basal muscle. As this middle cylinder is cartilage-like and hence somewhat pliable, the attractor can assist the anterior basal muscle in depressing it and hence in bringing the solid joints attached to it nearer together. It may likewise oppose the basal muscle in rotating the second joint.

18. Musculus oculi adductor (fig. 2).

This heavy and powerful but short muscle arises on the thick membrane separating the ventral part of the second joint from the head. It travels forwards and outwards to its insertion along the anterior distal wall of the second segment not far from the base of the optic cup, which is rotated strongly by its contraction.

19a and 19b. Musculus oculi abductor a and b (fig. 2).

Originating posteriorly on the heavy membrane which connects the second joint to the optic cup, the main part of this muscle is inserted on the posterior wall of the optic cup near to the corneal surface. This is the largest and heaviest of any of the muscles lying in the cup. The second branch originates beside the first but juts off at an angle towards the ventral surface, where it is soon inserted not far from the proximal border of the optic cup. It is much shorter than the main branch, from which it is separated near its insertion by the lateral retractor muscle. Both branches oppose the adductor by pulling the eye away from the midline, and rotating it in the opposite direction.

Musculi oculi retractores

Like the crayfish and shrimp, the blue crab possesses four retractor muscles, all of which originate on the membrane bordering the distal edge of the second segment and which are inserted on the sides of the optic cup near the cornea. They bring the cup nearer to the second segment or rotate it. The insertion of each muscle is marked externally by a characteristically different texture in the surface of the optic cup.

20a, 20b and 20c. Musculus oculi retractor dorsalis a, b and c (fig. 2).

This muscle has three branches, all of which arise from a heavy ossicle-like projection lying in the membrane and originating on the dorsal distal wall of the second segment. The main branch, the central one of the three, travels outwards to its attachment on the dorsal surface of the optic cup, where its insertion is marked externally by a small area of a slightly granular texture different from the smooth surface around it. The second branch (b) projects forwards at right angles to the first and is attached on the front wall of the opticcup near its proximal border. The third branch (c) projects also at right angles but in an opposite direction to b, and is attached to the posterior wall of the optic cup near its proximal edge. The three branches taken together with the ossicle-like piece from which they originate form a cross, and the attachment at the extremities of the cross produces a mechanical device of great strength for moving the optic cup dorsally, and for rotating it from side to side.

21. Musculus oculi retractor ventralis (fig. 2).

This is a relatively small and weak muscle, which arises ventrally in the membrane emanating from the distal edge of the second segment and is inserted on the ventral wall midway to the cornea. Since it runs parallel with the axis of the eye, it can not act as a rotator. Its only function is to retract the optic cup.

22. Musculus oculi retractor lateralis (fig. 2)

This muscle originates in a tendinous structure in the membrane of the posterior ventral wall of the second segment, and passes diagonally backwards and upwards between the two parts of the abductor to its insertion on the posterior wall of the optic cup just above the insertion of the shorter branch of the abductor. It has a strong rotatory function due to its position diagonal to the axis of the eye.

23a and 23b. Musculus oculi retractor medialis a and b (fig. 2)

This muscle has two branches, both of which arise from an exceedingly heavy ossicle-like projection from the anterior distal wall of the second segment. The upper branch (a) proceeds straight along the anterior wall of the optic cup to its attachment not far from the cornea. The lower branch (b) diverges slightly downwards to its attachment on the antero-ventral wall of the optic cup not far forward of the insertion of the ventral rotator. The medial retractor has the rotatory function in addition to being a retractor, as its diverging branches testify.

The appendages

The problem of choosing names for the various muscles governing the appendages has proved to be a very puzzling one, especially in regard to those muscles governing the mandible, the maxillae and the maxillipeds. It is often impossible in the living crab to assign to a definite one of the many complex muscles surrounding the base of each appendage a particular motion observed in that part of the appendage. In the telopodite the case is much simpler, as there are but two muscles governing each segment, and but two corresponding directions of motion. In the dissected crab, the many slender muscles controlling the various basal parts of the leg are likely to break if enough tension is put upon them to show in what manner they influence the distal segments. Even the coarse and heavy muscles on tendons which do not break can not invariably be assumed to cause the same motion in the segment of the stiffened dead tissue that they do in the pliable living organism. Thus it frequently becomes very difficult to determine whether a muscle in function is a promotor or an adductor, a remotor or an abductor. Coupled with this difficulty is the fact that the crab is so highly specialized away from the ancestral primitive condition that some of the appendages now lie in a partly reversed position, while one appendage, the mandible, is completely reversed. This makes it equally hard to give the muscles positional names according to their points of attachment, and there are, besides, so many small muscles controlling the basal segments that one soon has to resort to the expedient of giving some of them merely a number, having exhausted the available adjectives descriptive of their locations.

It is possible, however, to divide the muscles according to their place of origin, all the muscles originating on the carapace being called dorsal muscles, and those coming from the ventral surface and the sternal apodemes being referred to as ventral muscles.

Only those segments anterior to the second maxilla have both dorsal and ventral muscles. The second maxilla and the segments behind it lack dorsal muscles, but are fully equipped with ventral muscles.

The dorsal and ventral muscles are all extrinsic, meaning that they originate in the body itself beyond the boundaries of the true appendage. The intrinsic muscles are contained entirely within the appendage itself, and control the distal segments of the limb, and the flagellum if one be present.

As long as it has seemed possible to do it, I have followed the nomenclature adopted by Schmidt and later by Berkeley, in their respective anatomical analyses to facilitate comparison between the three forms involved. The muscles of the blue crab do not always present perfect analogies in either position or function to those of the crayfish and the shrimp, however, and where a difference in function seems possible, the positional name may be given as first choice, with Schmidt's or Berkeley's corresponding name in synonymy. When so many muscles were found that the positional name of the one in question could not be given with the use of only one or two qualifying adjectives, the whole muscle has been referred to merely by its number. It is not well to be too arbitrary in assigning definite names to some of the more obscure muscles of the blue crab until such time as other representatives of the order Decapoda shall have been dissected and compared carefully, muscle by muscle. It is quite possible that other genera of crabs may show up interrelationships of muscles that are quite obscure in Callinectes.

The first antenna (antennule).

In the blue crab this appendage is similar to that of the shrimp and of the crayfish in regard to its high degree of flexibility. The comparatively large size of the first joint is due to the presence of a large statocyst to which no muscles are attached, these tissues being entirely sensory in function. The structure of the two flagella in the shrimp and crayfish, as well as in the blue crab, does not give any support to Huxley's opinion that these flagella represented an endopodite and an exopodite, nor can the joint from which they arise be considered as a modified basipodite.

24 a, b. Musculus promotor a and b I antennae (fig. 3).

This muscle originates in two places on the posterior border of the aperture which connects the interior of the body with the interior of the antennule. Both parts are attached close together on an infolding of the membrane lying beneath the statocyst chamber in the first joint. The promotor raises the first joint, bringing it towards the midline and rotating it slightly in its socket.

25 a, b. Musculus remotor a and b I antennae (fig. 3)

One part of this short but heavy muscle arises on a round cartilaginous disk on the lateral edge of the aperture connecting body and antennule. It is attached to a tendon on the outer dorsal part of the first joint. The other branch of the remotor arises on the outer anterior border of the aperture, and runs to its attachment on the opposite side of the tendon to which the first branch goes. Both remotors pull the first joint strongly downwards towards the body, at the same time rotating it in its socket.

26. Musculus productor $_2$ I antennae (fig. 3).

This muscle arises dorsally on the inner proximal border of the first segment and passes forwards to its attachment on the heavy basal membrane on the lateral proximal border of the second segment, on which it exerts a strong downward pull.

27. Musculus reductor 2 I antennae (fig. 3).

This short muscle originates on the inner posterior wall of the first segment and is inserted anteriorly on the membrane of the proximal part of the second joint. It opposes the productor$_2$ by bringing the joint upwards towards the midline.

28. Musculus adductor$_2$ I antennae (fig. 3).

This is the largest of the four muscles governing the second joint of the antenna. It arises on the inner posterior wall of the first segment and is inserted anteriorly on the membrane at the inner basal part of the second segment. It thus parallels the reductor$_2$, and nearly conceals it. Like the latter, it brings the second joint upwards and towards the midline. No adductor occurs in <u>Astacus</u> in any of the joints of its first antenna.

29. Musculus abductor$_2$ I antennae (fig. 3).

It arises on the inner proximal border of the first segment, directly beneath the origin of the productor$_2$, paralleling it almost to its insertion on the membrane below the outer proximal edge of the second segment. This muscle brings the second segment strongly backwards and outwards.

30. Musculus productor$_3$ I antennae (fig. 3).

It arises on the outer proximal part of the second joint and is attached to the cartilage emanating from the outer proximal edge of the third joint, which is pulled downwards and outwards by it.

31. Musculus reductor$_3$ I antennae (fig. 3).

Arising also on the outer proximal wall of the second joint, this muscle goes to its attachment on the membrane of the inner proximal border of the third joint, which it brings inwards and upwards in opposition to the productor$_3$.

32. Musculus reductor$_4$ I antennae (fig. 3).

This is the only muscle lying in the third segment. It arises on the inner proximal wall, and is inserted on the membrane lying between the two flagella, which are pulled sharply together by its contraction, while the elasticity of the membrane pulls them sharply apart. Apparently there are no special muscles within the flagella themselves.

The second antenna

In the blue crab the second antenna is so different in structure from the corresponding appendage in the crayfish and shrimp that it is not feasible to attempt to draw a parallel very closely between them. The second antenna in the crayfish, as Schmidt remarks in his masterly analysis (Schmidt, 1915, p. 205), is the most highly segmented of all the head appendages, and hence possesses the greatest ability for motion. The same complicated structure was observed by Miss Berkeley in the shrimp Pandalus. Both these crustaceans have a well-developed, heavily muscled exopodite, as well as an endopodite in which all the typical segments may be recognized, the flagellum being taken to represent the dactylopodite in both cases.

There is no jointed exopodite in the blue crab; the only trace of it is a hard protuberance on the outer part of the basipodite. Since a complete fusion has taken place between the basipodite and the head carapace, there are no depressor or levator muscles. The coxopodite is reduced externally to a membranous pocket lying anteriorly between the basipodite and the head carapace, in which the fusion occurs posteriorly. Arising from the basipodite, and forming the base of the endopodite, come two segments which I shall arbitrarily call the ischiopodite and the meropodite, which are provided with the typical reductor and productor muscles.

Following these is a long annulated flagellum without definite muscles inside it. It is impossible to say whether the flagellum represents the division of the last three segments of the normal endopodite,--carpopodite, propodite and dactylopodite,--or of the carpopodite alone, if one wishes to assume the complete loss of the other two. Because of this uncertainty, the muscles lying in the so-called meropodite and controlling the action of the flagellum are referred to as the reductor and productor of the flagellum.

33. Musculus promotor II antennae (fig. 4).

It arises on the dorsal carapace in the protogastric region, and runs inwards and forwards to its attachment on a slender tendon-like structure which thickens and hardens into a sickel-shaped rod which curves outwards and forwards beneath the membranous pouch lying between the basipodite and the head carapace, and finally attaches itself to this same cartilage-like membrane, which is moved forwards and inwards by its action.

34. Musuculus remotor II antennae (fig. 4).

This short muscle arises partly on the head carapace where it fuses with the basipodite and partly on the upper edge of the membranous pouch below the basipodite. It passes backwards to its insertion on the posterior part of the sickel-shaped rod mentioned above. The membranous pouch is pulled backwards and downwards by its contraction.

35. Musculus productor ischiopoditis II antennae (fig. 4).

This muscle arises on the promimal median portion of the basipodite and is attached to the outer proximal border of the ischiopodite, which it moves outwards and downwards.

36. Musculus reductor ischiopoditis II antennae (fig. 4).

A little heavier than the preceding, this muscle arises near it on the inner proximal wall of the basipodite, and is inserted on the inner proximal margin of the ischiopodite, which is pulled strongly inwards towards the center by its action.

37. Musculus productor meropoditis II antennae (fig. 4).

This muscle arises on the outer proximal wall of the ischiopodite and is inserted on the outer proximal margin of the meropodite, on which it exerts an outward and downward pull.

38. Musculus reductor meropoditis II antennae (fig. 4).

Like the preceding in size and shape, this muscle originates on the inner proximal wall of the ischiopodite and goes to its insertion on the inner proximal edge of the meopodite, which receives a pull towards the center from it.

39. Musculus productor flagellaris II antennae (fig. 4).

Arising on the proximal posterior wall of the meropodite, this muscle is inserted on the base of the first annulus of the flagellum, which is pulled outwards and backwards by its contraction.

40. Musculus reductor flagellaris II antennae (fig. 4).

This muscle arises on the anterior wall of the meropodite and is inserted on the anterior part of the first ring of the flagellum, causing the latter to be brought inwards and forwards.

The mandible

As in the crayfish, shrimp and lobster, the mandible in the blue crab is firmly fixed at two articulations, (x and xx in Figure 5) and hence cannot rotate.

The position of these articulations, however, is quite different in the blue crab from corresponding articulations in the crayfish and its allies, and a different mechanism for controlling the mandible is required. In the crayfish, shrimp and lobster, one of the articulations is at the extreme upper anterior corner of the mandible while the other is at the lower posterior corner. Therefore any muscles connecting the lower anterior corner with the skeletal part near the midline will pull the l o w e r halves of the mandibles strongly together, functioning thus as adductors. A muscle attached to the upper posterior edge of the mandible, and running from the same central skeletal foundation, perhaps beside and even parallel to the adductors just described, will pull the mandibles just as strongly apart, performing the function of abductors. This opposition is made possible by the widely separated points of articulation of the mandible, which allow its upper and lower borders to pivot inwards and outwards between their hinges. This swinging motion is further intensified by such additional abductors and adductors as give sufficient power to the masticatory function of the mandible.

In the blue crab, the articulations of mandible with head skeleton are both anterior, one at the upper and one at the lower corner of the mandible. Because of these anterior articulations, any muscles going from the central foundation to any available spot on the inner posterior surface of the mandible behind these forward-lying hinges are bound to open the mandible, functioning as abductors. Hence there is no anterior adductor in the blue crab, and the thin sheet-like muscle of the blue crab which corresponds to that muscle in the crayfish functions now as a major abductor of the mandible, and all the work of closing the mandible has to be done by the very heavy and powerful posterior and lateral adductors.

In this appendage a division of the extrinsic muscles into those with dorsal origin and those with ventral origin is first clearly apparent. There is as a matter of fact only one ventral muscle, the greater abductor (41 in fig. 5A, C), and this might be referred to as _Musculus ventralis mesalis_, the mesal ventral muscle of the mandible, if positional names were adopted. There are three dorsal muscles of the mandible, a posterior outer (42), a posterior inner (43), and a third one, (44), in function a lateral adductor, which is very puzzling to name as to position, since it attaches itself to the now outer posterior angle of the mandible which has reversed itself in the blue crab from its primitive anterior position.

It has been repeatedly stated that the blue crab is a highly specialized creature which departs in certain noticeable ways from the more generalized morphological aspects of many other crustacean types. We might expect many of the blue crab's appendages to show a variation from the usual structure, and this expectation is fulfilled when we examine the mandible and compare it specifically to that of the crayfish and shrimp. Because of its two anterior articulations, to which reference has already been made, the mandible of the blue crab lies in a partly reversed position;--its true anterior border now as a matter of fact is its upper posterior border when the crab occupies a normal attitude, while its true posterior surface is now entirely ventral in position.

The primitive appendage, as shown by Mr. R. E. Snodgrass in his "Evolution of the Insect Head and the Organs of Feeding"* has essentially four muscles to control the movements of its basal part, two of which originate in the dorsal region of the body, and two on the ventral region (see fig. 6). The dorsal muscle which is inserted on the anterior upper border of the rim of the appendage is called the dorsal promotor (lettered I in figure 6), while the corresponding muscle inserted on the posterior upper border is the dorsal remotor (J). The muscle inserted on the anterior lower rim of the appendage is the ventral promotor (K), and the corresponding muscle with a posterior lower insertion is the ventral remotor (L).

An attempt has been made (fig. 5,B) to analyse the extrinsic muscles of the mandible in the blue crab to see just how they conform to the simple ancestral type. It was found that the dorsal muscle numbered 44, and functioning as the lateral adductor, corresponds to the primitive muscle I with insertion on the upper anterior rim of the appendage. The two remaining dorsal muscles, the minor abductor (42) and the posterior adductor (43) together represent the muscle J, since both originate dorsally and are inserted on the posterior (now ventral!) rim of the appendage. In the same way the muscle numbered 41, acting as the major abductor, represents a combination of the ventrally-rising primitive muscles K and L, since 41 is the only muscle of the appendage having a ventral origin.

*Smithsonian Report for 1931, (1932), p. 465, fig. 14.

41. Musculus abductor maior mandibulae (fig 5A, C).

Appearing as a broad sheet-like muscle, this muscle originates in two places on the head apodeme, and runs outwards to its insertion along the posterior part of the mandible, which it helps to open.

42. Musculus abductor minor mandibulae (fig. 5A, C).

It arises laterally on the dorsal head carapace on the inner part of the epibranchial region and is inserted by a very slender but strong tendon on the lower out part of the mandible, which is opened by it.

43. Musculus adductor posterior mandibulae (fig. 5A, C).

This very strong muscle arises on the urogastric region of the carapace in several heavy muscle bundles which shortly fuse together into a long and extremely heavy tendon which passes forwards and downwards to its attachment on the mandible at the point of its lower articulation with the head skeleton. It brings the mandible strongly towards the midline.

44. Musculus adductor lateralis mandibulae (fig. 5A, C).

This extremely heavy muscle arises on the head carapace partly at the base of the first spine and partly at the base of the third spine, the parts uniting on a heavy tendon attaching them to the outer posterior end of the mandible, which they bring strongly towards the midline.

45. Musculus extensor palpi mandibulae (fig. 5A).

This muscle arises on the inner surface of the mandible near the base of the tendon of the posterior adductor muscle. It is inserted on the heavy membrane connecting the palp and the mandible, and its contraction straightens the palp and brings it away from the center, opposing flexor a in its action. There is no extensor for the distal segment of the palp.

46. Musculus flexor palpi mandibulae a (fig. 5A).

This short but stout muscle arises on the outer part of the mandible and travels forwards and slightly inwards to its attachment on the posterior proximal border of the first segment of the palp. Its function is to lower the palp, thereby bringing it towards the median plane.

47. Musculus flexor palpi mandibulae b (fig. 5A).

This muscle fills the whole of the first segment of the palp. It arises in the membrane proximal to this first segment, and is inserted on the proximal joint of the last (second) segment. It lowers this last segment, thus bringing it towards the center.

The first maxilla

The first maxilla in the blue crab, as in the crayfish and shrimp, is flattened, and while it normally lies close to the outer anterior surface of the mandible, it has a considerable degree of freedom of motion. This is due to the fact that its basal part is really in two pieces, the posterior half rather loosely attached to the lower distal margin of the anterior half, and the two halves working together somewhat like the blades in a pair of scissors. The anterior half has been called the basipodite by Huxley, Schmidt, Berkeley and some other investigators, but since there are no muscles between it and the posterior half, and since the body muscles go to both of them equally, it appears that the structure is in reality a coxopodite, semi-divided and provided with hinges to give necessary pliability. Borrodaile also considers that both parts belong to the coxopodite. It appears that the true basipodite is completely fused with and indistinguishable from the inner border of the coxopodite, as the endopodite arises from this region.

Three dorsal muscles run to the first maxilla, although it is impossible to separate them at their origin because of their extremely attenuate form. They separate distinctly into three strands as they pass behind the mandible to their distinctly separate points of insertion on the first maxilla. The first of these (51, fig. 7) is the anterior inner, which may be called Musculus dorsalis anterior mesalis, and whose functional name is the anterior adductor of the coxopodite. The next (52) is a posterior inner, Musculus dorsalis posterior mesalis, and which acts as a posterior adductor to the coxopodite. There is but one outer dorsal muscle, which may be referred to as Musculus dorsalis externalis and which functions as an abductor of the coxopodite.

The ventral muscles may be classed as follows:

54. Upper inner: Musculus ventralis superior mesalis (levator)
55. Lower inner: Musculus ventralis inferior mesalis (depressor)
48. Anterior outer: Musculus ventralis anterior externalis (promotor)
49. Posterior outer: Musculus ventralis posterior externalis (remotor a)
50. Median outer: Musculus ventralis medialis externalis (remotor b)

The only intrinsic muscle in this appendage is 56, the adductor of the endopodite.

48. Musculus promotor I maxillae (fig. 7)

It arises on the head apodeme and runs forwards and outwards to its dorsal insertion in the extreme lateral part of the coxopodite beneath a disk-like ossification near the inner hinge of the coxopodite. This muscle moves the coxopodite forwards and upwards.

49-50. Musculus remotor I maxillae a and b (fig. 7)

The shorter branch of the remotor (49) arises on the ventral part of the head apodeme external to the origin of the main branch, travelling parallel to the latter to its insertion on the posterior dorsal angle of the basal rim of the coxopodite beneath and slightly median to the insertion of the promotor. Lying directly below the promotor, the longer branch of the remotor (50) arises on the ventral surface of the head apodeme somewhat posterior to the origin of the promotor. It is inserted ventrally in the anterior dorsal angle of the basal rim of the coxopodite at a point considerably posterior to the insertion of the promotor and quite near to the union of the coxopodite with the ring-like outgrowth which encircles it and holds it near to the mandible. Both remotor muscles oppose the promotor by lowering the coxopodite.

51. Musculus adductor anterior coxopoditis I maxillae (fig. 7)

This exceedingly long and slender muscle arises on the epibranchial region of the head carapace and is inserted without a tendon on the anterior margin of the base of the coxopodite near its mesal end. It brings the free end of the coxopodite towards the mouth.

52. Musculus adductor posterior coxopoditis I maxillae (fig.7)

This very slender long muscle originates on the head carapace with the preceding and indistinguishable from it at first, and travels forwards, inwards and ventrally to its insertion on the posterior margin of the base of the coxopodite, which it pulls forwards and inwards.

53. Musculus abductor coxopoditis I maxillae (fig. 7)

Arising on the head carapace at the origin of the preceding two and at first indistinguishable from them, this muscle, likewise very slender, is attached dorsally to the extreme outer border of the coxopodite on the same disk-shaped ossification that gives attachment to the promotor. It opposes the adductor in pulling the coxopodite away from the midline.

54. Musculus levator I maxillae (fig. 7)

It arises on the anterior part of the head apodeme, just median to the promotor, traveling forward to the dorsal median proximal border of the inner half of the coxopodite, which it raises.

55. Musculus depressor I maxillae (fig. 7)

Arising on the ventral surface of the head apodeme under and slightly posterior to the origin of the levator, this muscle continues forwards directly under the levator to its insertion on the ventral proximal border of the inner half of the coxopodite, which it pulls downward.

56. Musculus adductor endopoditis I maxillae (fig. 7)

It arises on the inner proximal border of the inner half of the coxopodite and branches into a fanlike formation at its manifold insertion in the central part of the endopodite, which it brings towards the center of the body. The basipodite is no longer distinguishable as such in this appendage, and we postulage its position only by the presence of the endopodite, which when present always arises from the basipodite.

The second maxilla

While this appendage has the most complex system of muscles of any in the blue crab, yet its muscles correspond more closely to those in Astacus and in Pandalus than do the muscles of its other appendages. The muscles leading to the parts bordering the mouth are relatively slender and weak, so that the appendage evidently does not assist greatly in the process of food-taking. Its true function is shown in the great development and complexity of the muscles controlling the scaphognathite, which cause the currents of water to pass continually over the gills. These muscles are attached to a very thick swelling, continuous at its outer end with the skeletal ridge running across the membrane covering the gill-chamber. Its inner course borders the juncture of scaphognathite and coxopodite in a crooked and irregular swelling which finally comes to an end as a cup-like thickening which bounds the outer proximal borders of endopodite and basipodite. This cup gives origin on its inner side to the adductor muscle of the endopodite and on its outer side to the flexor of the scaphognathite. No tendons are found in any muscles of the second maxilla. There is no levator muscle in this appendage in Callinectes, Astacus or Pandalus.

