MEMOIRS OF THE COLLEGE OF SCIENCE, KYOTO IMPERIAL UNIVERSITY, SERIES B,
VOL. XII, NO. 1, ART. 4, 1936.

Larval Development and Metamorphosis of *Argulus japonicus*

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With 24 Text-figures

(Received July 9, 1936)

The larval forms of *Argulus* are known in *A. foliaceus*, *A. americanus*, *A. catostomi*, *A. megalops*, *A. stizostethii*, *A. funduli*, *A. maculosus*, etc. As to those of *A. japonicus* there is only a brief description by K. NAKAZAWA (1913). The young stages of *A. japonicus* resemble closely those of *A. foliaceus* found in Europe. This fact coupled with the similarity of the mature forms, shows the close relationship between these two species.

The materials for this study were collected at Kôriyama, near Nara, in April 1935. In obtaining them, I am indebted to the kindness of Prof. K. ONODA, Mr. Y. INAOKA of the Nara Women's Higher Normal School and also to the generous assistance of Messers. O. NAGAI and S. NISIKAWA of the goldfish hatcheries of the same town. Dr. K. MATUI of the Toyohasi Branch of the Imperial Fisheries Institute gave me valuable informations and suggestions. To these gentlemen I express here my hearty thanks.

The egg

(Fig. 1)

One batch consists of from thirty to more than two hundred eggs laid in several rows on a hard substratum. Each egg is elliptical in shape and about 0.4×0.25 mm. in size. The eggs are adhered firmly to one another and also to the substratum by gelatinous substance. In CLAUS' opinion the superficial portion of the egg shell is changed to this substance by penetration of the water, while GROBBEN considers the substance to be a secretion from the oviduct. The chitinous shell is usually looked upon as the vitelline membrane.

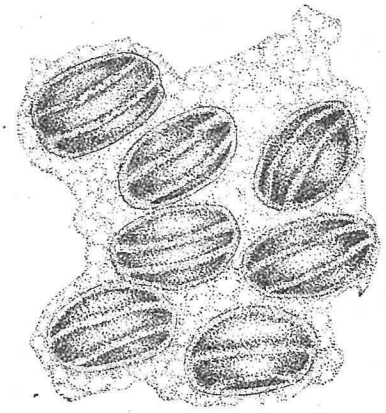


Fig. 1. Eggs. × 42

Besides, a very delicate membrane is found around the embryo in the fully-developed egg. The newly-laid egg is whitish in colour; but the colour turns soon to yellow and gradually to yellowish brown, marked usually with two dark bands of the gelatinous substance on its surface.

A pair of compound eyes appear on about the 10th day; the nauplius eye is formed on about the 15–17th day. The 6–7 day embryo lies in the shell with the dorsal side against the substratum and with the posterior part of the body bending to the ventral side. The tranluscent whitish colour of the yolk turns gradually to yellowish orange and finally to brownish violet. The length of the embryonic stage is usually 15-30 days. It varies greatly according to temperature; for instance, the data obtained in Toyohasi Branch of the Imperial Fisheries Institute show that it was only 12 days in room temperature of 30°C, while it was as long as 60 days in 15°C. The shell breaks between the two bands on the upper surface and the larva comes out of this slit.

The first larval stage

(Figs. 2—4)

0.7–0.9 mm. in length; the carapace is oval, the lateral lobes are very short; the thorax, the abdomen and all the legs are exposed (fig. 2). No groove is found on the carapace, except those limiting the cephalic area. The dorsal ribs exist; but the anterior ends are not forked; and the joint behind the nauplius eye is missing. The nauplius eye (n. e) has a gilt glimmer in the dark field and a pale blue tint in the light. The margin of the carapace in front of the level of the compound eyes is fringed with many chitinous ciliary processes and a few spinules. The compound eyes (e) are brown. The stomach has developed a pair of branches, which are still simple, and are forked only once and coloured violet brown. Many gland cells are seen (fig. 2 A), especially conspicuously at the base of the antennule and in the marginal area of the carapace. The gland cells in the latter are divided in two groups,