The coxopodite bears two mesal bilobed endites, the anterior of which has been assigned to the basipodite by Brooks and many later writers. There is no distinguishable basipodite present as such in either of the two maxillae in the blue crab, but in both maxillae the coxopodite is so irregularly shaped that its appearance does not superficially suggest that it is in reality all one structure. As in the first maxilla, the position of the basipodite in the second maxilla is to be inferred only by the position of the endopodite. This region is so irregularly convoluted and infolded to give sufficient room for insertion to the complex and numerous respiratory muscles that the original boundaries between coxopodite, basipodite, scaphognathite and endopodite are completely obliterated in the blue crab. In describing the muscles of the second maxilla, no further reference will be made to a basipodite.

As all the dorsal muscles are missing in this as in all the following segments, the naming of the ventral muscles remaining might appear to be an easy task, but such is not the case. The myological plan of the second maxilla is greatly complicated by the presence of no less than seven respiratory muscles, some of which are extrinsic, some intrinsic. As a matter of fact, the only muscle which permits of an easily descriptive positional name is 60, an anterior inner ventral muscle, Musculus ventralis mesalis, which functions as an adductor of the coxopodite. The remaining extrinsic ventral muscles (see fig. 8) are 57, promotor; 58, remotor; 59, depressor; and 63 through 66, respiratory muscles a through d respectively.

The remaining respiratory muscles _e_ through _g_, (_67_ through _69_) are intrinsic, as are likewise the adductor of the endopodite (_61_), and the flexor of the scaphognathite (_62_).

57. Musculus promotor II maxillae (fig. 8)

This long, cylindrical muscle originates on the dorsal surface of the endopleurite of the last head segment, which segment coalesces with the first two thoracic segments. It runs straight forwards to its insertion on the skeletal ridge that borders the proximal part of the coxopodite. It brings the coxopodite backwards and upwards, at the same time causing a similar movement in the attached anterior part of the scaphognathite.

58. Musculus remotor II maxillae (fig. 8)

Almost hidden by the respiratory muscles, the remotor arises on the dorsal surface of the endosternite of the same segment just in front of the apodemal foramen, and passes forwards and outwards between respiratory muscles one and two to its insertion on the thickened edge of the coxopodite slightly lateral to and below that of the promotor. It brings the coxopodite upwards and somewhat towards the center.

59. Musculus depressor II maxillae (fig. 8)

This is the smallest and weakest muscle in the entire appendage. It arises ventrally on the endosternite, appearing as two very thin branches which travel forwards through the coxopodite to their insertion on its proximal border. It causes the coxopodite to move downwards and inwards. In Astacus this muscle also has two branches.

60. Musculus adductor coxopoditis II maxillae (fig. 8)

This relatively short and slender but strong muscle arises on the inner anterior corner of the endosternite, running inwards and forwards to its insertion on the inner proximal border of the coxopodite. It pulls the coxopodite strongly backwards and thus towards the center.

61. Musculus adductor endopoditis II maxillae (fig. 8)

This slender thread-like muscle arises on the inner proximal part of the coxopodite, passing laterally to its insertion on the cup-like swelling at the lateral outer border of the endopodite. It causes the endopodite to be bent somewhat towards the inner region.

62. Musculus flexor scaphognathitis II maxillae (fig 8)

This muscle originates in the cup-like thickening which borders the outer part of coxopodite and endopodite, and runs outwards with pronounced ramification through the scaphognathite to its attachment on the cartilaginous fold which parallels the outer border of the scaphognathite. This segment is bent by means of the flexor muscle. In Pandalus there is an additional superior flexor muscle which is unbranched.

63-69. Musculi respiratorii II maxillae (fig. 8)

Arising on the dorsal surface of the endopleurite just mediad to the origin of the promotor, the first of these, Musculus respiratorins primus, (63) goes forwards and outwards beneath the promotor to its insertion on the lateral part of the skeletal swelling between coxopodite and scaphognathite. This and the remaining respiratory muscles induce a strong undulating motion in the scaphognathite, thus forcing the water which is drawn into the gill chamber to flow forwards. The second muscle, Musculus respiratorius secundus, (64), heavy and powerful like the first one, arises mediodorsally on the head apodeme, runs outwards and forwards, and passes above the first one and below the promotor to reach its insertion just above the first. The third, Musculus respiratorius tertius, (65), is a small and slender muscle completely hidden until the more dorsal muscles are removed. It originates on the thickened skeletal ridge on the anterior part of the head apodeme, and runs forward and slightly outwards to its insertion on the skeletal swelling of the scaphognathite just below the insertion of the remotor. The fourth, Musculus respiratorius quartus, (66), is an exceedingly heavy but short muscle arising under the third on the same skeletal ridge of the head apodeme, running outwards to its insertion on the scaphognathite, between two angles of the skeletal swelling marking its proximal border. The fifth, Musculus respiratorius quintus, (67), is a small, powerful muscle arising on an infolding of the apodemal membrane behind the fifth, then passing forwards and slightly inwards to its insertion on the skeletal swelling just beneath the insertion of the promotor. The sixth, Musculus respiratorius sextus, (68), arises on the same infolding just lateral to the fifth, and proceeds straight forwards to its insertion on the swelling, directly below the insertion of the third. The seventh, Musculus respiratorius septimus, (69), like the sixth, is short and slender, arising laterally to it on the infolding and being inserted on the swelling midway between the insertions of the fourth and the sixth.

The first maxilliped

The resemblance of this appendage to the maxillae rather than to the typical thoracic appendage has already been commented upon by several authors. The endopodite is weakly developed and devoid of muscles in the blue crab, but as its basal part is partly fused to the exopodite, it naturally partakes of the motion of the exopodite caused by the adductor muscle of the latter. The exopodite is relatively heavily muscled. The muscle extending through the flagellum originates entirely within the proximal segment of the flagellum, which is considerably enlarged. This origin is similar to that found in Astacus. In Pandalus the origin of this muscle is in the basal lobe of the first segment of the exopodite. The extremely poor development of the abductor of the flagellum in Pandalus appears to throw the whole task of moving he flagellum upon the flagellar muscle itself, which therefore needs the wider attachment space. In Astacus and Callinectes, where the abductor of the flagellum is relatively very large, the flagellar muscle is rather slender and weak.

Of the extrinsic muscles in the first maxilliped of the blue crab, it is possible to name positively only the promotor and the attractor of the epipodite. The small anomalous muscles which take the place of reductor, levator and depressor have been referred to by number only, as their true function is as yet obscure. Further dissection of other representative decapods may subsequently reveal some species in which the functions of the corresponding muscles will be more apparent, and it may be possible in this way to assign names by analogy to these which it is now inadvisable to attempt to name arbitrarily.

As in both maxillae, the basipodite of the first maxilliped is no longer traceable as a distinct segment, being either eliminated completely or indistinguishably fused with the coxopodite. Its normal position if it were present may be ascertained in relation to the origins of endopodite and expodite. In that case it would have lain between the second endite of the coxopodite and the epipodite.

70. Musculus promotor medialis I pedis maxillaris (fig.9).

This strong but slender muscle arises on the inner anterior border of the paraphragm between the first and second thoracic segments near the midline of the body. It passes forwards and slightly outwards to its tendinous insertion on the tough membrane composing the dorsal surface of the coxopodite. It causes the coxopodite, and with it to some extent the inner part of the whole appendage, to be brought upwards and inwards.

71. Musculus promotor lateralis I pedis maxillaris (fig. 9).

It is hidden partly beneath the first of the attractors of the epipodite and partly by the fused lamellae of the first and second thoracic paraphragms, on the outer ventral surface of which it arises. It runs forwards and slightly inwards to its attachment on the lateral border of the coxopodite just at the point of origin of the epipodite. It helps to raise the appendage, but otherwise opposes the medial promotor by exerting an outward pull.

72. (fig. 9)

This powerful but short muscle originates on the endosternite, passing outwards beneath the median promotor to its insertion on the extreme outer ventral borders of the coxopodite without a tendon. It is not feasible to attempt to name this muscle functionally, as no definite movement of the appendage can be assigned solely to it. It appears to lie in approximately the same position as does the levator muscle in Astacus.

73a-b. Musculus attractor epipoditis (a and b) I pedis maxillaris (fig. 9)

One branch arises on the dorsal portion of the paraphragm between the first and second thoracic segments, lying directly below the first respiratory muscle of the second maxilla. It passes outwards and forwards to its insertion on the outer dorsal proximal border of the epipodite, which it raises strongly, at the same time causing it to move backwards and inwards. The second branch, larger and more powerful than the first, passes under the first on its forward and outward path to its insertion beneath it on the ventral proximal border of the epipodite, which it brings strongly backwards and downwards.

74. (fig. 9)

This short muscle arises deeply within a cup-like membrane beside the inner epistomal rim and is inserted at the base of the first endite on the coxopodite. Again it is impracticable to give a functional name to this muscle, although it undoubtedly controls the coxopodite in some way. It might perform the duties of a levator, but this can not be ascertained directly.

75. (fig. 9).

This short but thick muscle arises on the mesal edge of the same cuplike membrane as does the preceding muscle, and is inserted deeply within the first endite of the coxopodite. It is not possible to name it as to function, although it presumably causes whatever motion the first endite is capable of making. Its position is somewhat similar to that of the depressor in Pandalus and Astacus.

76. (fig. 9).

This short but heavy muscle arises on the lateral edge of the same cuplike membrane which gives origin to the two preceding muscles and is inserted beside and lateral to 74, where the first and second endites come together. Again a functional name is not forthcoming as no positive motion can be assigned to this particular muscle.

77. Musculus adductor exopoditis I pedis maxillaris (fig. 9).

This muscle originates on the posterior surface of the coxopodite just lateral to the insertion of 76, and runs laterally to its insertion on the outer anterior proximal border of the exopodite just above the origin of 78. It brings the exopodite, and with it the partly fused endopodite, away from the epipodite and towards the center. Berkeley mentions a well-developed abductor exopoditis in Pandalus, not present in the blue crab. The endopodite of the blue crab has no muscles of its own.

78. Musculus abductor flagelli exopoditis I pedis maxillaris (fig.

Arising in two places on the inner ventral proximal wall of the exopodite, this powerful muscle unites and passes to its insertion on the inner proximal edge of the enlarged first segment of the flagellum. This muscle causes a strong upward and outward movement in the flagellum.

79. Musculus flagellaris exopoditis I pedis maxillaris (fig. 9).

Originating in the proximal segment of the enlarged first joint of the flagellum, it runs outward through the various segments nearly to the tip of the flagellum, giving off small fibers in each segment which attach themselves to the wall, thus giving a high degree of pliability to the flagellum.

The second maxilliped

In this appendage the first true hinges between the joints appear, just as they do in both Astacus and Pandalus. In section, the ischiopodite is found to be fused with the basipodite. The exopodite is merely an annulated flagellum as in Pandalus. The promotor appears to be inserted by a tendon, as are some of the muscles at the distal segments of the endopodite. A long, flat epipodite and two podobranchiae are present, with a slender attractor muscle to control the epipodite. In Astacus there are two podobranchiae and no epipodite; in Pandalus, a single podobranchia and an epipodite are present.

80. Musculus promotor II pedis maxillaris (fig. 10).

It arises usually in two parts on the inner median edge of the paraphragm between the first and second thoracic segments in a very broad attachment. The muscle fibers rapidly converge into a single thin tendon which is attached to the extreme inner edge of the coxopodite. It causes the entire endopodite to move inwards and upwards.

81. Musculus remotor II pedis maxillaris (fig. 10).

This arises on a more lateral part of the same two paraphragms next to the gill-chamber, and proceeds forwards and inwards to its insertion on the outer posterior border of the coxopodite. It lowers the outer part of the coxopodite, bringing it distinctly outwards and backwards.

82. Musculus levator II pedis maxillaris (fig. 10).

It arises as a heavy and massive muscle on the inner lateral edge of the paraphragm between the first and second thoracic segments, and passes without diminution in size to its insertion on the dorsal proximal membranous portion of the basi-ischiopodite. There is but one levator in Callinectes; both Astacus and Pandalus have two.

83a-b. Musculus depressor (a and b) II pedis maxillaris (fig. 10).

The main branch of the depressor arises on the inner edge of the paraphragm between the first and second thoracic segments midway between the origins of promotor and levator. It parallels these two muscles to its insertion on the inner posterior border of the coxopodite. It gives a strong inward and downward pull to the coxopodite and hence to the whole of the endopodite. The small depressor b arises near the junction of the coxopodite with the paraphragm and is inserted just ventral to the main branch. It assists in lowering the coxopodite.

84. Musculus attractor epipoditis II pedis maxillaris (fig. 10).

Arising laterally on the meeting point of the body wall and the coxopodite, this slender muscle travels laterally to its insertion on the proximal border of the epipodite, which it moves slightly inwards.

85. Musculus abductor exopoditis II pedis maxillaris (fig. 10).

It arises ventrally in the outer side of the coxopodite and proceeds laterally to its attachment on the median ventral proximal part of the exopodite. It causes the exopodite to move outwards and forwards.

86. Musculus flagellaris exopoditis II pedis maxillaris (fig. 10).

It arises on the proximal border of the enlarged first joint of the flagellum and runs nearly to the tip, giving off short fibers at every annulation. As a consequence the flagellum has a considerable degree of mobility.

87. Musculus abductor flagelli exopoditis II pedis maxillaris (fig.10

This muscle arises in two parts on the proximal dorsal side of the basal joint of the exopodite, fuses and runs to its insertion on the first joint of the flagellum, to which it imparts a strong outward motion.

88. Musculus productor meropoditis II pedis maxillaris (fig. 10).

This arises on the ventral lateral border of the basi-ischopodite and is inserted on the inner ventral proximal edge of the meropodite. The muscle is short but powerful. It moves the meropodite forward.

89. Musculus reductor meropoditis II pedis maxillaris (fig. 10).

A more slender but likewise short muscle, this rises on the dorsal proximal border of the basi-ischopodite and is inserted on the lateral proximal border of the meropodite. It tends to pull the meropodite backwards.

90. Musculus abductor carpopoditis II pedis maxillaris (fig. 10).

It originates in many bundles of fibers near the inner proximal border of the meropodite and is inserted on the proximal inner edge of the carpodite. It moves the carpodite upwards and outwards.

91. Musculus adductor carpopoditis II pedis maxillaris (fig. 10).

About the same size as the preceding, this muscle arises in a bundle of fibers on the inner surface of the meropodite, and is inserted on the proximal inner edge of the carpopodite which it moves downwards and inwards.

92. Musculus productor propoditis II pedis maxillaris. (fig. 10).

Arising on the outer proximal wall of the carpopodite, this muscle narrows rapidly to its tendinous insertion on the outer proximal edge of the propodite, which it moves strongly forwards.

93. Musculus reductor propoditis II pedis maxillaris. (fig. 10).

This relatively small muscle arises on the inner proximal part of the carpopodite and is inserted by a tendon on the inner proximal border of the propodite which it bends backwards, and hence toward the mouth.

94. Musculus productor dactylopoditis II pedis maxillaris. (fig. 10).

Arising on the outer proximal part of the propodite, it is inserted by a short tendon on the outer proximal border of the dactylopodite, which it moves forwards.

95. Musculus reductor dactylopoditis II pedis maxillaris. (fig. 10).

Like the preceding in size and shape, this muscle arises on the inner proximal part of the propodite and passes quickly to its tendinous insertion on the inner proximal edge of the dactylopodite, which is brought inwards and backwards.

The third maxilliped

This appendage in the blue crab, as in the crayfish, retains its function of a true mouthpart, and is essentially similar to the second maxilliped in structure. In the shrimp, on the other hand, the third maxilliped no longer assists in the taking of food, but is pediform and has completely lost its exopodite, while its endopodite has fewer segments, a characteristic condition in the Caridea. The endopodite in the blue crab is bent inwards in its natural position, in fact, it can not be straightened perfectly due to the shape of the segments and the uniformly weak development of all the extensors excepting the one controlling the dactylopodite.

The coxopodite and the basipodite of the third maxilliped of the blue crab appear to be represented by a single segment, the protopodite. Brooks (1882) has labeled as "basipodite" the narrowed proximal part of the ischiopodite, which externally appears to be set off from the main part of the segment by a suture. An examination of the musculature of this segment, however, shows no evidence that it is composed of two elements. Furthermore, the exopodite does not originate upon this proximal region of the ischiopodite, which it would naturally do if a true basipodite were involved here.

96. Musculus promotor III pedis maxillaris (fig. 11).

It arises mostly on the dorsal side of the endosternite of the third thoracic segment, and partly on the ventral (now anterior) side of the paraphragm, which is very narrow here. It is a powerful and wide muscle, narrowing and thickening as it goes forward to its insertion on a heavy tendinous ligament of the dorsal proximal inner corner of the protopodite, which is moved inwards and forwards by it.

97. Musculus remotor III pedis maxillaris (fig. 11).

Arising laterally on the endosternite this strong muscle is inserted by a tendon on the lateral proximal edge of the protopodite. It opposes the promotor effectively, although it is somewhat less developed.

98 a-c. Musculus levator (a, b and c) III pedis maxillaris (fig. 11).

This muscle is much smaller than the preceding. Its main branch (a) arises on the endosternite beneath the promotor, and is inserted near the center of the posterior wall of the protopodite. The shortest branch, (b), originates near the main branch on the endosternite, and joins the main branch before its insertion on the protopodite. Another branch, (c), arises in the extreme lateral border of the protopodite not far from the insertion of the remotor, and passes inwards to its insertion anterior to that of the main branch on the posterior wall of the protopodite.

The levators move the basipodite outwards and forwards.

99. Musculus depressor III pedis maxillaris (fig. 11).

This is a very heavy muscle which originates over a relatively broad area on the epimeral plate beneath and beside the promotor, as well as the dorsal side of the endopleurite. Its many branches run forwards and inwards to join before the insertion of the muscle on the ventral median distal part of the protopodite. It opposes the levators.

100. Musculus adductor exopoditis III pedis maxillaris (fig. 11).

This slender but strong muscle originates in the extreme distal anterior part of the protopodite and runs inwards to its insertion on a short hard projection of the inner proximal border of the exopodite, which is pulled strongly towards the midline by the contraction of the muscle. The crayfish does not appear to have this muscle.

101. Musculus abductor exopoditis III pedis maxillaris (fig. 11).

This is a short, loosly-knit muscle arising ventrally on the median border of the protopodite and running obliquely outwards and forwards to its insertion on the heavy membrane attached to the ventral proximal wall of the exopodite. It moves the exopodite away from the center and slightly outwards.

102. Musculus abductor flagelli III pedis maxillaris (fig. 11).

This strong muscle originates in two places on the proximal part of the exopodite. The two sections soon unite, and the muscle is inserted by a tendon to the outer proximal edge of the greatly enlarged first segment of the flagellum, which is moved strongly upwards and outwards by its action.

103. Musculus flagellaris exopoditis III pedis maxillaris (fig. 11)

Originating on the proximal wall of the enlarged first segment of the flagellum, this muscle goes almost to the tip of the flagellum, giving off fibers to each annulus, and thus insuring freedom of motion to the flagellum.

104. Musculus flexor meropoditis III pedis maxillaris (fig. 11).

This muscle arises in numerous groups of fibers on both dorsal and ventral walls of the ischiopodite. These fibers all join a tendon before their final insertion on the inner proximal edge of the meropodite, which is strongly pulled down by their action. There is apparently no extensor muscle, the tension of the joint itself being apparently sufficient to bring the meropodite back into position after its contraction by the flexor.

105 . Musculus extensor carpopoditis III pedis maxillaris.(fig. 11).

This very slender and weak muscle originates midway on the walls of the meropodite and is inserted on the outer proximal edge of the carpopodite, which it pulls upwards rather weakly.

106 . Musculus flexor carpopoditis III pedis maxillaris. (fig. 11).

As might be expected from the condition in the preceding segment, this muscle which causes the bending toward the center is very well developed. It originates widely on the proximal margin of the meropodite, and narrows to its tendinous insertion on the inner proximal margin of the carpopodite.

107. Musculus flexor propoditis III pedis maxillaris. (fig. 11).

This muscle is similar to the flexor in the preceding segment in size and function. It originates on the outer walls of the carpopodite, narrowing to an insertion on the outer proximal edge of the propodite.

108 . Musculus extensor propoditis III pedis maxillaris.(fig. 11).

Originating on the inner proximal walls of the carpopodite and inserted by a tendon on the inner proximal corner of the propodite, this muscle is like the corresponding one in the preceding segment in form and function.

109. Musculus flexor dactylopoditis III pedis maxillaris (fig. 11).

This muscle originates on the outer proximal border of the propodite and is inserted by a tendon on the outer proximal edge of the dactylopodite. Relative to the size of its opposing extensor, it is better developed than any other flexor in this endopodite, and apparently can exert a strong outward pull upon the dactylopodite.

110. Musculus extensor dactylopoditis III pedis maxillaris (fig. 11).

Originating on the inner proximal margin of the propodite, this muscle is inserted on the inner proximal edge of the dactylopodite, which is brought strongly downwards by it. In this segment the extensor and the flexor are nearly the same in size and apparent strength.

The pereiopods

The five pairs of pereiopods, or true legs, occur upon the last five of the eight thoracic segments. The promotor, the remotor and the levator muscles of each pereiopod are extrinsic in the origin of all their parts. The depressor of the telopodite, however, is both extrinsic and intrinsic in origin, for the larger and heavier branches originate in the body wall or some of its apodemes, while there are usually two or more branches originating proximally on the anterior and posterior walls of the coxopodite.

The functions of the different pairs of legs become evident upon examining their distal segments. On the first pair of legs, the dactylopodite arises on the anterior (preaxial) border of the propodite nearly at the middle; the unhampered tip of the propodite curves and tapers to a point, while the dactylopodite curves in a way to oppose it effectively, the two forming a powerful pinching claw, the chela, which is rendered still more effective by the horny teeth which have developed on the opposable surfaces. The claw is held out in front of the carapace, and may swing widely forwards and sideways in a horizontal plane, and less widely in a perpendicular plane, both movements serving as the means to repulse an enemy or to seize and tear up food. The extension of the leg forwards has caused it to assume a position half-turned from the normal one, and now the true anterior (preaxial) surface of the first pereiopod is uppermost.

The second, third and fourth pereiopods resemble one another rather closely, as they are nearly the same in size, and perform the same kinds of motions, being adapted for walking. In these, the dactylopodite arises on the distal part of the propodite, tapering rapidly and becoming much flattened. The tip is pointed and sharp, and on these tips the crab is able to walk. The overhang of the carapace allows little upward motion to these legs, and so they have retained the normal position of hanging downwards beneath the body. The anterior surface of these legs is preaxial, as is usually the case in arthropods.

The fifth and last pereiopod is the swimming leg, and projects backwards and upwards behind the carapace when the crab is swimming. Its basal muscles are very powerful, especially the remotor, which is relatively weak in the preceding pereipods. The terminal segment is very thin and flat like the blade of a paddle, ovoid in shape, and propels the crab sidewise very swiftly. Like the first pereiopod, the fifth is also a half-turn away from its normal position, but in a direction opposite to that of the first, so that its anterior (preaxial) face is now downwards, and its postaxial face uppermost.

Since the muscles of the segments distal to the basipodite are essentially similar in all the pereiopods, those of the third pereiopod have been chosen to be described in detail, while the corresponding muscles of the other legs may be referred to the third as a model, taking into consideration the fact that the first and fifth legs are not identical with it in position. The basic muscles are sufficiently different in each leg to merit a full description.

A cross-section of the body at the level of the anterior part of the fourth and of the sixth thoracic segments shows the relations of some of the muscles of the first and third legs to their respective surroundings. (See fig. 13).

The promotor of the fifth pereiopod deserves notice because of the peculiar disposition of its anterior branch. This projects forwards through the thorax into the fourth thoracic segment, surrounded by a membrane, on the posterior surface of which its own fibers originate, and on the anterior surface of which about a dozen branches of muscles pertaining to the legs of the fourth, fifth, sixth and seventh segments also take their origin.

Another feature of the endoskeletal structure must here be explained. An intermediate endopleurite exists in the center of each of the basal chambers occupied by the fourth, fifth, sixth and seventh segments. This endopleurite is fastened to the membrane covering the anterior projection of the promotor of the fifth pereiopod, and gives additional room for attachment to the numerous branches of muscles governing the movements of the leg base.

The first pereiopod

111 a - b. Musculus promotor a and b. (figs. 12A, 13B)

The anterior branch a originates upon a narrow curved apodeme which comes inwards and forwards from the floor of the gill-chamber and attaches itself laterally by a process to the sternum and medially to the endosternite between the third and fourth thoracic segments. The muscle passes outwards and downwards to its attachment on a heavy membrane coming from the preaxial promimal border of the coxopodite. The posterior branch b originates on the anterior border of the intermediate endopleurite of this segment and ends upon a heavy tendon attached to the anterior border of the coxopodite and directly behind the attachment of branch a. These two parts give a strong forward pull to the basal part of the leg.

112. Musculus remotor (fig. 12C)

This is the only unbranched muscle controlling the leg base. It takes origin partly on the lateral surface of the membrane enclosing the anterior promotor of the fifth pereiopod behind 113c and partly on the anterior part of the endopleurite separating the fifth and sixth thoracic segments. It is inserted on a heavy tendon attached to the upper postaxial border of the coxopodite. The leg base is pulled backwards by the contraction of this muscle.

113 a-c. Musculus levator a-c (fig. 12 A, B)

The first branch a originates on the anterior border of the endosternite separating the fourth and fifth thoracic segments. It passes outwards to its insertion on the upper postaxial proximal border of the coxopodite. A second and much shorter branch, b, begins on the lower rim of the intermediate endopleurite. A third branch c, begins behind this endopleurite on the lateral surface of the membrane holding the anterior promotor branches of the fifth pereiopod which extends forwards through the thorax and gives attachment to many muscles, and runs into branch b at their mutual insertion. These muscle parts act together in raising the leg base.

114 a-g. Musculus depressor a-g (figs. 12, A, B, C; 13B)

The first branch a originates mesally on the sternum and passes outwards to its insertion on the tendon attached to the membrane on the preaxial proximal border of the basi-ischiopodite. The second branch b is very indistinctly separated from the first, originating in several sections along the anterior edge of the endosternite separating the fourth and fifth thoracic segments. A third branch c, which appears to be quite distinct, originates on the extreme lateral part of the same endosternite beneath 113a, and comes forwards to its insertion on the membrane of the lower proximal border of the basi-ischiopodite. The fourth branch d begins behind the intermediate endopleurite on the under surface of the pleural wall separating the gill-chamber from the fifth thoracic segment. The remaining branches, e, f and g, originate at different points in the posterior part of the coxopodite. These three last-named branches are not compact, and it is possible to subdivide them still further than this. The distinctness of these minor branches varies considerably according to the state of preservation of the tissues, and consequently appears to be much less evident in some individuals than in others. They are inserted side by side along the lower and post-axial proximal margins of the basi-ischiopodite. The depressor muscle as a whole gives a very strong downward movement to the leg base.

115. Musculus reductor meropoditis

See 137.

116. Musculus abductor carpopoditis

See 138.

117. Musculus adductor carpopoditis

See 139.

118. Musculus productor propoditis

See 140.

119. Musculus reductor propoditis

See 141.

120. Musculus abductor dactylopoditis

See 142.

121. Musculus adductor dactylopoditis

See 143.

The second pereiopod

122 a-d. Musculus promotor a-d (fig. 12D)

The most anterior part, a, arises on the posterior surface of the endosternite separating the fourth and fifth thoracic segments, passing downwards and outwards to its insertion on a heavy tendon coming from the proximal preaxial rim of the coxopodite. The long and slender branch b originates mesally on the prolongation of the endopleurites where they come together just below the attractor of the epimera. It travels ventrally for half its length, separated from the visceral cavity only by a very thin sheet of tissue. It passes at last into the fifth thoracic segment behind branch a of the promotor, where it finally attaches itself to the same tendon. The third branch c originates on the lateral part of the membrane covering the anterior promotor of the fifth pereiopod which extends forwards through the thorax as previously stated. The most lateral branch d originates on the lateral anterior surface of the intermediate endopleurite, being inserted beside branch c on the broad tendon common to all branches of the promotor. The contraction of this muscle causes the leg base to be moved strongly forwards.

123. Musculus remotor (fig. 12F)

As in the first leg, this is the only unbranched muscle belonging to the leg base. It arises on the anterior surface of the endopleurite separating the fifth and sixth thoracic segments, passing downwards and outwards to its tendinous insertion on the upper postaxial border of the coxopodite. It opposes the promotor.

124 a-d. Musculus levator a-d (fig. 12D, E)

This heavy muscle appears to be divided into four main parts, although the third and fourth are not very distinct from each other. The first branch, a, arises on the posterior surface of the endosternite between the fourth and fifth thoracic segments, and is inserted by an extremely strong tendon on the upper (in this case postaxial) border of the basi-ischiopodite. A second branch, b, arises on the lateral part of the membrane encasing the anterior promotor of the fifth pereiopod. The two remaining branches, c and d, arise close together on the anterior surface of the endosternite between the fifth and sixth thoracic segments, and are inserted between branches a and b on the same strong tendon. The entire muscle causes the leg to be raised.

125 a-e. Musculus depressor a-e (fig. 12D, E, F)

The first branch, a, originates mesally on the posterior surface of the endosternite separating the fourth and fifth thoracic segments, as well as on the sternal wall of the fifth segment. It is inserted on the lower (in this case preaxial) rim of the basi-ischiopodite. A very short branch b runs from the anterior part of the coxopodite to the same insertion, while a similar short branch, c, originates in the rear of the coxopodite. A slightly longer branch d begins on the outer part of the sternal wall near the endosternite between the fifth and sixth thoracic segments. The longest branch, e, originates on the anterior wall of the endopleurite separating the fifth and sixth segments, coming forwards and downwards to its insertion with the other branches. The muscle as a whole opposes the levator.

126. Musculus reductor meropoditis

See 137.

127. Musculus abductor carpopoditis

See 138.

128. Musculus adductor carpopoditis

See 139.

129. Musculus productor propoditis

See 140.

130. Muscelus reductor propoditis

See 141.

131. Musculus abductor dactylopoditis

See 142.

132. Musculus adductor dactylopoditis

See 143.

The third pereiopod

133a-g. Musculus promotor a-g (figs. 12A; 13A)

The anterior branch a originates on the posterior surface of the endosternite separating the fourth and fifth thoracic segments, going outwards to its insertion on the tendon attached to the anterior proximal rim of the coxopodite. The second branch b originates on the same prolongation of the endopleurites on which 122 b of the preceding segment takes origin. It travles ventrally beside 122b, separated from the visceral masses only by a thin membrane, passing finally under the anterior extension of the promotor of the fifth pereiopod until it joins its tendon. Branch c originates mesally on the anterior upper edge of the endosternite separating the sixth and seventh segments near to its point of fusion with the endopleurite. The next two branches d and e, not very distinct from each other, arise on the lateral part of the membrane encasing the anterior promotor of the fifth pereiopod. Branch f arises on the anterior lateral surface of the intermediate endopleurite, while branch g arises just behind it on the posterior surface of the same endopleurite. All these go to the same insertion with branch a. The muscle pulls the leg base forwards.

134. Musculus remotor (fig. 12H, I)

This unbranched muscle arises on the pleural wall and on the endosternite separating the sixth and seventh segments. Its insertion is on the proximal postaxial border of the coxopodite. Its contraction causes the leg base to be drawn backwards.

135a-c. Musculus levator a-c (fig. 12H)

The most ventral branch, a, begins on the anterior wall of the sixth and seventh thoracic segments. The branch b, originating just above it on the same endosternite, is perhaps not truly distinct from it. The third branch, c, originates on the lateral part of the membrane covering the anterior promotor of the fifth pereiopod. These three branches are all inserted upon a heavy tendon attached to the proximal postaxial rim of the basi-ischiopodite. The leg base is raised by their contraction.

136a-e. Musculus depressor a-e (figs. 12G,H,I, 13A)

The first of the numerous branches to this muscle, a, originates partly on the posterior wall of the endosternite between the fifth and sixth thoracic segments, partly on the anterior wall of the endosternite between the sixth and seventh segments, and partly on the sternal wall between. It passes to a heavy tendon attached to the tough membrane bordering the proximal anterior rim of the basi-ischiopodite. The next branch b begins on the endopleurite between the sixth and seventh segments just above the anterior prolongation of the promotor of the fifth pereiopod. The next branch c lies partly behind branch b, originating on the endosternite near to its fusion with the endopleurite separating the sixth and seventh segments. Branch d originates anteriorly in the coxopodite, and branch e posteriorly in the same segment. All these are inserted on the heavy tendon or on the membrane beside it. Their mutual contraction pulls the leg base forcibly downwards.

137. Musculus reductor meropoditis (figs. 12I; 13A)

This fan-shaped muscle begins in several places on the preaxial part of the basi-ischiopodite, and is inserted postaxially on the proximal border of the meropodite. The hinge between these two segments is only slightly developed preaxially, and not much more so postaxially, so that the rearward motion imparted by this muscle is slight. It is opposed by the stiffness of the preaxial connection which causes the leg to become straightened again after its contraction.

138. Musculus abductor carpopoditis (figs. 12I, 13A)

This large muscle originates in a great many bundles of fibers attached on the whole dorsal surface of the meropodite from its anterior to its posterior walls. These bundles run together before their insertion on a long blade-like tendon which is inserted on the posterior dorsal proximal border of the carpopodite. This muscle extends the carpopodite so that it lies in a straight line with the meropodite.

139. Musculus adductor carpopoditis (figs. 12I, 13A)

This originates in the same way as the abductor but lies ventrally in its segment and is inserted similarly by a very long tendon leading to the anterior ventral proximal border of the carpopodite. This muscle is therefore in perfect opposition to the adductor, bending the carpopodite at right angles to the meropodite.

140. Musculus productor propoditis (fig. 13A)

This densely-fibered fan-like muscle originates on the entire outer border of the carpopodite, its parts coming together on a heavy leaf-shaped tendon which is inserted on the proximal median anterior border of propodite, to which it gives a strong forward motion.

141. Musculus reductor propoditis (fig. 13A)

This muscle arises on the outer and postaxial walls of the carpopodite, narrowing to its tendinous insertion on the posterior proximal border of the propodite, which is moved backwards by it.

142. Musculus abductor dactylopoditis (fig. 13A)

This rather slender and feather-shaped muscle arises in many small fibers on the preaxial wall of the propodite. It is inserted by a very long blade-like tendon on the outer proximal edge of the dactylopodite, which is moved outward by its action.

143. Musculus adductor dactylopoditis (fig. 13A)

Very similar to the preceding in shape and size, this muscle arises largely on the postaxial part of the protopodite and is inserted also on a blade-like tendon to the inner proximal border of the dactylopodite. The terminal segment is bent strongly towards the midline by this muscle.

The fourth pereiopod

144a-d. Musculus promotor a-d (fig. 12J)

The first branch a originates mesally on the endosternite between the seventh and eighth thoracic segments and is inserted on a heavy tendon attached to the membrane on the anterior border of the coxopodite. The second branch b originates dorsally to a on the same endosternite and just below the membrane covering the anteriorly extending promotor muscle of the fifth pereiopod. The branch c originates partly on the lateral surface of the membrane of the promotor of the fifth pereiopod and partly on the endosternite separating the seventh and eighth segments. The branch d originates on the posterior surface of the intermediate endopleurite, which in this segment is very small. All these branches are inserted with or beside the first one. The whole muscle moves the leg base forwards.

145. Musculus remotor (fig. 12L)

As in the three preceding pereiopods, the remotor of the fourth pereiopod is unbranched. It originates on the lower surface of the pleural wall, passing outwards and downwards to its tendinous insertion on the upper posterior rim of coxopodite. It opposes the promotor by bringing the leg backwards.

146a-b. Musculus levator a-b. (fig. 12J,K)

The first branch a originates partly on the posterior wall of the endosternite separating the sixth and seventh segments above 147a, and partly on the anterior wall of the endosternite separating the seventh and eighth segments. The second branch b originates on the anterior wall of the endosternite between the seventh and eighth segments. It would be possible to subdivide this part into smaller subdivisions, as several strands go more deeply than others. The branches of this muscle go to a mutual insertion on a heavy tendon coming from the upper proximal border of the coxopodite. Their contraction causes the leg base to be elevated.

147a-d. Musculus depressor a-d (fig. 12J,K,L)

The first branch, a, originates partly on the posterior wall of the endosternite separating the sixth and seventh segments, partly on the sternal wall of the seventh segment, and partly on the anterior surface of the endosternite between the seventh and eighth segments of the thorax. The second branch, b, lies behind the posterior part of the first branch, spreading in a fan shape over the endosternite between the seventh and eighth segments of the thorax. It might be considered as being more than a single branch, as it is not very compact at its source. The third and fourth branches, c and d, begin on the anterior and posterior walls respectively of the coxopodite. All branches of this muscle go to the same heavy tendon fastened to the proximal ventral rim of the basi-ischiopodite. The muscle opposes the levator effectively.

148. Musculus reductor meropoditis

See 137.

149. Musculus abductor carpopoditis

See 138.

150. Musculus adductor carpopoditis

See 139.

151. Musculus productor propoditis

See 140.

152. Musculus reductor propoditis

See 141.

153. Musculus abductor dactylopoditis

See 142.

154. Musculus adductor dactylopoditis

See 143.

The fifth pereiopod

155a-c. Musculus promotor a-c (fig. 12M)

The longest and heaviest branch a originates anteriorly on the median plate and passes posteriorly and laterally to its insertion on the tendon on the membrane at the antero-ventral border of the coxopodite. The next branch b is very prominent, originating on the posterior surface of the membrane which projects diagonally forwards through the preceding segments and on the anterior surface of which some of the branches of muscles of the second, third and fourth pereiopods were attached. The third branch c is the smallest. It arises on the posterior surface of the endosternite between the seventh and eighth segments, being inserted above branch b on its tendon. The muscle imparts a forward motion to the leg.

156a-b. Musculus remotor a-b (fig. 12M,O)

In this pereiopod the remotor differs from the corresponding muscle in the other pereiopods in that it is branch and in addition is much more strongly developed than in the other legs, owing to the fact that it has to give a powerful backstroke to this fifth leg which serves as the paddle and which alone causes the very effective swimming movements of the crab. The first branch a originates dorsally on a T-shaped part of the endopleurite which is attached medially on the median plate. The posterior branch b originates on the posterior wall of the eighth segment. Both branches are inserted on a heavy tendon attached to the membrane on the proximal postaxial (in this case dorsal) border of the basi-ischiopodite. The muscle as already stated directs the leg backwards.

157a-c. Musculus levator a-c (fig. 12M, N)

The large first branch a originates on the median plate just posterior to the first branch of the promotor. It travels laterally beneath the second branch of the promotor and beneath the dorsal half of the remotor also, to its insertion on a heavy tendon attached to the anterior (dorsal) proximal border of the basi-ischiopodite. The second branch b is small and weak. It originates on the sternum between the main branches of the promotor and the depressor, and goes upwards and laterally to its insertion on the same tendon. The third branch c is a heavy and strong one, arising on the sternal wall near to the wedge formed by the first abdominal segment. The entire muscle pulls the leg strongly upwards.

158a-f. Musculus depressor a-f (fig. 12M, N, O)

The first branch a, very large and heavy, originates mesally on the sternal wall of the eighth thoracic segment. Branch b is very small, originating laterally on the sternal wall. Branch c parallels the first branch, beginning partly on the sternal wall and partly on the median plate. The fourth branch d originates on the posterior sternal wall at the end of the thorax. The fifth and sixth branches, e and f, originate on the dorsal and posterior walls respectively of the coxopodite. All these branches converge upon an extrmely heavy tendon attached to the proximal preaxial (in this case posterior) border of the basi-ischiopodite. This extraordinarily powerful muscle pulls the leg base downwards.

159. Musculus reductor meropoditis

See 137.

160. Musculus abductor carpopoditis

See 138.

161. Musculus adductor carpopoditis

See 139.

162. Musculus productor propoditis

See 140.

163. Musculus reductor propoditis

See 141.

164. Musculus abductor dactylopoditis

See 142.

165. Musculus adductor dactylopoditis

See 143.

The pleopods

A. The male

In the male blue crab, appendages occur only on the first two segments of the abdomen. The distal abdominal segments are much narrower than in the female, and the third, fourth and fifth segments are fused so that their original sutures are scarcely visible, as I have pointed out previously in this study.

In the first pleopod of the male, the coxopodite is large and partially sclerotized. The basipodite is irregularly shaped, and its distal border is a membrane which attaches the long, whiplike flagellum and gives it the necessary freedom of movement. In this membrane is likewise a pocket in which the flagellum of the second pleopod normally rests.

The name "flagellum" is chosen arbitrarily for the distal part of the pleopod, as it does not show the character of a true flagellum. But neither is there sufficient evidence for considering it a highly modified endopodite or exopodite.

The second pleopod is very much weaker than the first, which completely covers it. Its coxopodite is very thin-walled and partly membranous. A small basipodite is present, controlled by a single muscle originating in the coxopodite. The basipodite and flagellum are sclerotized, but an extensive membrane lies between them, as in the first pleopod. Preaxially the basipodite is represented only by a membrane, as its sclerotized part is entirely postaxial in position.

166. Musculus promotor coxopoditis I pedis spurii (fig. 14A)

This muscle originates on the ventral surface of the last thoracic somite just lateral to the origin of the first ventral superficial abdominal muscle. It is inserted on the inner preaxial promimal border of the coxopodite, which it erects strongly. This is the only extrinsic muscle belonging to the first pleopod.

167. Musculus abductor basipoditis I pedis spurii (fig. 14A)

Arising on the walls of the outer part of the coxopodite, this muscle is inserted on the outer proximal margin of the basipodite, which is pulled away from the center by its contraction.

168. Musculus adductor basipoditis I pedis spurii (fig. 14A)

This is a heavy muscle arising on the inner proximal walls of the coxopodite. It is inserted on the inner proximal border of the basipodite, which is pulled towards the center by its action.

169. Musculus abductor flagelli I pedis spurii (fig. 14A)

This small and compact muscle arises on the distal postaxial border of the basipodite, and is attached to the extended proximal edge of the flagellum. It causes the tip of the flagellum to move strongly outwards.

170. Musculus promotor coxopoditis II pedis spurii (fig. 14B)

This heavy muscle arises on the anterior margin of the second abdominal segment lying entirely beneath the first pleopod. It is inserted on the inner proximal part of the coxopodite, which is erected by its contraction.

171. Musculus adductor basipoditis II pedis spurii (fig. 14B)

Arising in numerous strands on the inner postaxial wall of the coxopodite, this muscle is attached to the inner proximal border of the basipodite, which is brought towards the center by its contraction. No abductor of the basipodite is present in this appendage, as the elasticity of the membrane apparently gives the necessary opposition to the adductor.

172. Musculus abductor flagelli II pedis spurii (fig. 14B)

Like the corresponding muscle in the first abdominal appendage, this muscle arises on the lateral part of the wall of the basipodite and terminates on the proximal preaxial border of the flagellum, which is brought away from the center as well as slightly forwards by its action.

B. The female

The first and the sixth abdominal segments of the female blue crab lack appendages. The second, third, fourth and fifth segments each have pleopods which become increasingly smaller posteriorly. The coxopodite and basipodite are separated by a membrane on the postaxial surface; preaxially the two are fused. A description of the muscles pertaining to the first abdominal appendage, attached to the second abdominal segment, applies to the other three pairs of abdominal appendages, in which the muscles are similar but weaker.

173. Musculus promotor coxopoditis I pedis spurii (fig. 14C).

It arises on the dorsal border of the second abdominal segment and is inserted on the middle of the preaxial proximal border of the coxopodite, which it brings strongly forwards.

174. Musculus abductor coxopoditis I pedis spurii (fig. 14C)

This muscle likewise originates on the dorsal border of the second abdominal segment lateral to the origin of the promotor. It passes slightly outwards to its insertion on the extreme lateral proximal border of the coxopodite. The appendage is moved away from the midline by its action. In the three pleopods which follow this one, the abductor of the coxopodite takes its origin below and behind that of the promotor muscle, so that in the last pleopod it is nearly obscured by the promotor when viewed preaxially.

This is the only noteworthy difference in any of the muscles of the following three appendages as compared with those of the first appendage, except that they become smaller as the appendages themselves decrease in size.

175. Musculus adductor coxopoditis I pedis spurii (fig. 14C)

This muscle is much larger than its opponent, the abductor. It arises on the median dorsal border of the second abdominal somite from almost the midline to the origin of the promotor. It is inserted at the extreme median proximal margin of the coxopodite, which it pulls inwards and forwards.

176. Musculus reductor basipoditis I pedis spurii (fig. 14C)

This is a very short but quite powerful muscle arising laterally along the proximal posterior border of the coxopodite at the only place where the fusion is not complete between basipodite and coxopodite. It runs inward without narrowing to its insertion along the proximal posterior wall of the basipodite, which is moved backward by its action.

177. Musculus abductor exopoditis I pedis spurii (fig. 14C)

Arising on the lateral anterior border of the basipodite near the insertion of the abductor of the basipodite, the abductor of the exopodite is inserted on the lateral wall of the exopodite, on which it produces a feeble outward pull.

178. Musculus adductor exopoditis I pedis spurii (fig. 14C).

This rather slender muscle arises on the median proximal preaxial wall of the basipodite and extends outwards to its insertion on the inner proximal end of the exopodite, which is moved inwards by its pull.

There are no muscles to govern the endopodite, which moves only as the basipodite moves.

179. Musculus promotor coxopoditis II pedis spurii

See 173.

180. Musculus abductor coxopoditis II pedis spurii

See 174.

181. Musculus adductor coxopoditis II pedis spurii

See 175.

182. Musculus reductor basipoditis II pedis spurii

See 176.

183. Musculus abductor exopoditis II pedis spurii

See 177.

184. Musculus adductor exopoditis II pedis spurii

See 178.

185. Musculus promotor coxopoditis III pedis spurii

See 173.

186. Musculus abductor coxopoditis III pedis spurii

See 174.

187. Musculus adductor coxopoditis III pedis spurii

See 175.

188. Musculus reductor basipoditis III pedis spurii

See 176.

189. Musculus abductor exopoditis III pedis spurii

See 177.

190. Musculus adductor exopoditis III pedis spurii

See 178.

191. Musculus promotor coxopoditis IV pedis spurii

See 173.

192. Musculus abductor coxopoditis IV pedis spurii

See 174.

193. Musculus adductor coxopoditis IV pedis spurii

See 175.

194. Musculus reductor basipoditis IV pedis spurii

See 176.

195. Musculus abductor exopoditis IV pedis spurii

See 177.

196. Musculus adductor exopoditis IV pedis spurii

See 178.

The skeleton

A brief survey of some of the skeletal peculiarities found in the blue crab is not out of place in a study of its myology, since the shape of the skeleton and the arrangement of the muscles attached upon it are mutually interdependent.

The segments of the head and thorax of the crab are immovably ankylosed, as I have repeatedly emphasized. To some extent, this fact simplifies the musculature, as it at once precludes the presence of true trunk muscles which are necessary only when the segments move individually.

The muscles of the last five thoracic segments are separated internally by a series of irregularly shaped partitions. Each of these partitions consists of two thin plates, formed by the anterior wall of one segment closely applied to the posterior wall of the preceding segment. The lower half of each partition is formed by a pair of the plates arising from the sternal borders of neighboring segments, and is called an endosternite. The upper half of each partition is similarly formed by a pair of the plates which originate on the pleural walls of neighboring segments, and is called an endopleurite. Each endosternite coalesces with its corresponding endopleurite, and it is at this line of coalition that the break occurs during ecdysis to allow the crab to moult completely.

The endosternites and endopleurites formed in the manner just described are entirely intersegmental. A secondary infolding of the pleural wall occurs, however, in the fourth, fifth, sixth and seventh thoracic segments. To this infolded structure which is strictly intrasegmental I have given the name of secondary endopleurite. No corresponding infolding occurs in the sternal parts of these segments. The secondary endopleurite is firmly attached at its inner margin to the anterior surface of the membrane encasing the promotor of the fifth pereiopod. The remotor muscle always finds its origin behind the secondary endopleurite, while some of the branches of the depressor and levator do so likewise in certain segments. This indicates that these partitions are in truth only secondary, since the remotor of a particular segment would not arise outside its own segment.