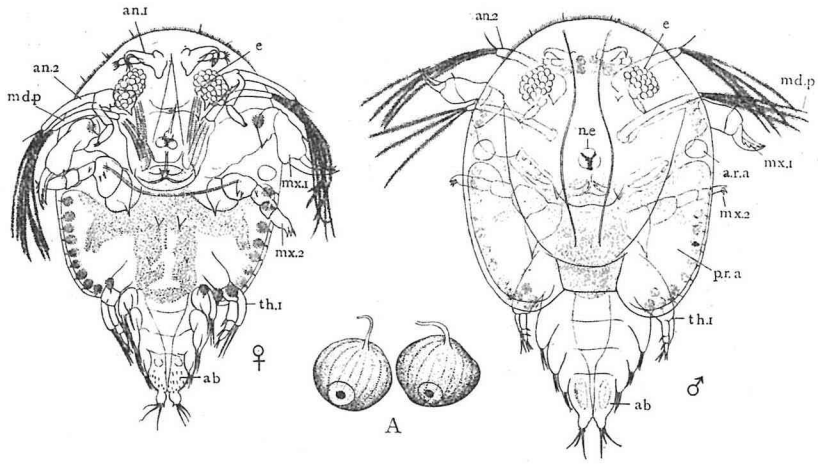


Fig. 2. Larva of the first stage. × 60.
ab. abdomen, an. 1. antennule, an. 2. antenna, a. r. a. anterior respiratory area, md. p. mandibular palp, mx. 1. maxillula, mx. 2. maxilla, n. e. nauplius eye, th. 1. 1st thoracic leg. A. gland cells × 320.

one in front of the small anterior respiratory area (a. r. a) and the other along the lateral margin of the large posterior respiratory area (p. r. a).

The antennule (fig. 2, an. 1, fig. 3 A) resembles that of the adult; but the proximal segment is lacking. The third segment has on its distal edge three setae, of which one is very small; the distal segment is about half as long as the former and has several setae at the tip. The large antenna (fig. 2, an. 2, fig. 3 B) is situated far behind the antennule. The two basal segments are equal in length, and have each a spine on the posterior side. The second segment is provided with a large antennal palp on its distal end. The third segment is very short and with a small seta at the end; the fourth has two setae at the middle of its anterior margin and a small seta on the posterior side. The fifth is slightly longer than the fourth, and has a curved spine and a few setae at the tip. The antennal palp (an. p) is not jointed, a little shorter than the three distal segments combined, and ends in five setae, four of which are long and plumose. Each antenna is jointed to a transverse chitinous bar (fig. 3 C, tr. b.) by a complicated thickening of the base. On each side of this bar, a forward process and a backward spine (post-antennal spine of the adult) are present; the middle is slightly constricted and has a small orifice. This bar probably serves as a support of the large antennae which are locomotive organs with-

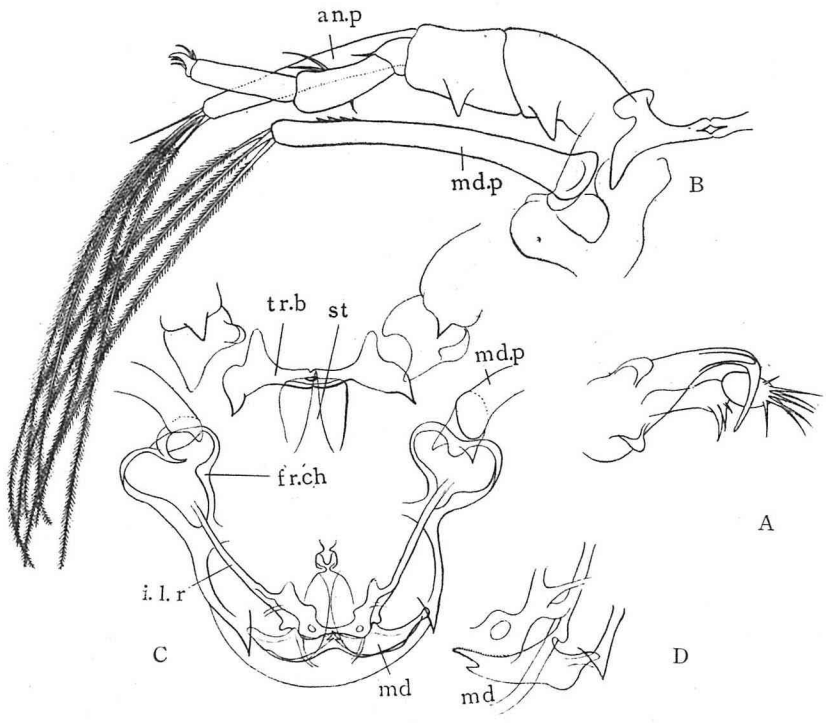


Fig. 3. Larva of the first stage.
A. antennule, × 250; B. antenna and mandibular palp, × 250; C. ventral view of the region adjacent to mandibles, × 250; D. mandible, × 500.
an. p. antennal palp, fr. ch. chitinous framework i. l. r. inner longitudinal bar, md. mandible, md. p. mandibular palp, st. sting, tr. b. transverse bar.

out doubt. CLAUS has compared this bar to the "Bauch Wirbel" of copepods.