The endoskeletal partitions of the last five segments of the thorax present an interesting complexity due to the overdevelopment of the fifth pereiopod, as I have already noted. The muscle attachments of this pereiopod have been increased by the forward prolongation of a branch of the promotor muscle through the three preceding segments. The pocket-like membrane which encases this part of the muscle serves as a place of attachment for the several endopleurites where they meet the endosternites, as well as for the secondary endopleurites, while these attachments hold it firmly in place to resist the heavy pull which the muscle exerts upon it. The anterior termination of this prolongation may be seen upon the posterior wall of the fourth thoracic segment, where it appears as an oval, semitransparent window partly separating the endopleurite and endosternite lying between the fourth and fifth thoracic segments.

While the median plate extends forwards as far as the endosternite separating the first and second pereiopods, it serves exclusively as a place of origin for branches of the four basal muscles of the telopodite of the fifth pereiopod. Some part of each of these muscles originates upon the median plate, although none of the muscles originates entirely upon it.

The third maxilliped and the first pereiopod bear a pair of gills which lie side by side in the gill-chamber. The second maxilliped likewise possesses two gills, one of which lies in the extreme anterior part of the gill-chamber in front of the gills belonging to the pereiopods, and which can be distinguished from them only by its smaller size and its anterior position. The other gill of the second maxilliped lies at right angles to the first, extending outwards and backwards from the anterior corner of the gill-chamber. The second and third pereiopods each possess a single gill. The first maxilliped and the fourth and fifth pereiopods lack gills.

The general structure of the crustacean appendage

In order to understand the true relationships between the exceedingly diverse and often highly specialized crustaceans which exist today, it is a matter of importance to attempt to reconstruct a generalized ancestral type, from which all these existing divergencies may have arisen by various evolutionary processes.

A typical leg of any of the higher crustaceans consists of not more than seven segments, including the basal segment called the coxopodite, which is followed by the basipodite bearing the endopodite of five segments, each segment having a pair of muscles to move it. Any or all of these seven segments may be provided with exites--lobes growing on the external part of the limb, or endites--lobes growing on the internal part of the limb. These exites and endites when they are large and moveable, may have special muscles of their own.

In the insects, the basal segment of the leg is obviously divided into a coxa and a subcoxa, the latter forming sclerotized plates in the pleural wall of the thorax. In the crustaceans, it is quite possible to trace a similar development of the limb basis. Consequently we may look upon the coxopodite as being equivalent to the coxa of the insect, while the sternal and possibly the pleural regions of the thorax in the blue crab represents the subcoxal regions of the legs.

The coxopodite is sometimes ankylosed with the basipodite, in which case the resulting structure goes by the name of protopodite. The coxopodite may exist by itself, as in the mandible and the two maxillae of the isopod and the amphipod (fig. 21, A, B, C; fig. 22 A, B, C), or it may give rise to a basipodite with or without an exopodite and endopodite. The coxopodite may have one or more epipodites (fig. 24, E, F), which are usually gill-like, non-segmented structures forming a part of the respiratory system.

In the lower crustaceans, the leg has an exopodite as well as an endopodite, both of which always arise from the basipodite. In the higher crustaceans, the exopodite still persists in the maxillipeds and the pleopods.

The exopodite may have any number of joints, and its distal part may be modified to form a flagellum, as in the maxilliped and true legs of the mysid (fig. 19 D; fig. 20, A, B, C). The endopodite, on the contrary, is very definitely limited to a maximum of five segments. Frequently the distal segments are not present, and some of the proximal ones may have ankylosed. The endopodite exists in its typical form as a walking leg in the higher crustaceans, the names of its segments being the ischiopodite, the meropodite, the carpopodite, the propodite and the dactylopodite. The typical crustacean leg has two principle places for bending,-- one is at the basal joint between the coxopodite and the basipodite, and the other is at the "knee" joint between the meropodite and the carpopodite. Hence there are typically three segments between the basal joint and the "knee" joint, and three more beyond the "knee" joint. When fewer segments occur in either section, we may know that the leg is not entirely typical. For instance, in the second maxilliped of the amphipod (fig. 23 A), only two segments occur distal to the "knee" joint, and therefore we know that it is the dactylopodite which is absent. In the leg of the blue crab (fig. 12 A, B), two moveable segments occur between the basal joint and the "knee" joint. One can easily see in this case that the basipodite is nearly ankylosed with the ischiopodite, the resulting structure thereby becoming a basi-ischiopodite. In the leg of the higher crustaceans the exopodite is absent. The basipodite plus the endopodite is often referred to as the telopodite.

When more than seven segments appear to be visible externally as is the case in the mysid Anaspides, the additional supposed segments are due to slight creases or furrows in the body wall, and are not true segments with their necessary complement of muscle. Some shrimps also apparently have many additional segments in the distal part of the legs, but neither are these true segments, as their myology proves.

The so-called exopodite of the triolobite leg arises on the actual basal segment of the limb, and the question has been raised as to whether it is a true exopodite or an epipodite. If it is an exopodite homologous with that of living crustaceans, then it throws the trilobite absolutely into the Class Crustacea. If, on the other hand, it is an epipodite, then it makes the trilobite ancestral to all the Arthropoda so far as the structure of its legs is concerned.

Bibliography

Berkeley, A. A. (1928). The musculature of Pandalus danae Stimpson. Trans. Royal Canadian Inst. of Toronto, 16, pp. 181-231, 8 plates.

Binder, G. (1929). Das Muskelsystem von Daphnia. Lotos Prag., vol. 77, pp. 30-32.

Borner, C. (1921). Die Gliedmassen der Arthropoden. In A. Lang's Handbuch der Morphologie der Wirbellosen Tiere. Vol. 4. Arthropoda.

Borradaile, L. A. (1922). On the mouth-parts of the Shore Crab. Journ. Linn. Soc., Zool., vol. 35, pp. 115-142, plates 10-11.

Borradaile, L. A. (1926). Notes upon crustacean limbs. Ann. Mag. Nat. Hist. ser. 9, vol. 17, pp. 193-213, plates 7-10.

Brooks, W. K. (1882). Handbook of invertebrate zoology for laboratories and seaside work. Cassino, Boston, chapters 18, 20, 21.

Calman, W. T. (1896). On the genus Anaspides and its affinities with certain fossil Crustacea. Trans. Roy. Soc. Edinburgh, vol. 38, part 4, No. 23, pp. 787-802, 2 plates.

Calman, W. T. (1909). Crustacea. Part 7, third fascicle of "A Treatise on Zoology" edited by Sir Ray Lankester. London.

Cannon, H. G. and Manton, S. M. (1927). On the feeding mechanism of a mysid crustacean, Hemimysis lamornae. Trans. Roy. Soc. Edinburgh, vol. 55, part 1, No. 10, pp. 219-253, 4 plates.

Cannon, H. G. and Manton, S. M. (1929). On the feeding mechanism of the syncarid Crustacea. Trans. Roy. Soc. Edinburgh, vol. 56, pp. 175-189, 8 figs.

Chilton, C. (1916). Fauna of the Chilka Lake. Some terrestrial Isopoda from the shore of the lake. Mem. Indian Mus., vol. 5, pp. 461-482, 36 figs.

Daniel, R. J. (1928). The abdominal muscular systems of Praunus flexuosus. Proc. Trans. Liverpool Biol. Soc., vol. 42, pp. 5-41.

Daniel, R. J. (1929). The abdominal muscular systems of Meganyctiphanes norvegica. Proc. Liverpool Biol. Soc., vol. 43, pp. 148-180.

Hansen, H. J. (1921). Studies on Arthropoda I. Copenhagen. 80 pp. 4 plates.

Bibliography (continued)

Hansen, H. J. (1925). Studies on Arthropoda. II. On the comparative morphology of the appendages in the Arthropoda. A. Crustacea. Copenhagen. pp. 1-176. 8 plates.

Hansen, H. J. (1930). Studies on Arthropoda. III. On walking legs in Malocostraca, etc. Copenhagen. pp. 39-49.

Huxley, T. H. (1880). The crayfish. An introduction to the study of zoology. Appleton, New York, 371 pp. 80 figs.

Jackson, H. G. (1928). The morphology of the isopod head. Part 2. The terrestrial isopods. Proc. Zool. Soc. London, pp. 561-595.

Netz, Willy (1917). Das Skelett des Flusskrebses (Potamobius astacus Leach). Dissertation. Marburg. 104 pp. 38 figs.

Pearson, J. (1908). Cancer. Mem. Liverpool Marine Biol. Committee 16, 209 pp., 13 plates.

Rathbun, M. J. (1930). The Cancroid crabs of America, of the families Euryalidae, Portunidae, Atelecyclidae, Cancridae and Xanthidae. U. S. Nat. Mus. Bull. 152.

Raymond, P. E. (1920). The appendages, anatomy, and relationships of Trilobites. Mem. Connecticut Acad. Arts & Sci., vol. 7, 169 pp., 11 plates.

Schmidt, Walter (1915). Die Muskulatur von Astacus fluviatilis (Potamobius astacus L.) Ein Beitrag zur Morphologie der Decapoden. Zeitschr. fur wiss. Zool., 113, 2, pp. 165-251, 26 figs.

Smith, G., Woods, H., Shipley, A.E., Warburton, C., Thompson, D'A. W. (1909). Crustacea and Arachnids. The Cambridge Natural History, vol. 4.

Snodgrass, R. E. (1927). Morphology and mechanism of the insect thorax. Smithsonian Misc. Coll., 80, No. 1, 108 pp., 44 figs.

Snodgrass, R. E. (1928). Morphology and evolution of the insect head and its appendages. Smithsonian Misc. Coll., 81, No. 3, 158 pp., 57 figs.

Snodgrass, R. E. (1929). The thoracic mechanism of a grasshopper, and its antecedents. Smithsonian Misc. Coll., 82, No. 2, 111 pp., 54 figs.

Snodgrass, R. E. (1932). Evolution of the insect head and the organs of feeding. Smithsonian Report for 1931, pp. 443-489, 25 figs.

List of abbreviations

a-b, primitive dorsoventral axis of the appendage

A Cxpd, anterior part of the coxopodite

Add, tendon of adductor of the mandible

Ant, anterior border

Bnd, endite of the basipodite

Bs-Iscpd, basi-ischiopodite

Bspd, basipodite

Cex, exite of the coxopodite

Cnd, endite of the coxopodite

Crpd, carpopodite

Cxpd, coxopodite

Dcpd, dactylopodite

End, endite

Endpd, endopodite

Eppd, epipodite

Ex, exite

Expd, exopodite

Flb, flabellum

Flg, flagellum

I, tergal promotor muscle

Iscpd, ischiopodite

J, tergal remotor

K, sternal promotor

L, sternal remotor

Mrpd, meropodite

Palp, palp

List of abbreviations (continued)

P Cxpd, posterior part of the coxopodite

Post, posterior border

Prpd, propodite

Prtpd, protopodite

Ptg, paratergite

S, sternum

Scg, scaphognathite

St, statocyst

T, tergum

Tn, telson

Fig. 1. Muscles of the abdomen of the male blue crab

A. Dissection of the abdomen from the ventral side to show the dorsal muscles

7b. Small branch of musculus dilator ani

8-13. Musculi dorsales superficiales abdominis

B. Dissection of the abdomen from the dorsal side to show the ventral muscles.

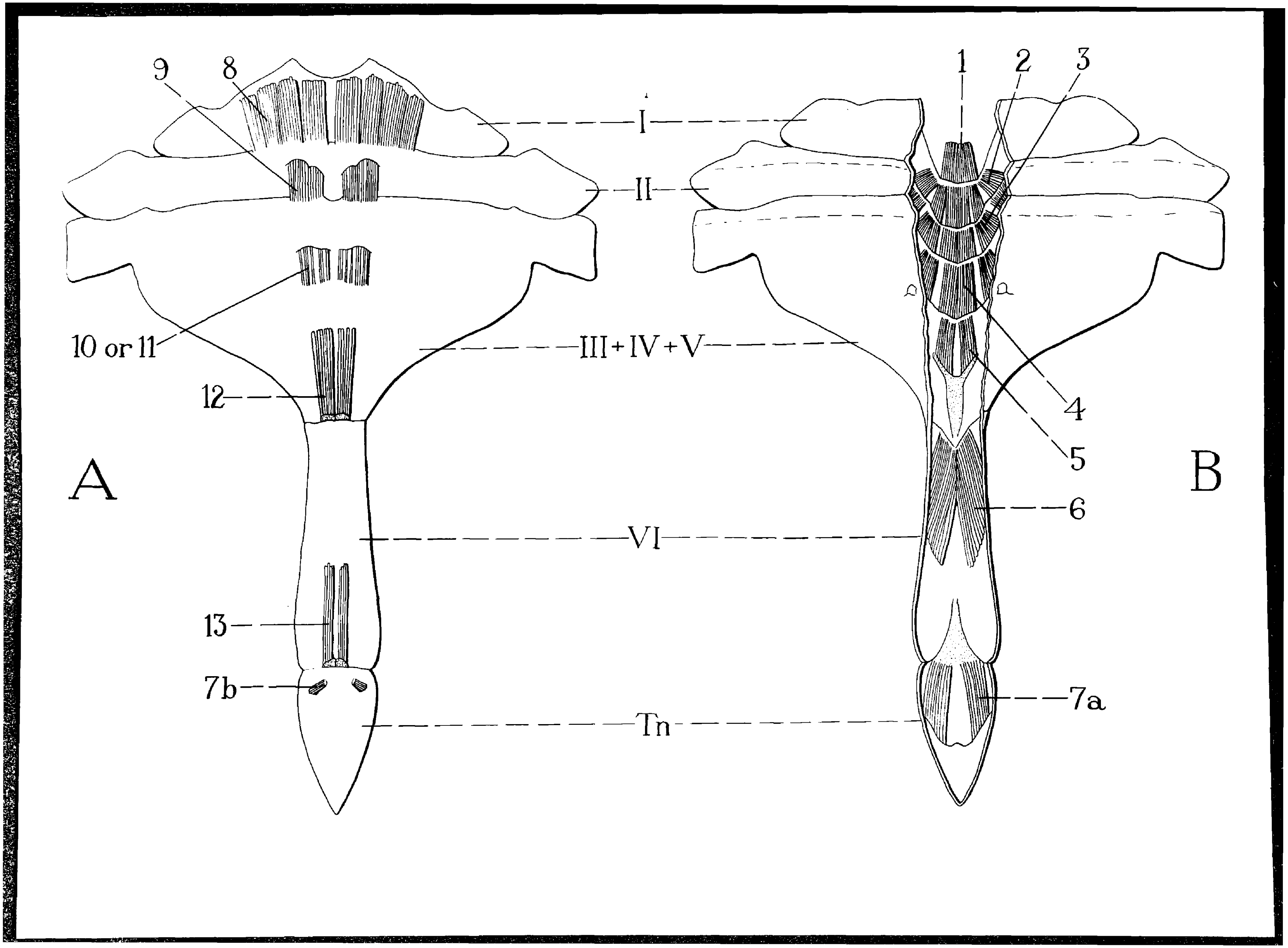
1. Musculus superficialis thoraco-abdominis

2-6. Musculi ventrales superficiales abdominis

7a. Main branch of musculus dilator ani

I-VI. Abdominal somites 1 through 6

Tn. Telson



9
8
I
II
10 or 11
III + IV + V
12
A
VI
13
7b
Tn
1
2
3
4
5
B
6
7a

Fig. 2. Dorsal dissection of the eye of the blue crab
On the right side the deeper muscles are exposed

15. Musculus oculi basalis anterior

16. " " " posterior

17. " " attractor

18. " " adductor

19a and 19b Musculus oculi abductor

20a, 20b and 20c. Musculus oculi retractor dorsalis

21. Musculus oculi retractor ventralis

22. " " " lateralis

23a and 23b Musculus oculi retractor medialis

I. Middle cylinder

II. Second segment

III. Optic cup

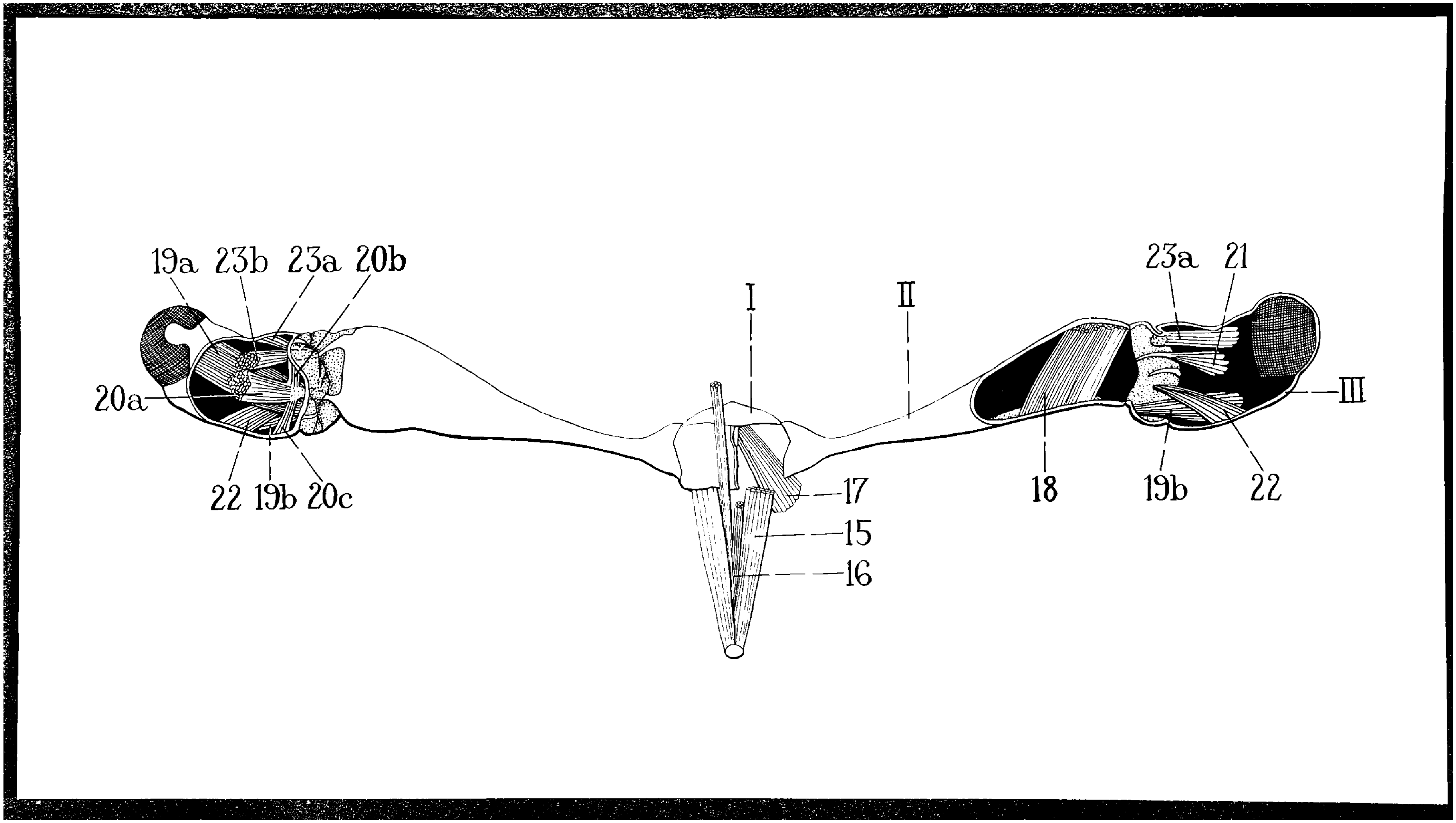

19a
23b
23a
20b
20a
22
19b
20c
I
II
17
15
16
23a
21
III
18
19b
22

Fig. 3. Dorsal dissection of the first antenna of the blue crab with the deeper muscles laid bare on the right side

24a and 24b. Musculus promotor I antennae

25a and 25b. " remotor I "

26. Musculus $productor_2$ I antennae

27. " $reductor_2$ I "

28. " $adductor_2$ I "

29. " $abductor_2$ I "

30. " $productor_3$ I "

31. " $reductor_3$ I "

32. " " $_4$ I "

St., statocyst.

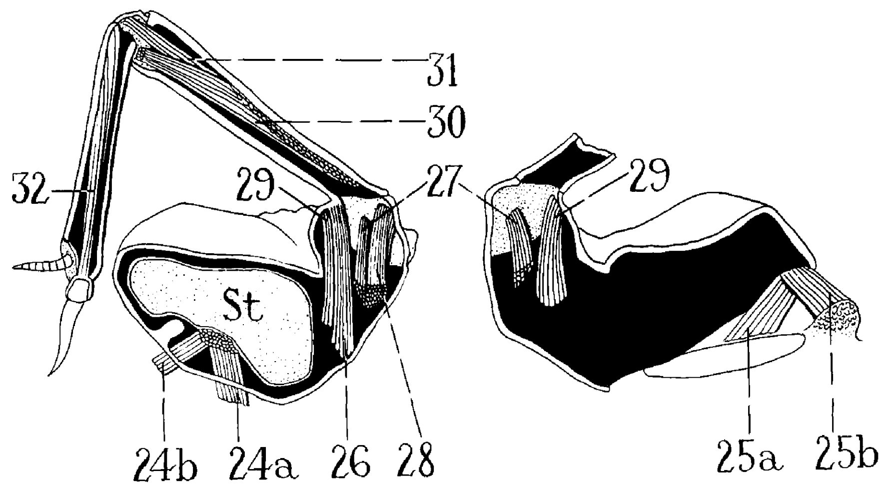

31
30
32
29
27
29
St
24b
24a
26
28
25a
25b

Fig. 4. The second antenna

33.	Musculus	promotor II antennae
34.	"	remotor II "
35.	"	productor ischiopoditis II antennae
36.	"	reductor " " "
37.	"	productor meropoditis " "
38.	"	reductor " " "
39.	"	productor flagellaris " "
40.	"	reductor " " "

Cxpd, coxopodite; Bspd, basipodite; Iscpd, ischiopodite; Mrpd, meropodite; Flg, flagellum.

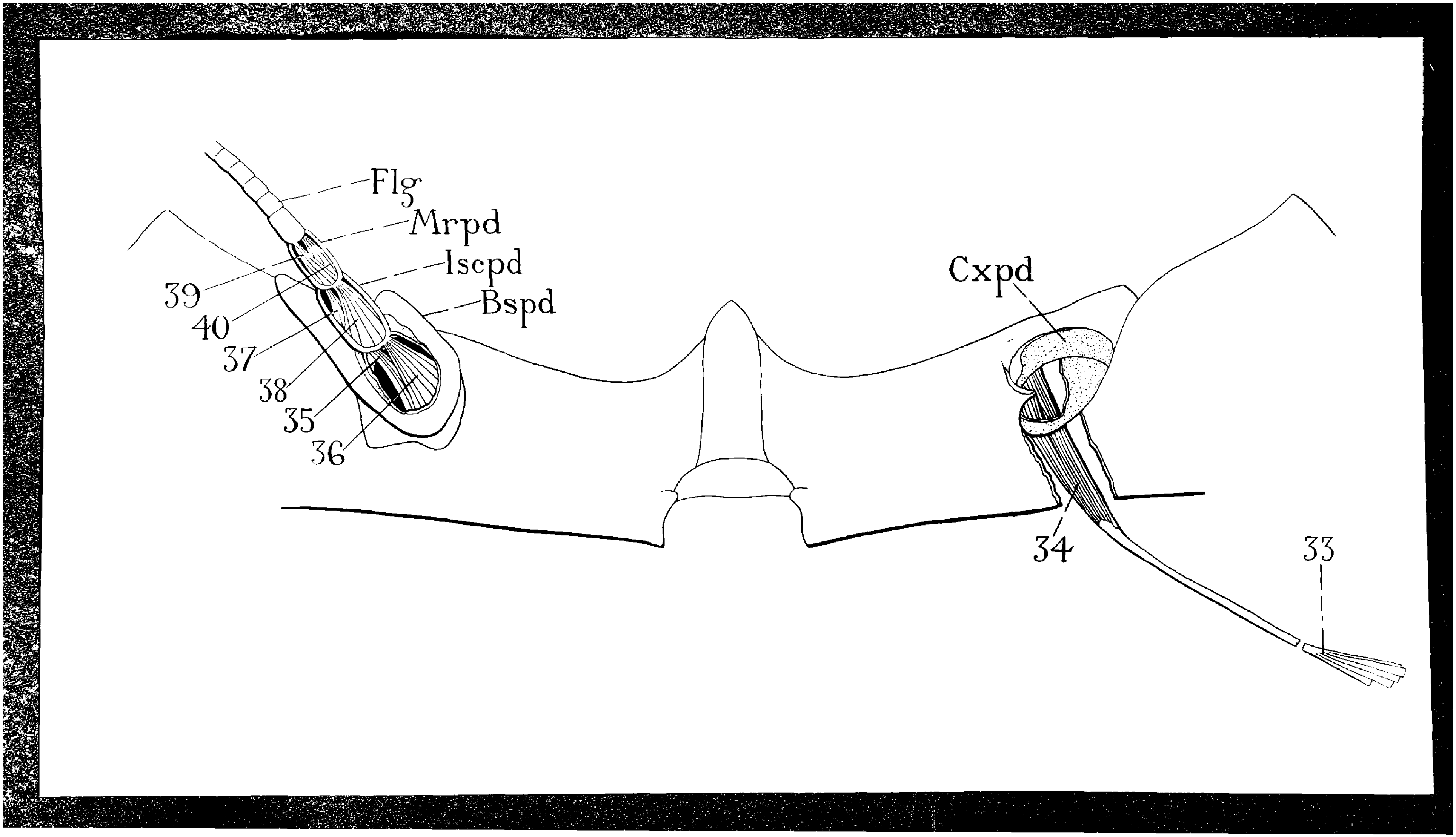

Flg
Mrpd
Iscpd
Bspd
39
40
37
38
35
36
Cxpd
34
33

Fig. 5. The mandible

A. Dorsal view of the mandible in place

B. Analysis of the mandible as an appendage

C. Mesal view of the mandible

41. Musculus abductor maior mandibulae

42. " " minor "

43. " adductor posterior "

44. " " lateralis "

45. " extensor palpi "

46. " flexor a " "

47. " " b " "

x-xx, hinges of the mandible

T42, tendon of Musculus abductor minor mandibulae

T44, " " " adductor lateralis "

S, cut ends of two stomach muscles

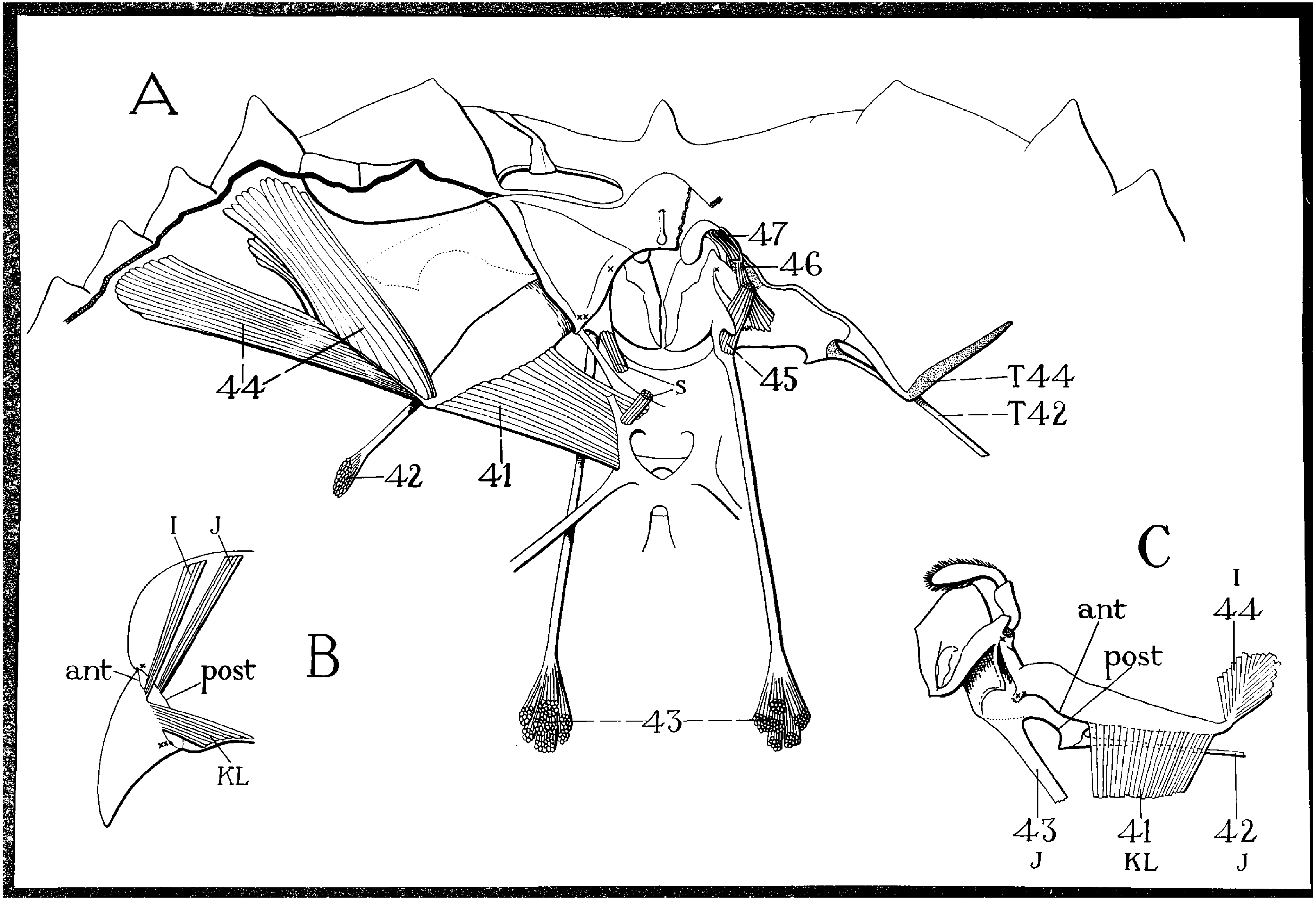
I, the dorsal promotor

J, " " remotor

KL, the ventral promotor and ventral remotor combined

Ant, anterior border of the mandible

Post, posterior " " " "



A
47
46
44
45
S
T44
T42
42
41
43
B
I
J
ant
post
KL
C
I
44
ant
post
43
J
41
KL
42
J

Fig. 6 Diagram of the theoretical elementary musculature of the segmental appendages (after Snodgrass).

a-b, primitive dorsoventral axis of the appendage

I, tergal promotor muscle

J, tergal remotor

K, sternal promotor

L, sternal remotor

T, tergum

S, sternum

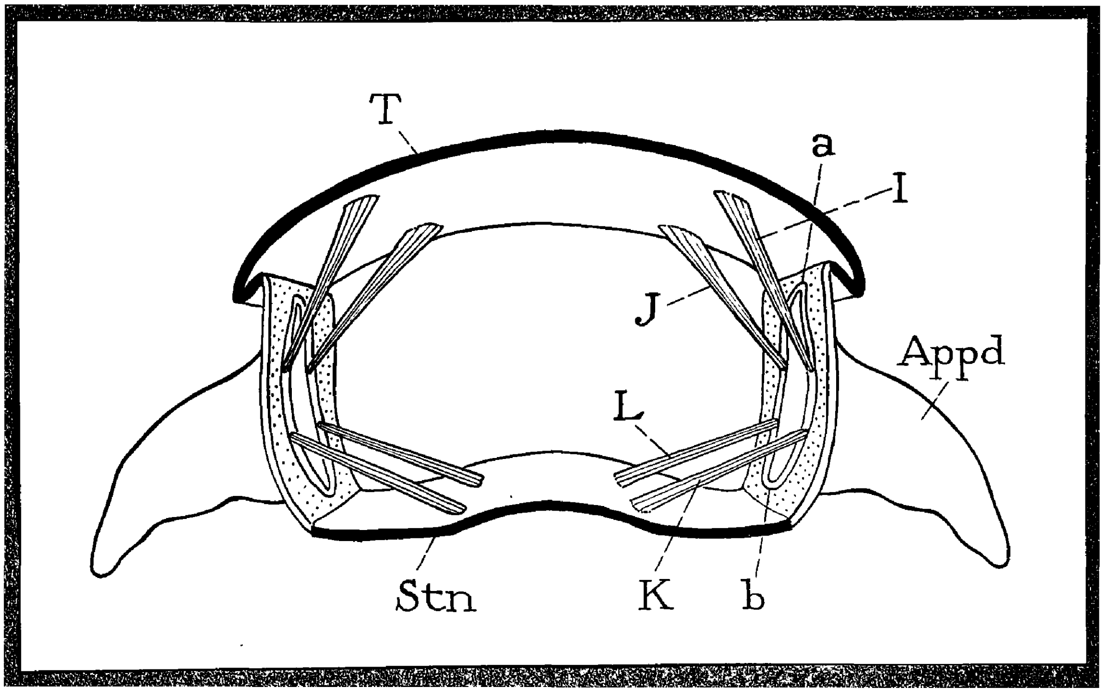

T
a
I
J
Appd
L
Stn
K
b

Fig. 7. The first maxilla

48. Musculus promotor I maxillae

49-50. " remotor " "

51. " adductor anterior I maxillae

52. " " posterior I maxillae

53. " abductor coxopoditis I maxillae

54. " levator I maxillae

55. " depressor I maxillae

56. " adductor endopoditis I maxillae

A Cxpd, anterior part of the coxopodite. P cxpd, posterior part of the coxopodite. Cnd, and Cnd_2, first and second endites of the coxopodite. Endpd, endopodite.

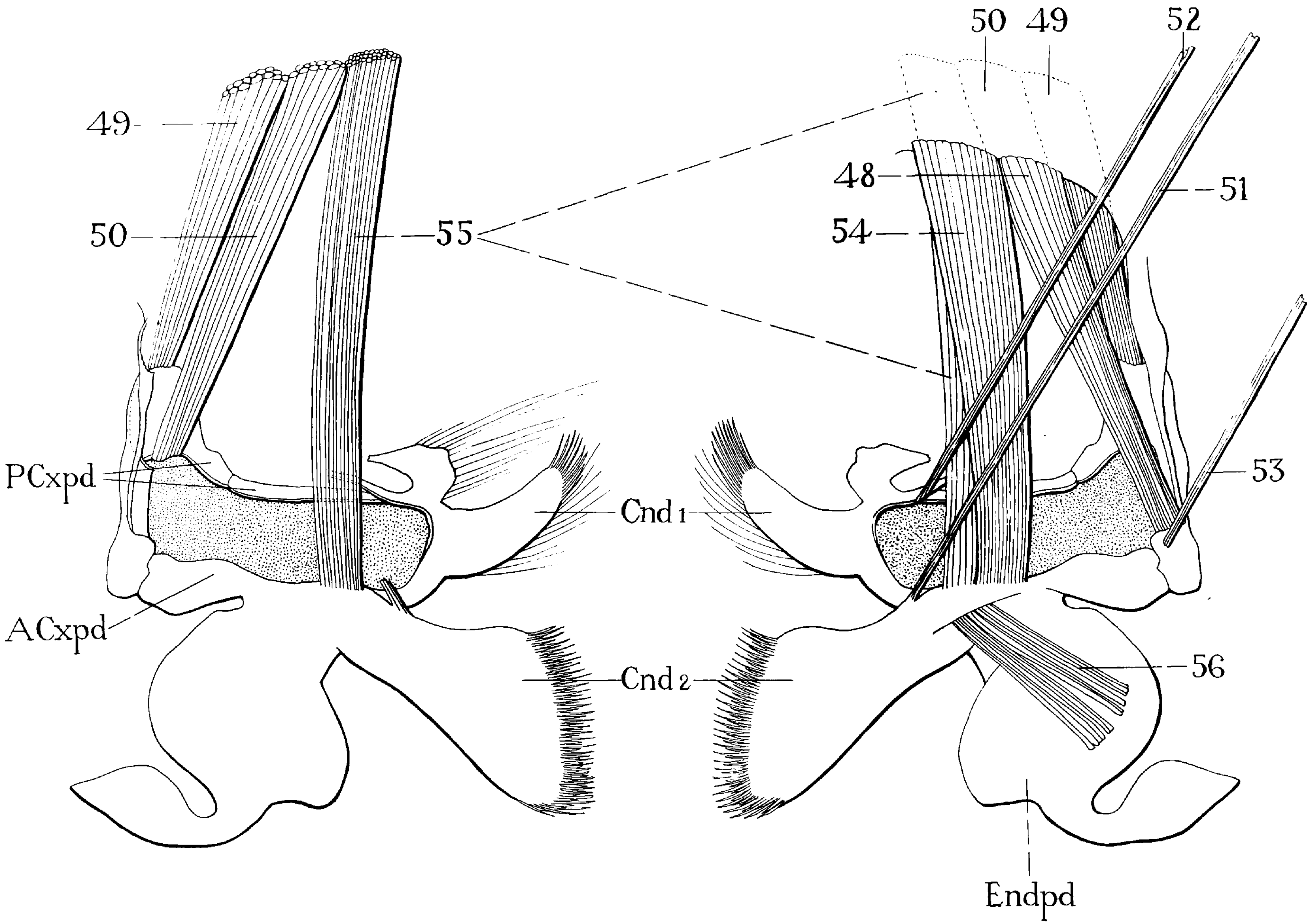

50
49
52
49
48
51
50
55
54
PCxpd
53
Cnd 1
ACxpd
56
Cnd 2
Endpd

Fig. 8. The second maxilla

57. Musculus promotor II maxillae

58. " remotor " "

59. " depressor " "

60. " adductor coxopoditis II maxilla

61. " " endopoditis " "

62. " flexor scaphognathitis II "

63-69. Musculi respiratorii II maxilla

Cnd_1 and Cnd_2, first and second endites of the coxopodite. Endpd, endopodite. Scg, scaphognathite.

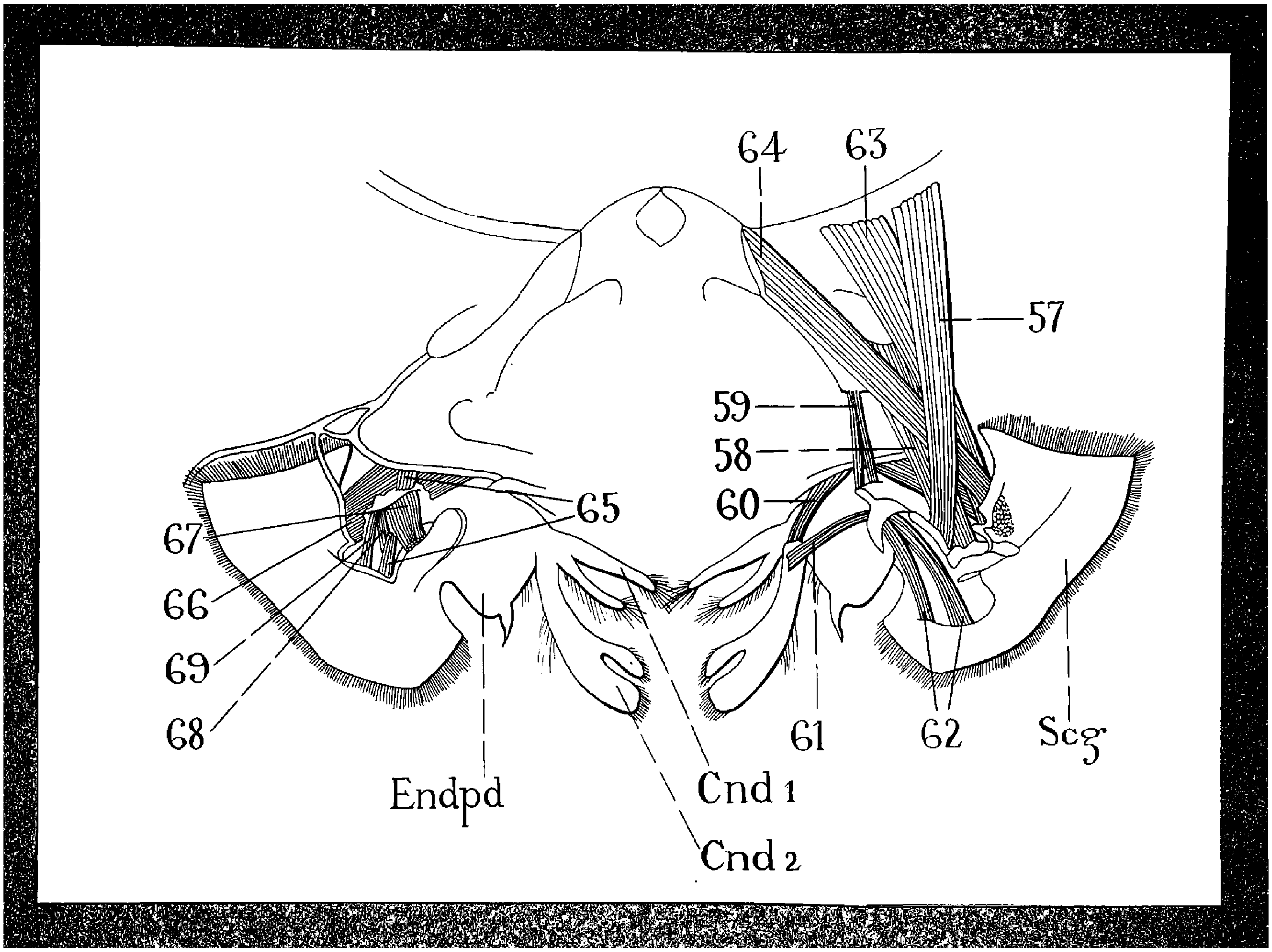

64
63
57
59
58
60
65
67
66
69
68
Endpd
Cnd 1
Cnd 2
61
62
Scg

Fig. 9. The first maxilliped

70. Musculus promotor medialis I pedis maxillaris

71. " " lateralis I pedis maxillaris

72. Unnamed muscle

73a-b. " "

74. " "

75. " "

76. " "

77. Musculus adductor exopoditis I pedis maxillaris

78. " abductor flagelli " " " "

79. " flagellaris exopoditis I pedis maxillaris

Cnd_1 and Cnd_2, first and second endites of the coxopodite.
Cxpd, coxopodite. Endpd, endopodite. Eppd, epipodite. Expd, exopodite.

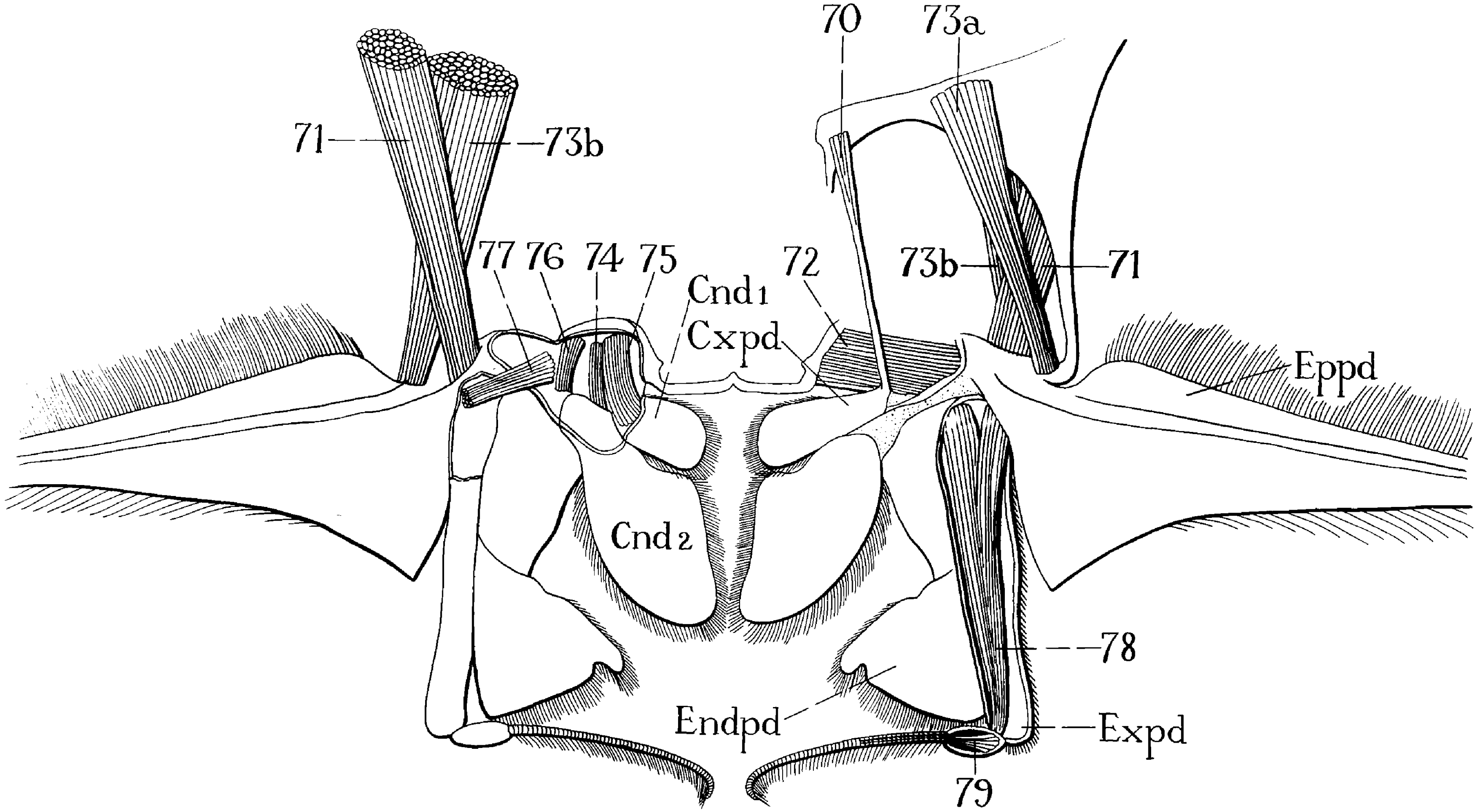

70
73a
71
73b
77 76 74 75
Cnd1
Cxpd
72
73b
71
Eppd
Cnd2
78
Endpd
Expd
79

Fig. 10. The second maxilliped

80. Musculus promotor II pedis maxillaris

81. " remotor " " "

82. " levator " " "

83a-b. " depressor a-b II pedis maxillaris

84. " attractor epipoditis II pedis maxillaris

85. " abductor exopoditis " " "

86. " flagellaris " " " "

87. " abductor flagelli exopoditis II pedis maxillaris

88. " productor meropoditis " " "

89. " reductor " " " "

90. " abductor carpopoditis " " "

91. " adductor " " " "

92. " productor propoditis " " "

93. " reductor " " " "

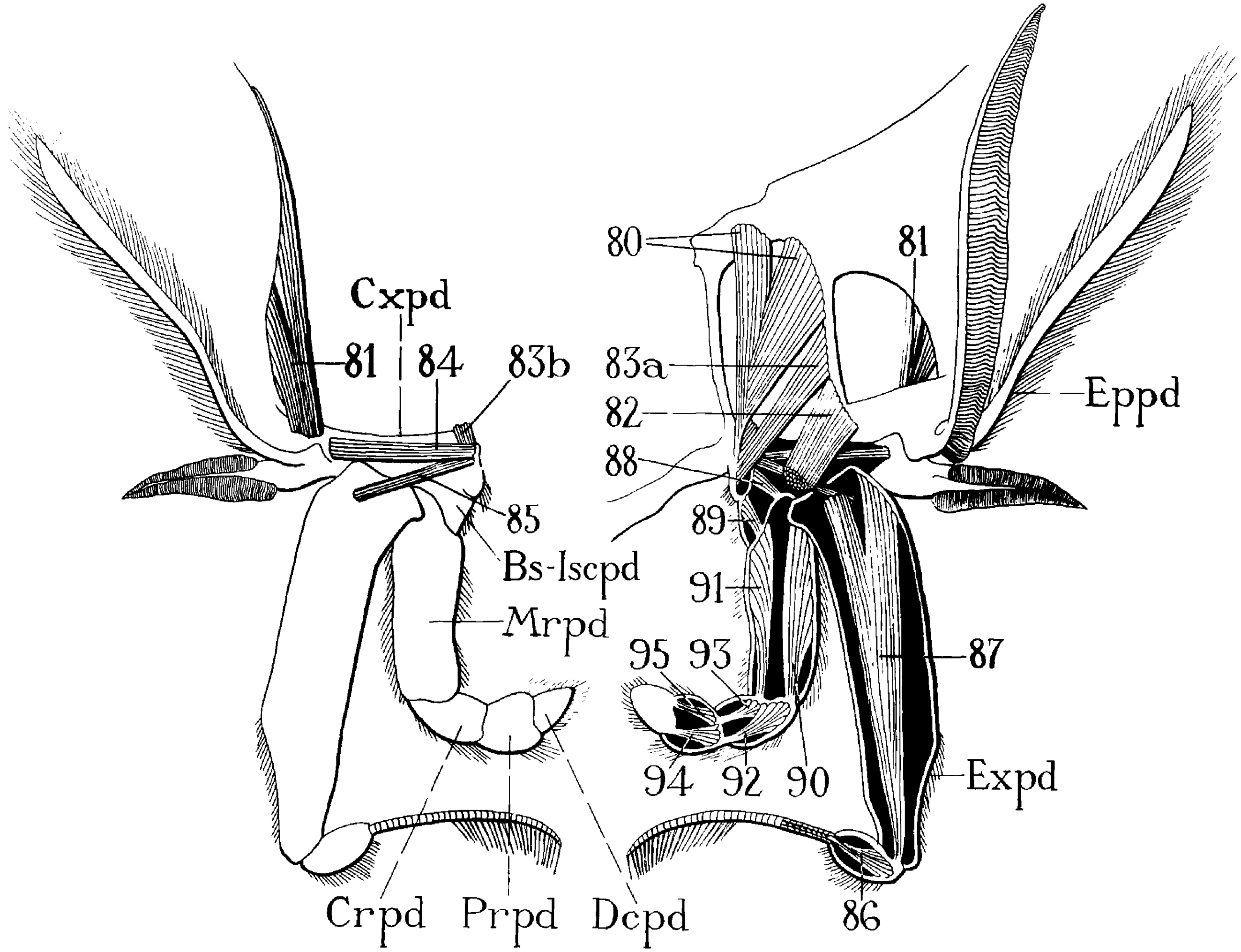
94. " productor dactylopoditis " " "

95. " reductor " " " "

Bs-Iscpd, basi-isichiopodite. Crpd, carpopodite. Cxpd, coxoped

Dcpd, dactylopodite. Eppd, epipodite. Expd, exopodite.

Mrpd, meropodite. Prpd, propodite.



Cxpd
81
84
83b
85
Bs-Iscpd
Mrpd
Crpd
Prpd
Dcpd
80
81
83a
82
88
89
91
95
93
87
94
92
90
Eppd
Expd
86

Fig. 11. The third maxilliped

96. Musculus promotor III pedis maxillaris

97. " remotor " " "

98a-c. " levator a-c III pedis maxillaris

99. " depressor " " "

100. " adductor exopoditis III pedis maxillaris

101. " abductor " " " "

102. " " flagelli " " "

103. " flagellaris exopoditis III pedis maxillaris

104. " flexor meropoditis " " "

105. " extensor " " " "

106. " flexor carpopoditis " " "

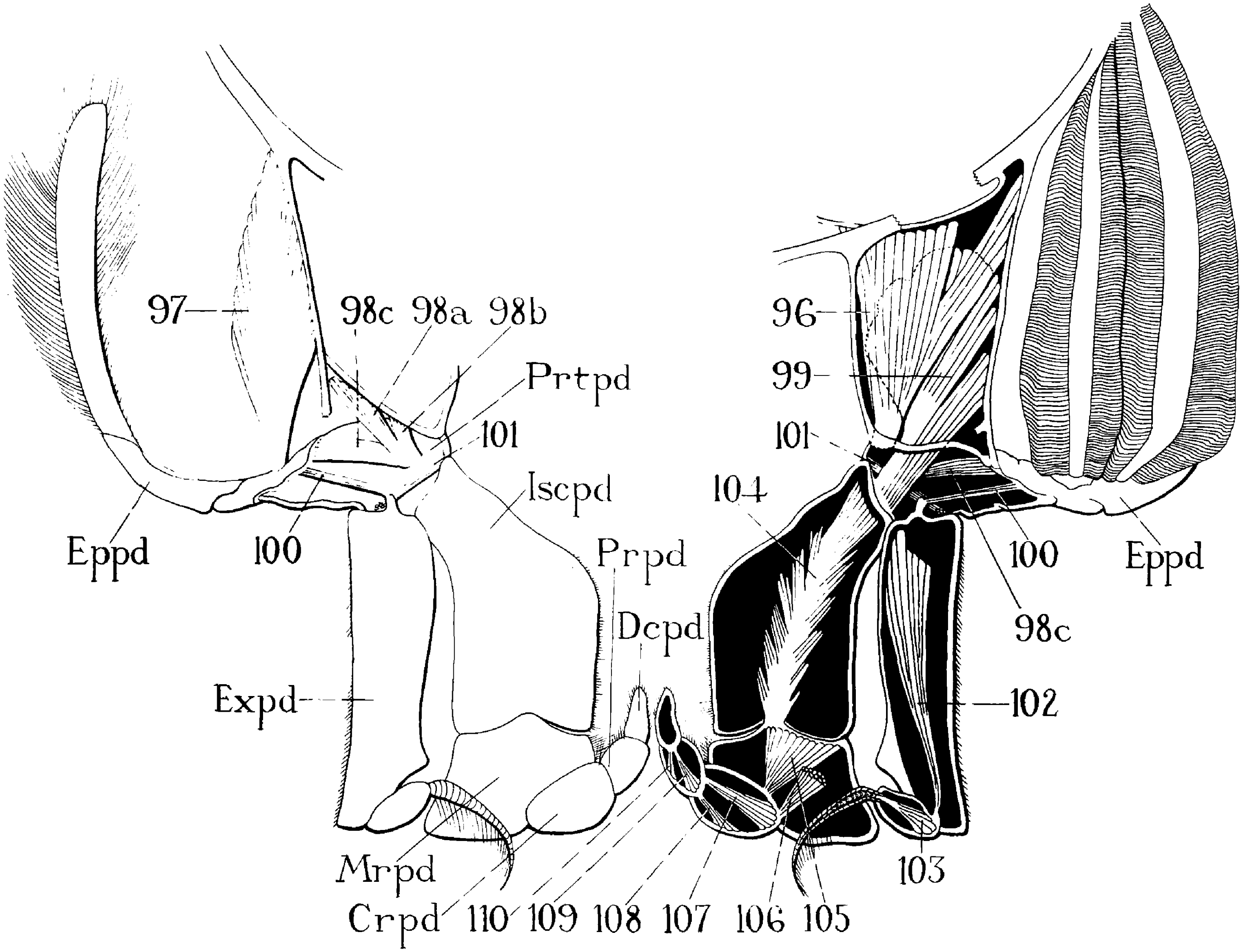
107. " " propoditis " " "

108. " extensor " " " "

109. " flexor dactylopoditis " " "

110. " extensor " " " "

Crpd, carpopodite. Dcpd, dactylopodite. E ppd, epipodite. Expd, exopodite. Iscpd, ischiopodite. Mrpd, meropodite. Prpd, propodite. Prtpd, protopodite.



97
98c
98a
98b
Prtpd
101
Iscpd
Eppd
100
Prpd
Dcpd
Expd
Mrpd
Crpd
110
109
108
107
106
105
96
99
101
104
100
Eppd
98c
102
103

Fig. 12. The pereiopods

A, B, C. The first pereiopod

111a-b. Musculus promotor a-b

112. " remotor

113a-c. " levator a-c

114a-g. " depressor a-g

115. " reductor meropoditis

116. " abductor carpopoditis

117. " adductor "

D, E, F. The second pereiopod

122a-d. Musculus promotor a-d

123. " remotor

124a-d. " levator a-d.

125a-e. " depressor a-e

126. " reductor meropoditis

127. " abductor carpopoditis

128. " adductor "

G, H, I. The third pereiopod.

133 a-g. Musculus promotor a-g

134. " remotor

135 a-c. " levator a-c

136 a-e. " depressor a-e

137. " reductor meropoditis

138. " abductor carpopoditis

139. " adductor "

Bs-Iscpd, basi-ischiopodite. Cxpd, coxopodite.

Fig. 12 The pereiopods (continued)

J, K, L. The fourth pereiopod

144a-d. Musculus promotor a-d

145. " remotor

146a-b. " levator a-b

147a-d. " depressor a-d

148. " reductor meropoditis

149. " abductor carpopoditis

150. " adductor "

M, N, O. The fifth pereiopod

155a-c. Musculus promotor a-c

156a-b. " remotor a-b

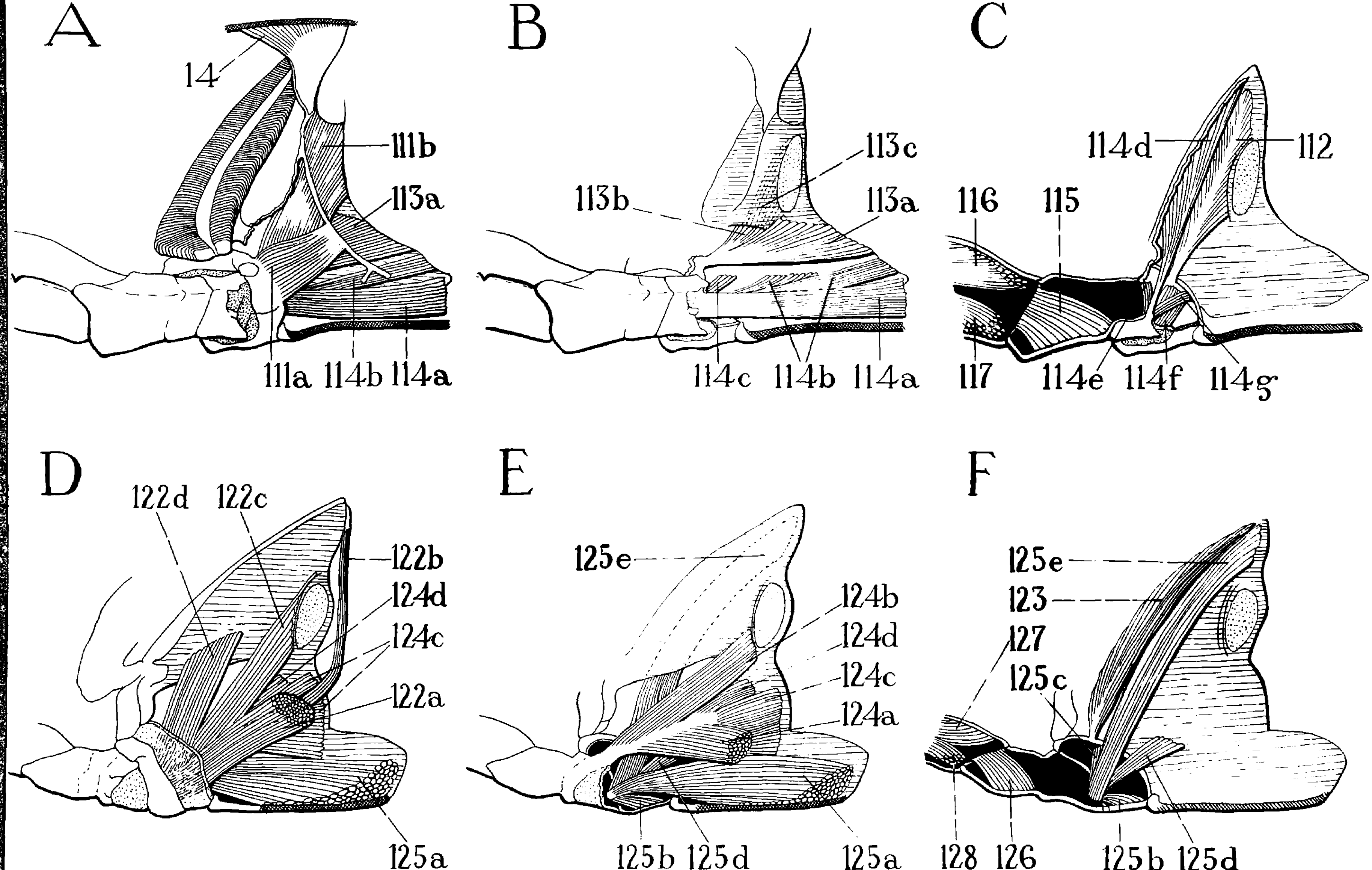
157a-c. " levator a-c

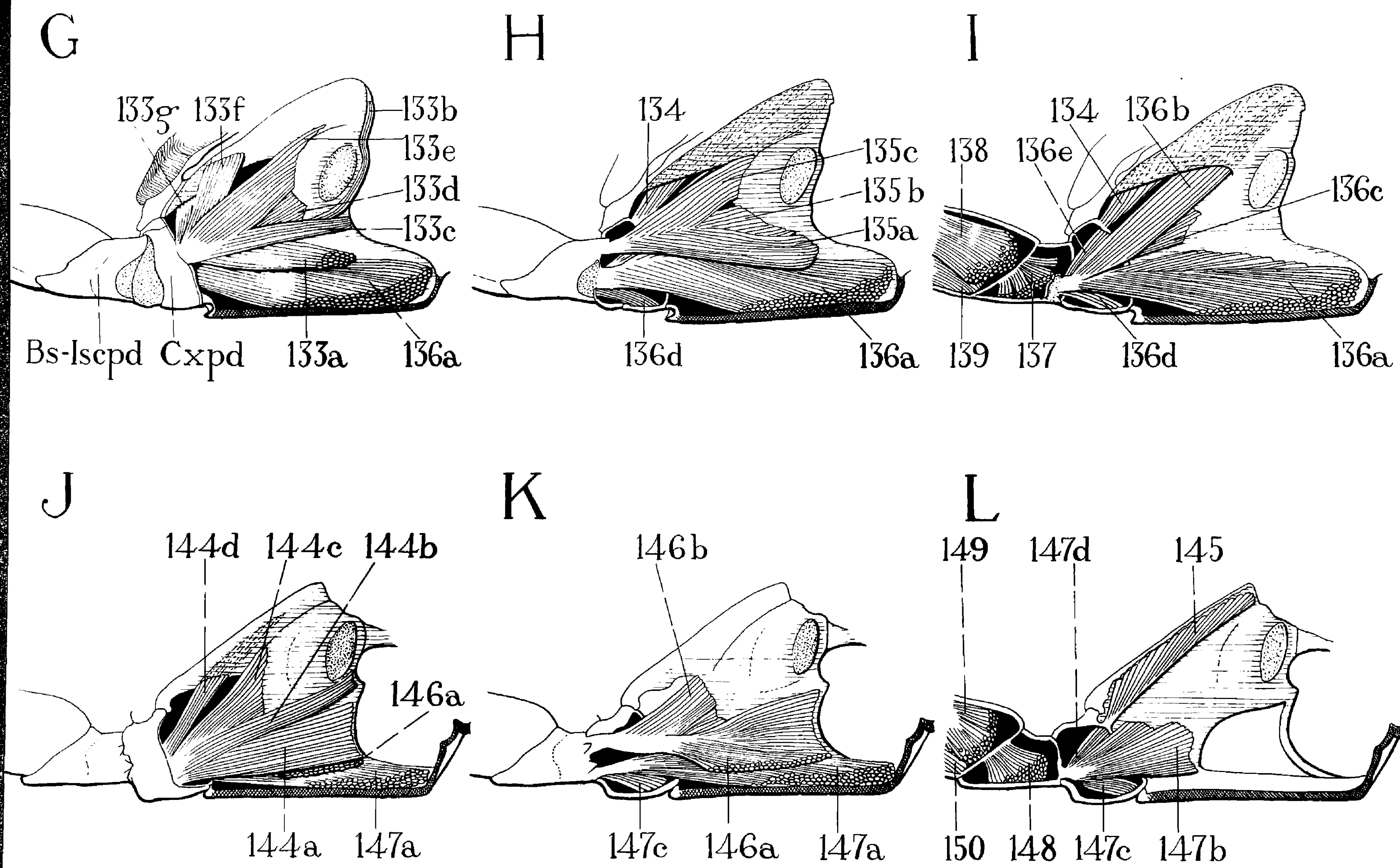
158a-f. " depressor a-f

159. " reductor meropoditis

160. " abductor carpopoditis

161. " adductor "


A
14
111b
113a
111a
114b
114a
B
113c
113b
113a
114c
114b
114a
C
114d
112
116
115
117
114e
114f
114g
D
122d
122c
122b
124d
124c
122a
125a
E
125e
124b
124d
124c
124a
125b
125d
125a
F
125e
123
127
125c
128
126
125b
125d


G
133g
133f
133b
133e
133d
133c
Bs-Iscpd
Cxpd
133a
136a
H
134
135c
135 b
135a
136d
136a
I
134
136 b
138
136e
136c
139
137
136d
136a
J
144d
144c
144b
146a
144a
147a
K
146 b
147c
146a
147a
L
149
147d
145
150
148
147c
147b

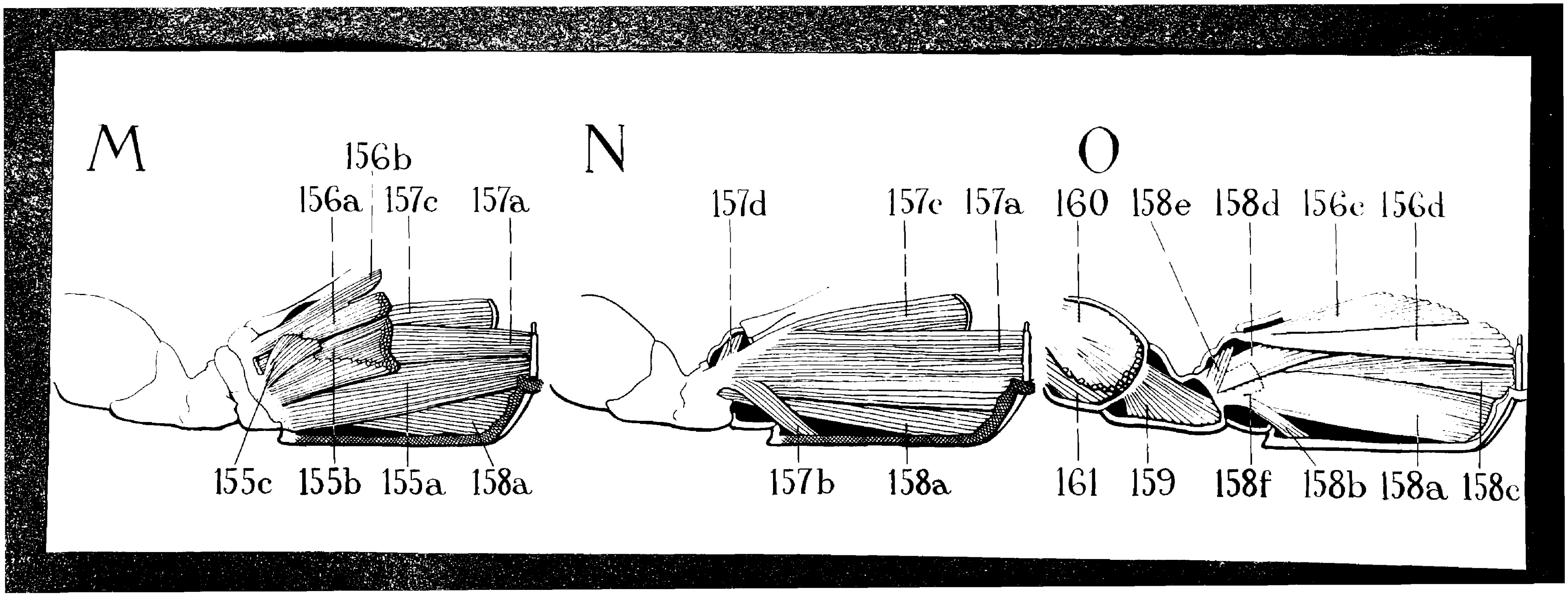

M
156b
156a
157c
157a
155c
155b
155a
158a
N
157d
157c
157a
157b
158a
O
160
158e
158d
156c
156d
161
159
158f
158b
158a
158c

Fig. 13. Transverse section of the thorax

A. Section through the third pereiopod

122b. Branch of Musculus promotor of second pereiopod

133c-g. Branches of Musculus promotor of third pereiopod

136a. Branch of Musculus depressor " " "

137. Musculus reductor meropoditis " " "

138. " abductor carpopoditis " " "

139. " adductor " " " "

140. " productor propoditis " " "

141. " reductor " " " "

142. " abductor dactylopoditis " " "

143. " adductor " " " "

155a. Branch of Musculus promotor of fifth pereiopod

156d. " " " remotor " " "

157a. " " " levator " " "

B. Section through the first pereiopod

14. Musculus attractor epimeralis

111a-b. Branches of Musculus promotor of first pereiopod

114a. Branch of Musculus depressor " " "

115. Musculus reductor meropoditiis " " "

116. " abductor carpopoditis " " "

117. " adductor " " " "

118. " productor propoditis " " "

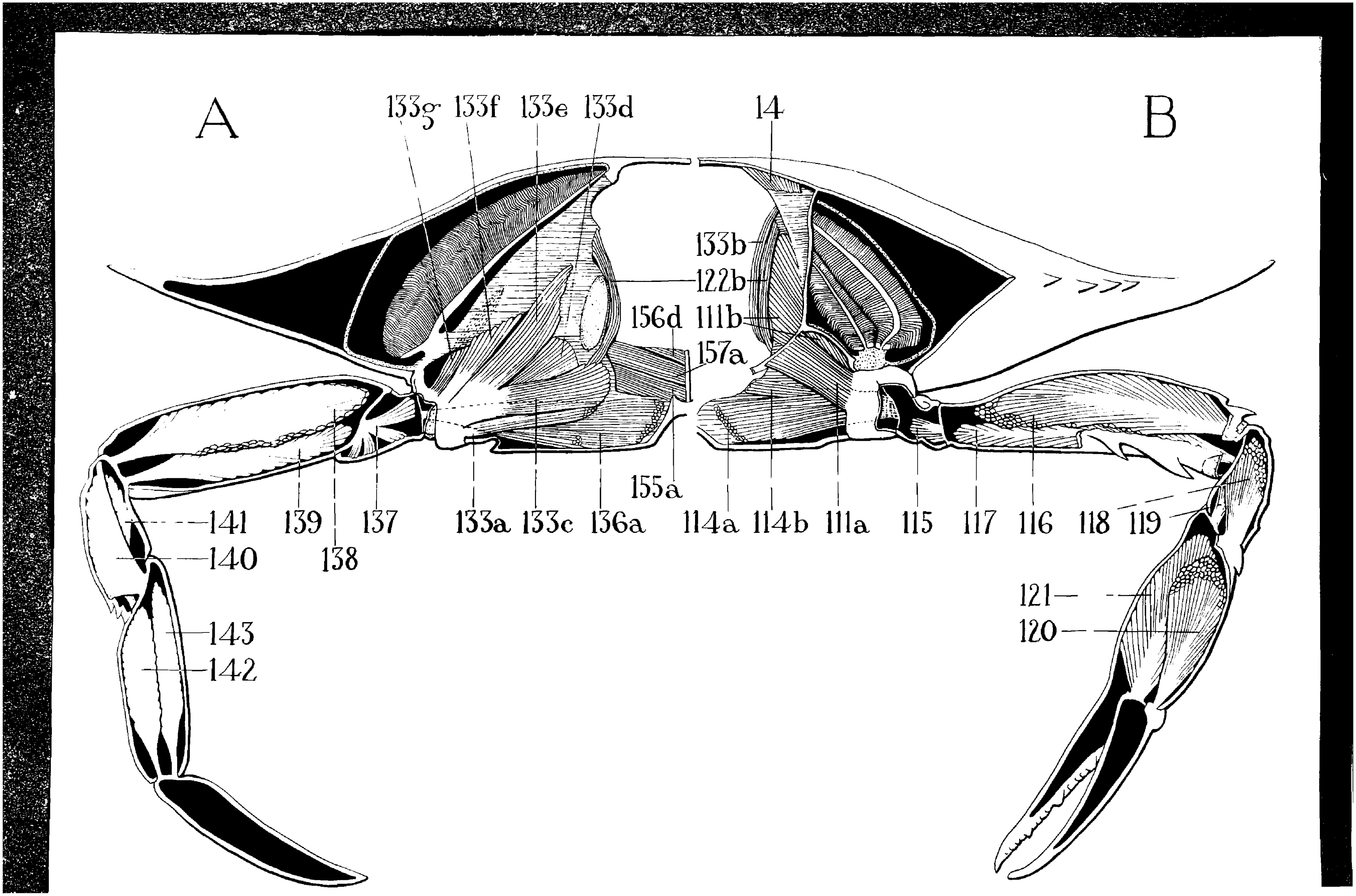
119. " reductor " " " "

120. " abductor dactylopoditis " " "

121. " adductor " " " "

122b. Branch of Musculus promotor of second pereiopod

133b. " " " " " third "



A
B
133g
133f
133e
133d
14
133b
122b
156d
111b
157a
155a
141
139
137
133a
133c
136a
114a
114b
111a
115
117
116
118
119
138
140
143
142
121
120

Fig. 14. The pleopods

A. The first pleopod of the male

166.	Musculus	promotor	coxopoditis	Ipedis		spurii
167.	"	abductor	basipoditis	I	"	"
168.	"	adductor	"	"	"	"
169.	"	abductor	flagelli	"	"	"

B. The second pleopod of the male

170.	Musculus	promotor	coxopoditis	II	pedis	spurii
171.	"	adductor	basipoditis	"	"	"
172.	"	abductor	flagelli	"	"	"

C. The first pleopod of the female

173.	Musculus	promotor	coxopoditis	I	pedis	spurii
174.	"	abductor	"	"	"	"
175.	"	adductor	"	"	"	"
176.	"	reductor	basipoditis	"	"	"
177.	"	abductor	exopoditis	"	"	"
178.	"	adductor	"	"	"	"

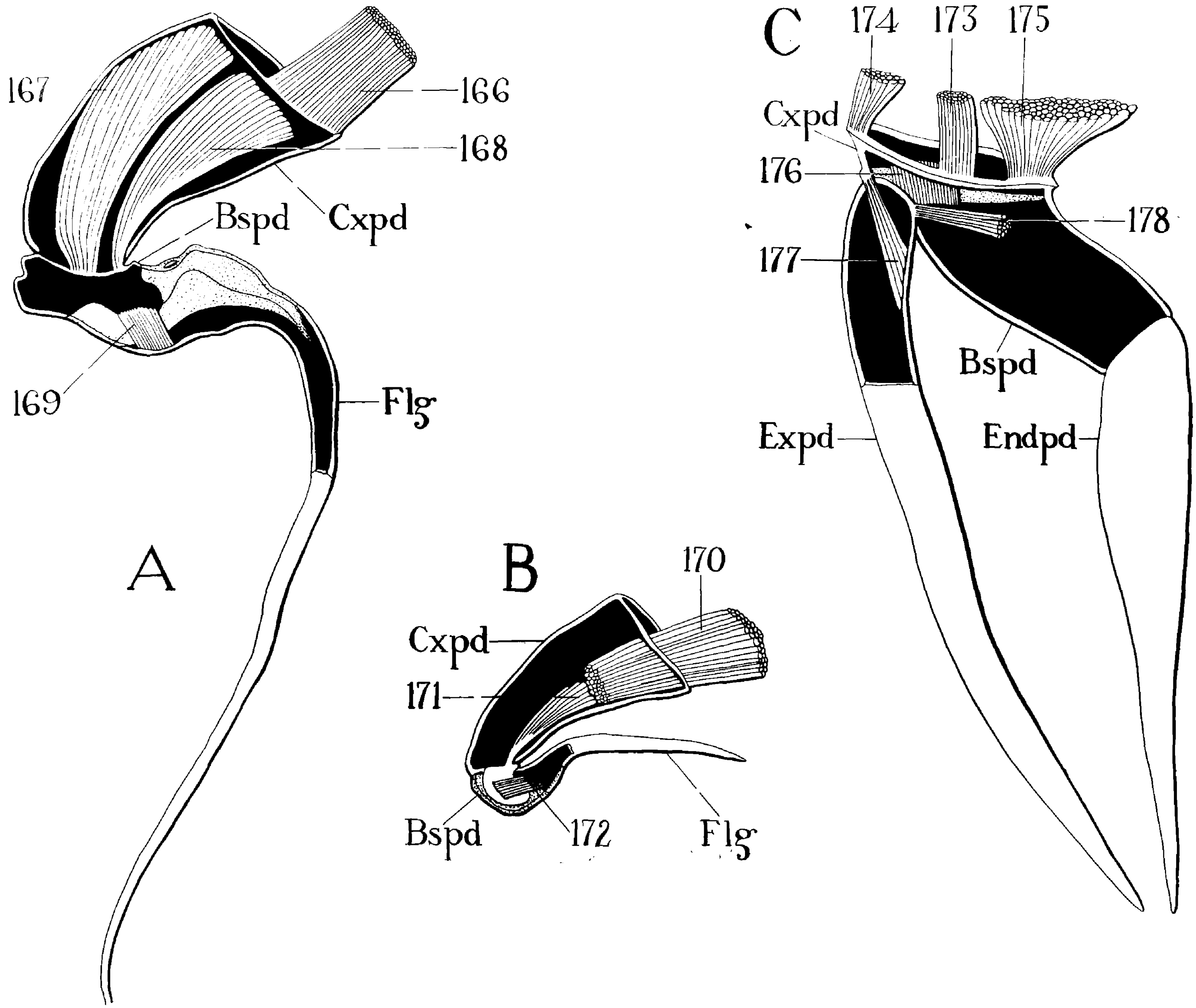

A
167
166
168
Bspd
Cxpd
169
Flg
B
170
Cxpd
171
Bspd
172
Flg
C
174
173
175
Cxpd
176
178
177
Bspd
Expd
Endpd

Fig. 15 Dorsal view of the blue crab

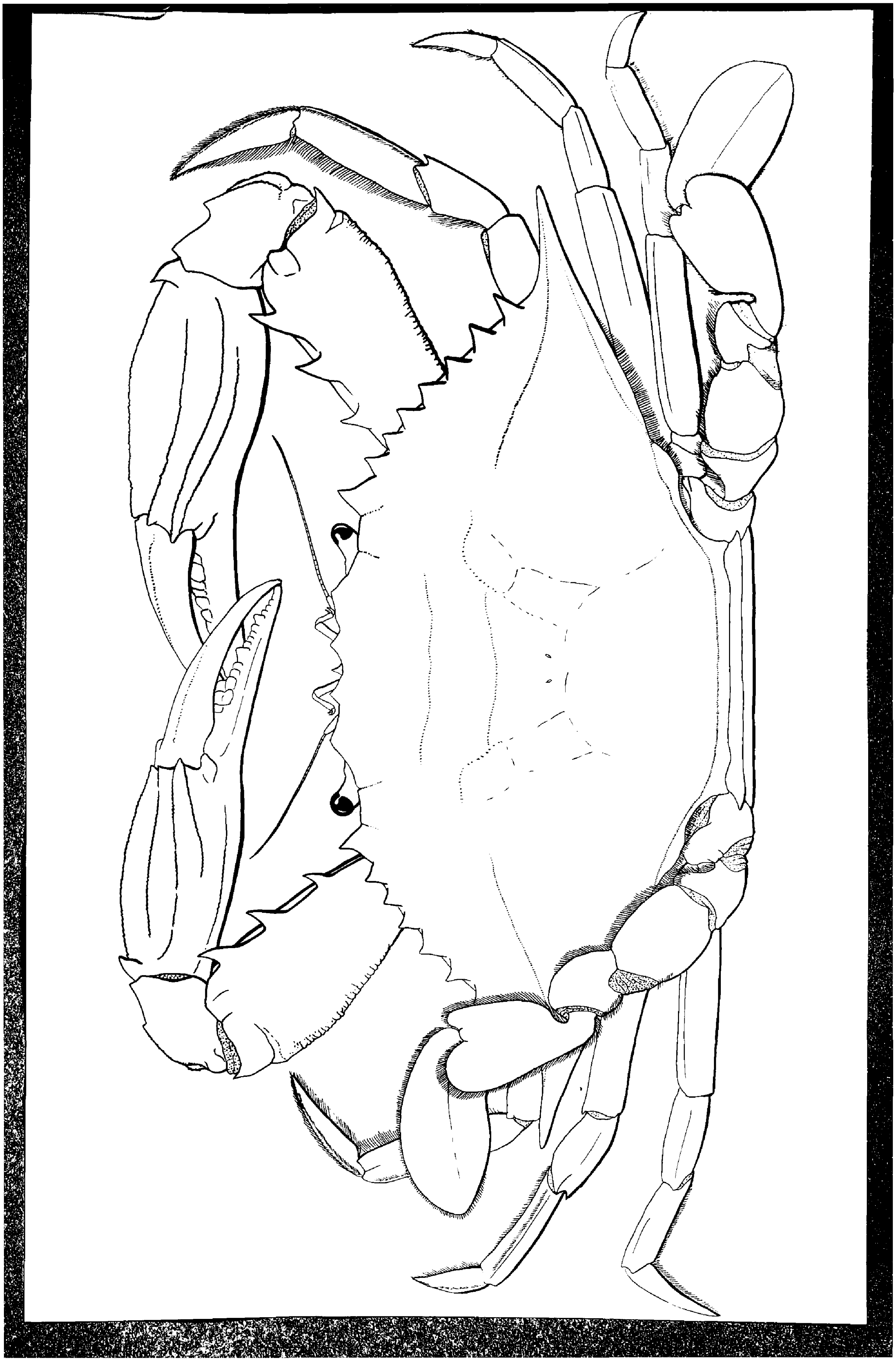


Fig. 16. Ventral view of the blue crab

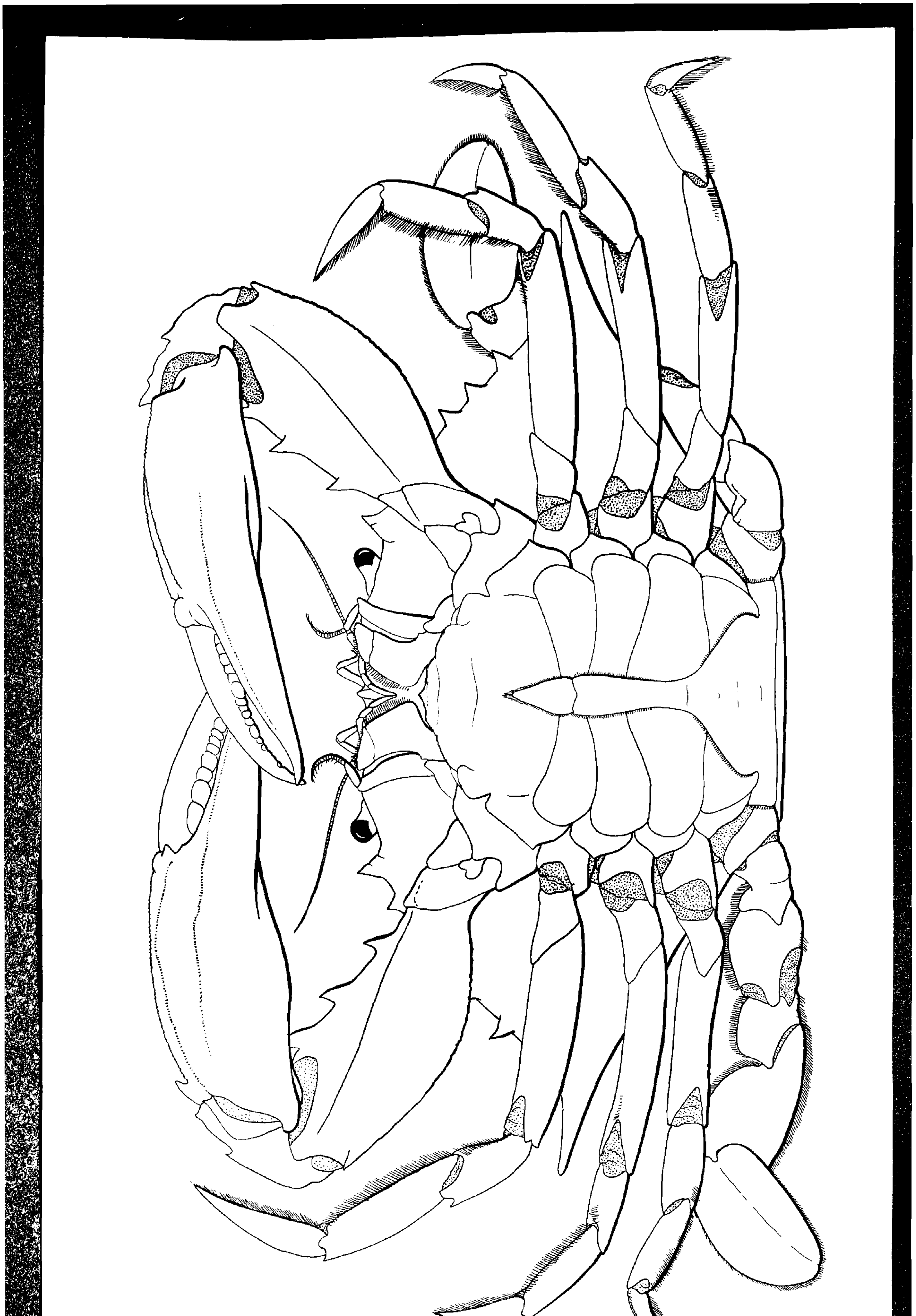
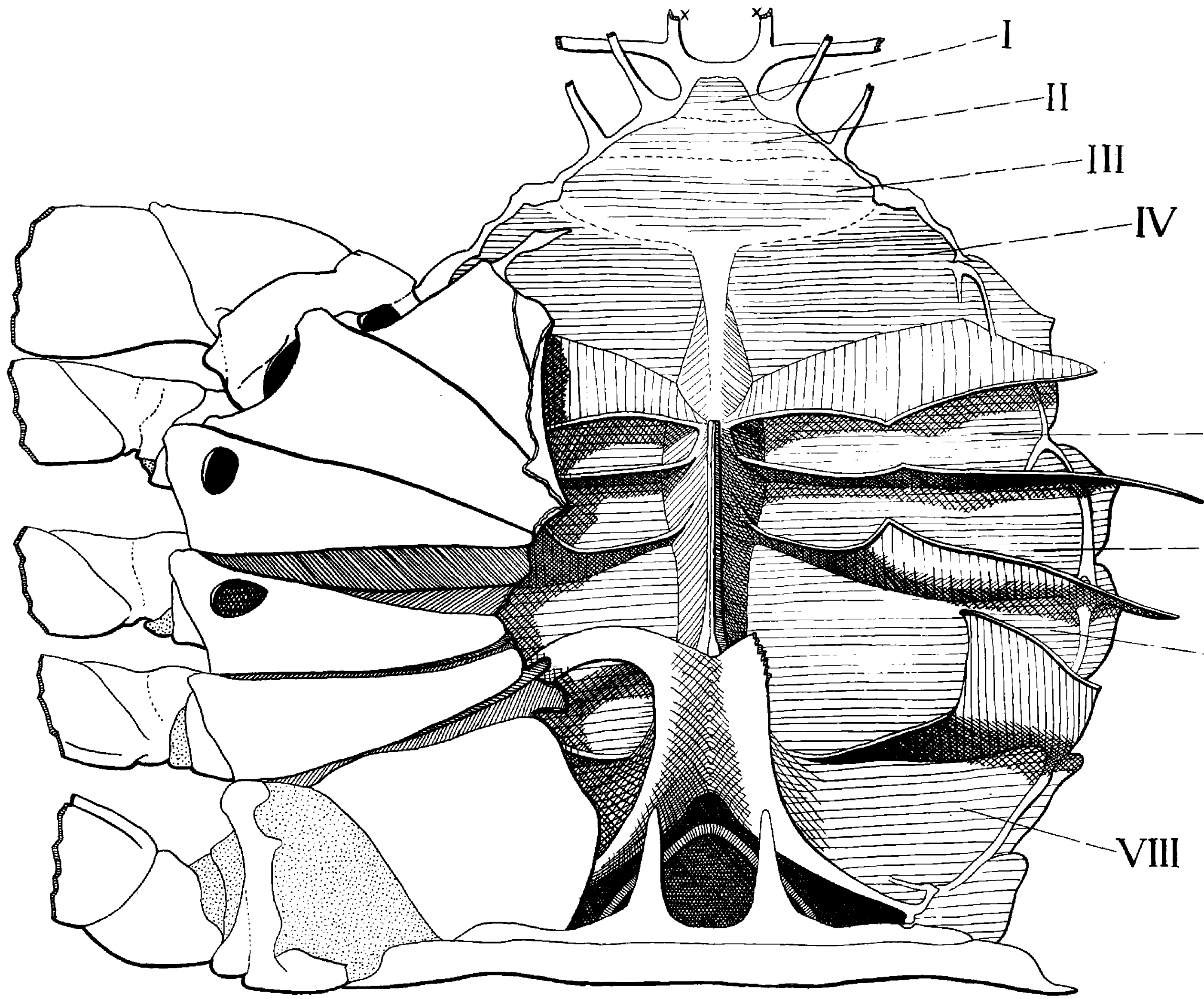


Fig. 17. Dorsal view of thorax with carapace removed to show internal skeletal parts

I-VIII, first through eighth somites of thorax



I
II
III
IV
V
VI
VII
VIII

Fig. 18. Lateral section of thorax to show internal skeletal parts.

I-VIII, first through eighth somites of thorax

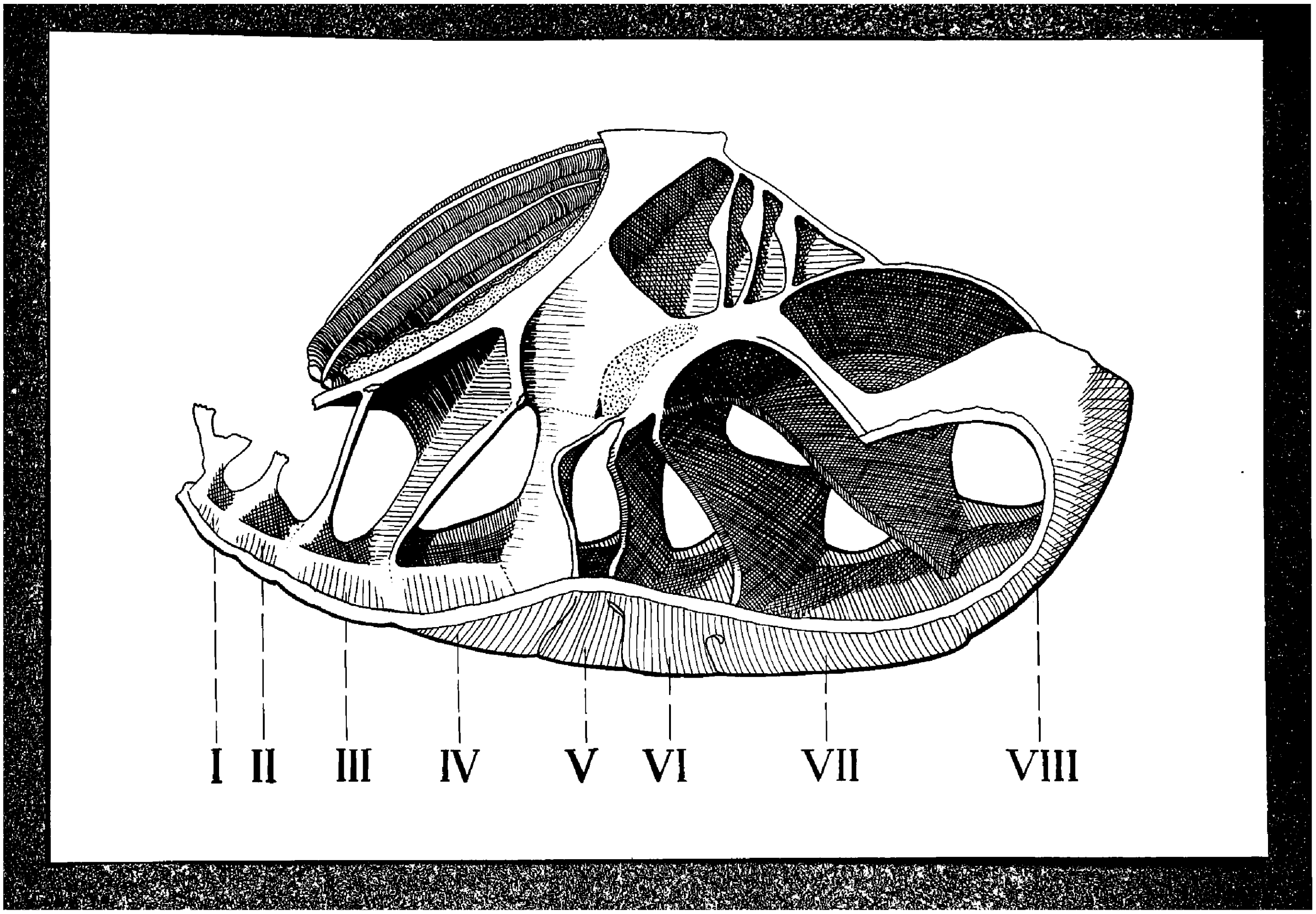

I
II
III
IV
V
VI
VII
VIII

Fig. 19. Appendages of Michtheimysis stenolepis

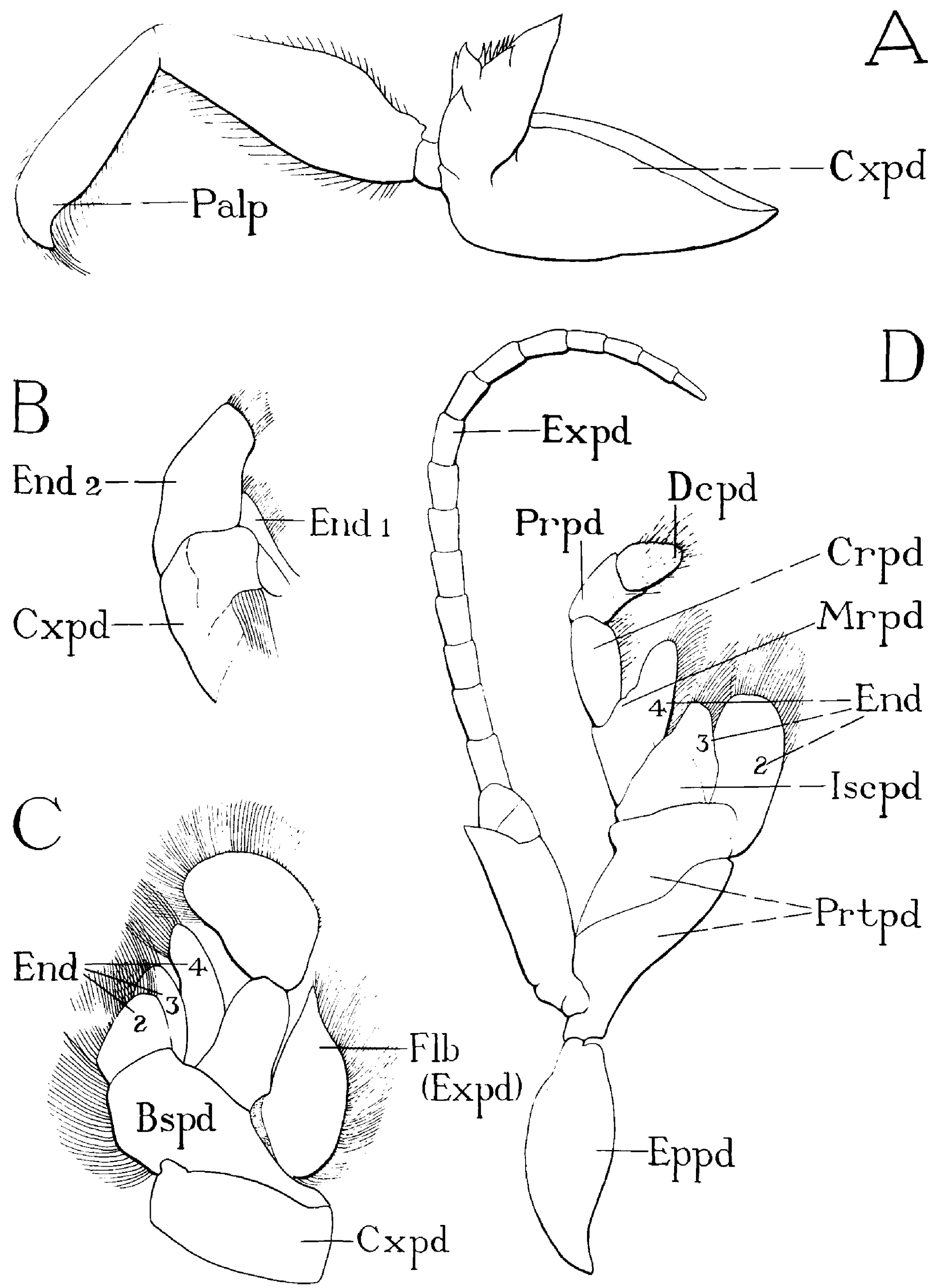
A. The mandible

B. The first maxilla

C. The second maxilla

D. The first maxilliped

Bspd, basipodite. Crpd, carpodite. Cxpd, coxopodite. Dcpd, dactylopodite. End, endite. Eppd, epipodite. Expd, exopodite. Flb, flabellum. Iscpd, ischiopodite. Mrpd, meropodite. Prpd, propodite. Prtpd, protopodite.



A
Palp
Cxpd
B
End 2
End 1
Cxpd
C
End
4
3
2
Flb
(Expd)
Bspd
Cxpd
D
Expd
Dcpd
Prpd
Crpd
Mrpd
End
4
3
2
Iscpd
Prtpd
Eppd

Fig. 20. Appendages of <u>Michtheimysis stenolepis</u>

A. The second maxilliped

B. The third maxilliped

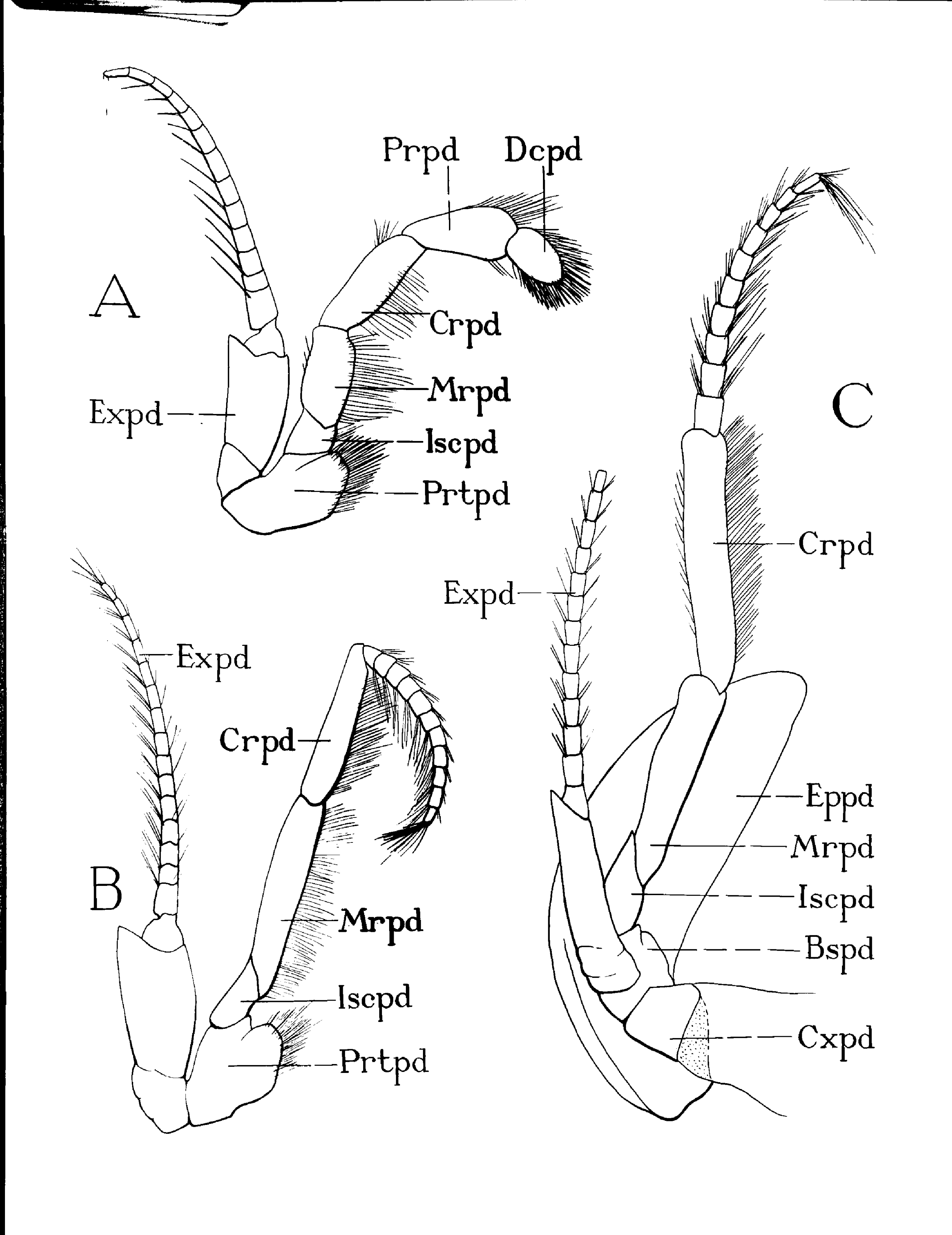
C. The fifth pereiopod

Bspd, basipodite. Crpd, carpopodite. Cxpd, coxopodite.

Dcpd, dactylopodite. Eppd, epipodite. Expd, exopodite.

Iscpd, ischiopodite. Mrpd, meropodite. Prpd, propodite.

Prtpd, protopodite.



A
Prpd
Dcpd
Crpd
Mrpd
Expd
Iscpd
Prtpd
B
Expd
Crpd
Mrpd
Iscpd
Prtpd
C
Crpd
Expd
Eppd
Mrpd
Iscpd
Bspd
Cxpd

Fig. 21 Appendages of <u>*Ligia exotica*</u>

A. The mandible

B. The first maxilla

C. The second maxilla

D. The maxilliped

E. the first pereiopod

Bnd, endite of the basipodite. Bs-Iscpd, basi-ischiopodite. Bapd, basipodite. Dcpd, dactylopodite. End, endite. Endpd, endopodite. Eppd, epipodite. Ex, exite. Mrpd, meropodite. Prpd, propodite.

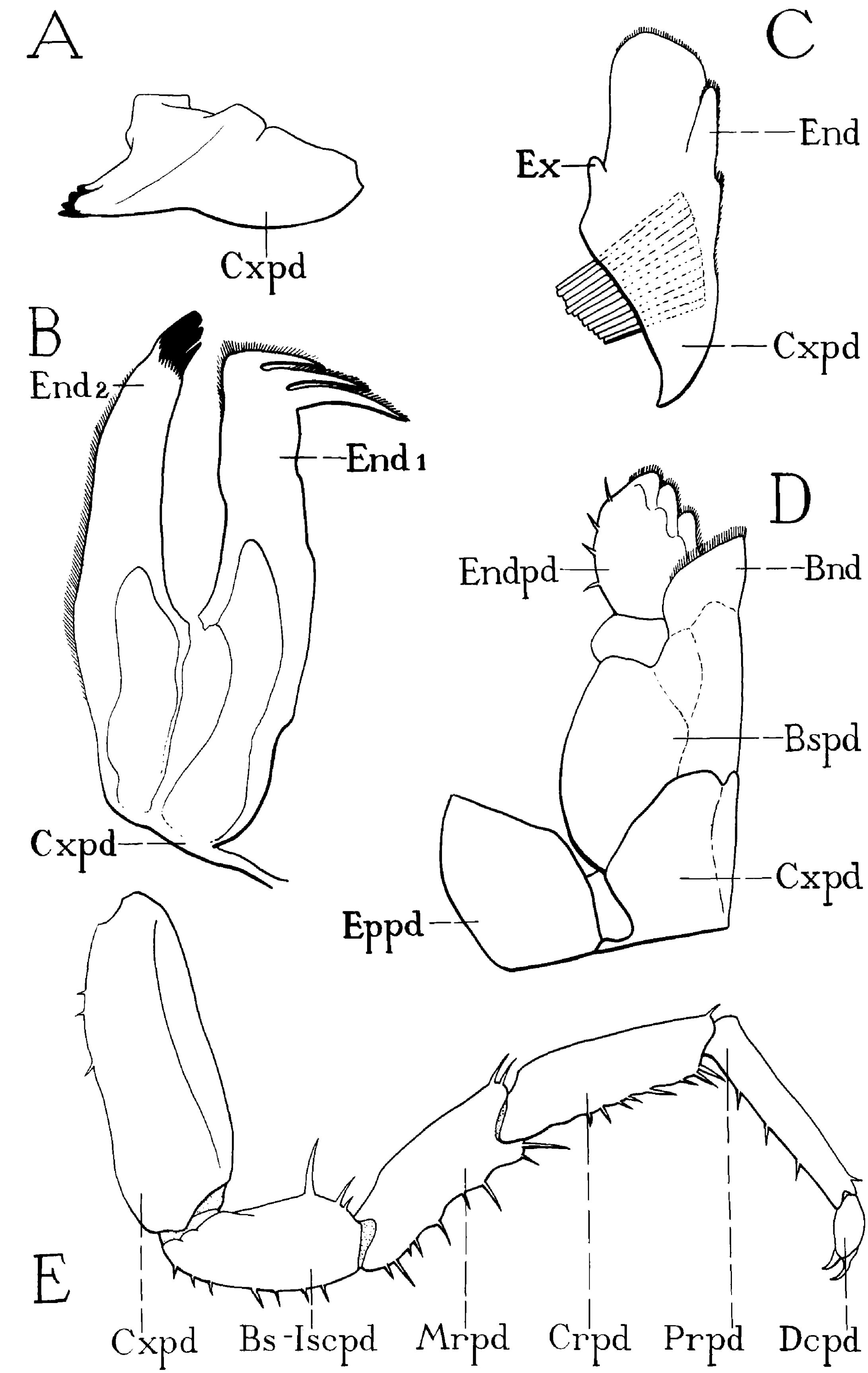

A
Cxpd
B
End2
End1
Cxpd
C
End
Ex
Cxpd
D
Endpd
Bnd
Bspd
Cxpd
Eppd
E
Cxpd
Bs-Iscpd
Mrpd
Crpd
Prpd
Dcpd

Fig. 22. Appendages of *Orchestoidea californiana*

A. The mandible

B. The first maxilla

C. The second maxilla

D. The first maxilliped

Bspd, basipodite. Cxpd, coxopodite. End, endite.

Endpd, endopodite.

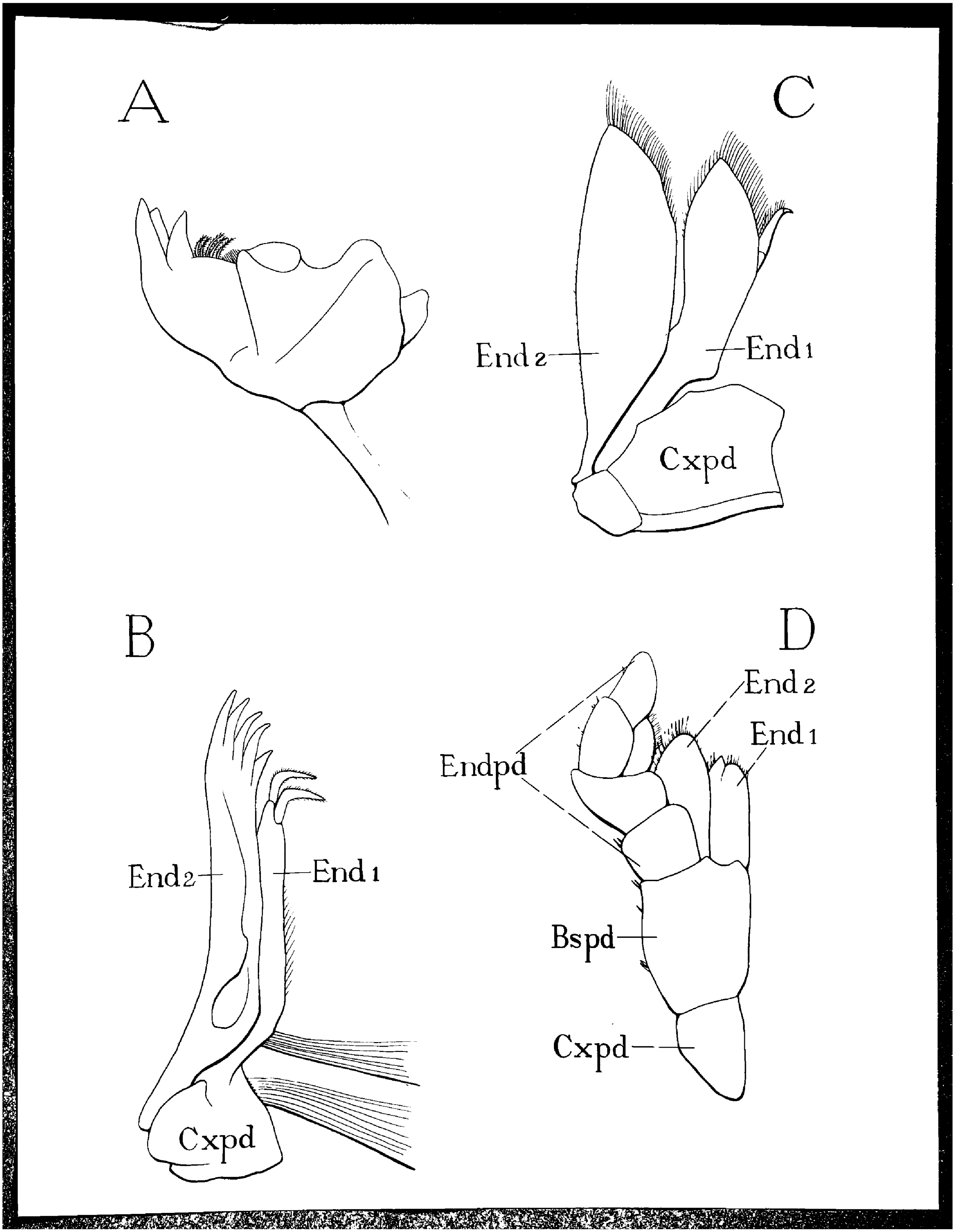

A
C
End 2
End 1
Cxpd
B
D
End 2
End 1
Cxpd
Endpd
End 2
End 1
Bspd
Cxpd

Fig. 23. Appendages of <u>Orchestoidea californiana</u>

A. The second maxilliped

B. The third maxilliped

C. The fifth pereiopod

Bspd, basipodite. Crpd, carpopodite. Cxpd, coxopodite.

Iscpd, ischiopodite. Mrpd, meropodite. Prpd, propodite.

Ptg, paratergite.

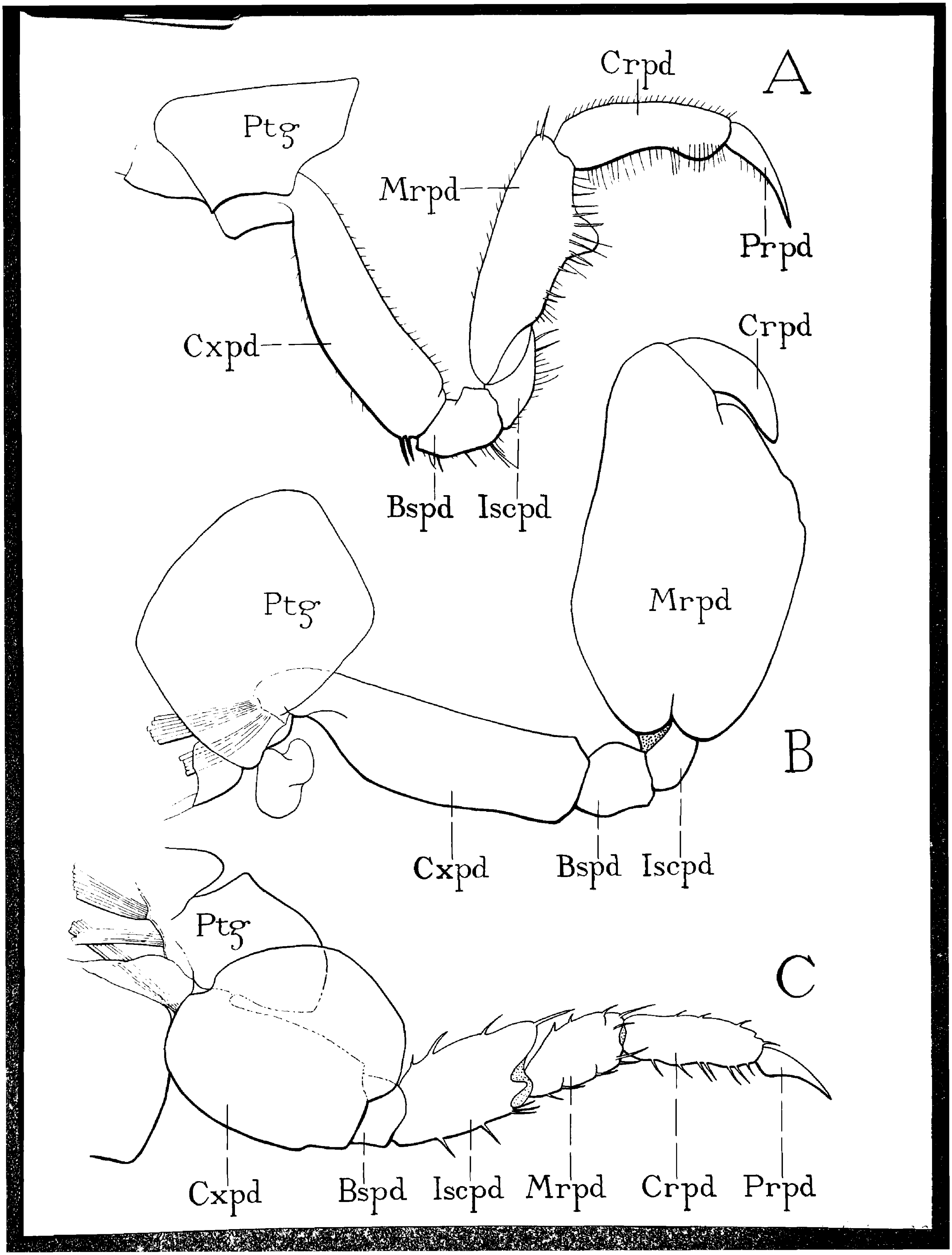

A
Crpd
Ptg
Mrpd
Prpd
Cxpd
Crpd
Bspd
Iscpd
Ptg
Mrpd
B
Cxpd
Bspd
Iscpd
Ptg
C
Cxpd
Bspd
Iscpd
Mrpd
Crpd
Prpd

Fig. 24. Appendages of <u>Penaeus setiferus</u>

A. The mandible

B. The first maxilla

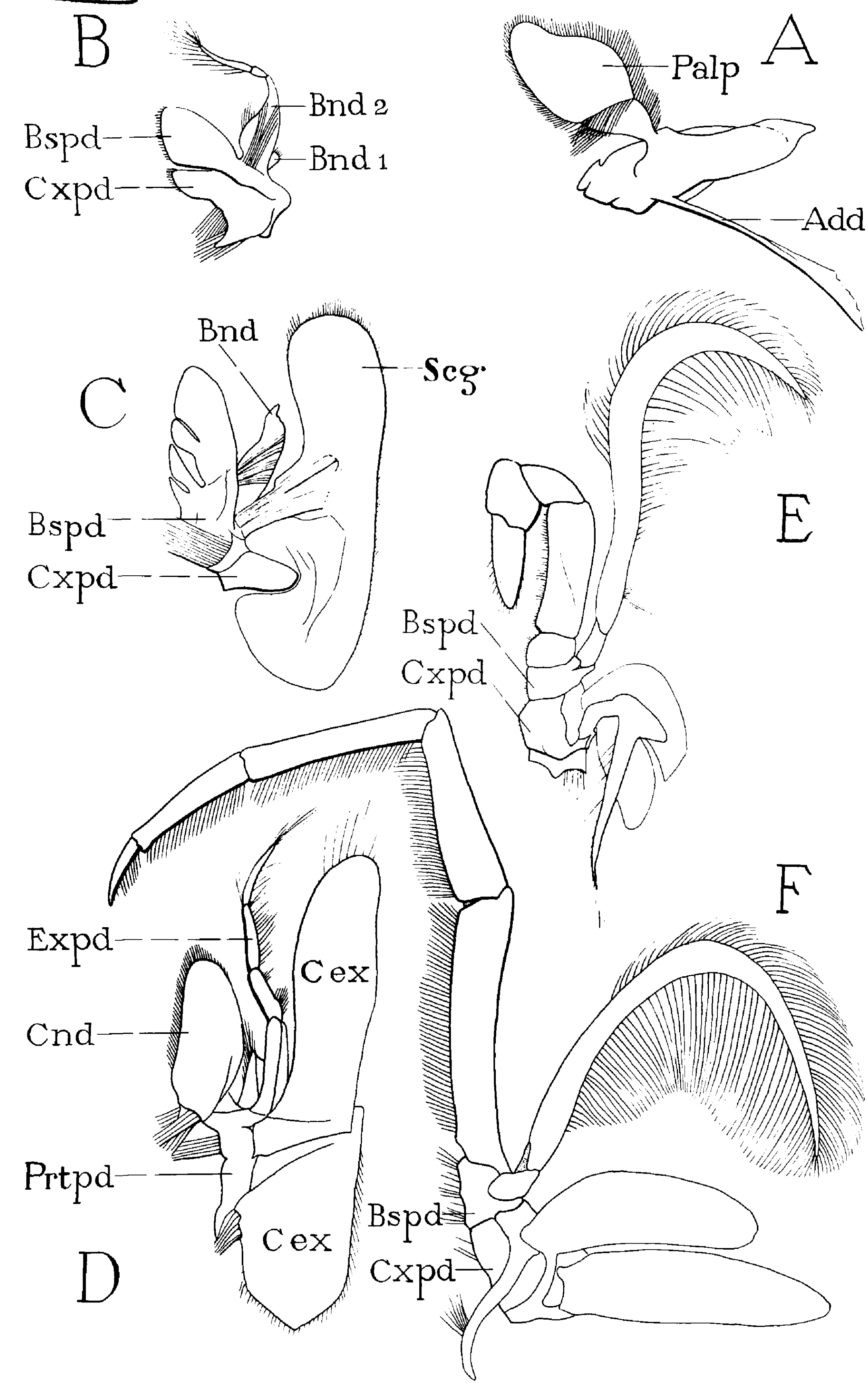
C. The second maxilla

D. The first maxilliped

E. The second maxilliped

F. The third maxilliped

Add, tendon of the adductor muscle of the mandible. Bnd, endite of the basipodite. Bspd, basipodite. Cex, exite of the coxopodite. Cxpd, coxopodite. Expd, exopodite. Prtpd, protopodite. Scg, scaphognathite.


B
Bnd 2
Bspd
Bnd 1
Cxpd
A
Palp
Add
Bnd
Scg
C
Bspd
Cxpd
E
Bspd
Cxpd
F
Expd
Cex
Cnd
Prtpd
Cex
D
Bspd
Cxpd