A small sting (st) is found at the base of the proboscis. The latter is essentially the same as that of the adult (fig. 3 C); but it is very short, and with the buccal fold not yet serrated, and without any labial process. The supporting bars and rods are nearly completed except the posterior transverse bar and those supporting the buccal folds. The labial spine is missing. The pointed mandible (m. d) has an acuminate process on the lower margin near the tip. The mandibular palp (fig. 3 B, md. p) is attached to the mandible by a chitinous framework and is situated at the base of the proboscis, just behind the antenna. It is unsegmented, fairly long, though somewhat shorter than the antenna; the antero-distal margin is serrated faintly and ends in three long

plumose setae. The palp is supported at the base by a circular framework of chitin and serves probably as a swimming organ. The junction of the framework with the mandible is thickened strongly and forms a spine. This framework serves as the support of the proboscis as well; it develops to the simple outer longitudinal support in the next stage, while the inner longitudinal rod (i. l. r) is differentiated already. Thus the inner and outer longitudinal rods as well as other chitinous thickenings found on the proboscis are apparently modified parts of the exoskeleton of the mandible proper.

A pair of the maxillulae (fig. 2, mx 1, fig. 4 A) are found on either side of the proboscis. It consists of three segments, a bulky basal segment, a small middle segment provided with a spine at its postero-proximal edge and a terminal segment. CLAUS considers the terminal segment to consist of two segments fused into one; a faint striation is found at a short distance from the distal margin. The segment has a seta on the anterior margin in this striated part; the tip is provided with two large curved claws, of which one has three small processes on its anterior margin. Evidently, this is the only clasping organ occurring in this stage.

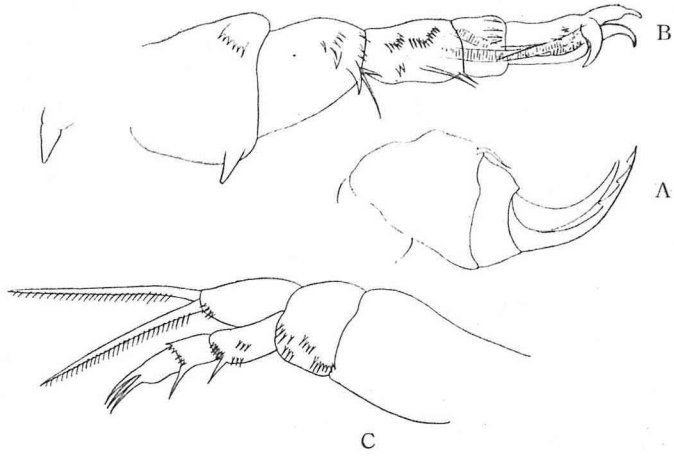


Fig. 4. Larva of the 1st stage. A Terminal segment of maxillula, B Maxilla, C First leg. × 210.

The maxilla (fig. 2, mx 2, fig. 4 B) is five-jointed as in the adult, and armed with a few incomplete scales and setae. The basal segment has at its postero-distal corner a spine which corresponds with the middle spine of the three spines found in the adult; the second and third segments are equal in length, the fourth is about

half as long as the former, and the last is twice as long as the fourth and provided with two curved claws and one papilla. Two pairs of post-maxillary spines are present behind the maxillae, of which the anterior spines are somewhat larger than the posterior.

The many backward spinules which are found on the ventral surface of the adult are entirely missing. In living larvae, horse-shoe-shaped maxillary glands are visible between the maxillae and maxillulae.

Of the thoracic appendages, only the first pair (fig. 2, th. 1, fig. 4 C) are functional, while the others are still rudimentary and immobile; each of the latter has unsegmented exo- and endopodites, of which the former ends in two setae and the latter in one seta. In the first leg, the coxa, basis, exopodite, and three-jointed endopodite are completed, but the precoxa is indistinguishable. In the endopodite the two basal segments are provided with a seta at the postero-distal corner, and the terminal segment ends in three setae; the middle and terminal segments are equal in length. The exopodite is as long as the basal segment of the endopodite and is provided with two long plumose setae at the tip. Both the endo- and exopodites and the basis are covered sparsely with scales and setae.

The abdomen (fig. 2, ab) is very small and only 1/10 as long as the body. The abdominal (posterior) lobes have spinules along the margin and on the postero-ventral side, and are not projected posteriorly. The caudal furcae are comparatively large, with three setae and a few minute spinules. The sexes can be distinguished by the presence either of rather large rudimentary testes in the anterior part of the abdomen or of smaller round young seminal receptacles at the base of the same.

The second larval stage

(Figs. 5—7)

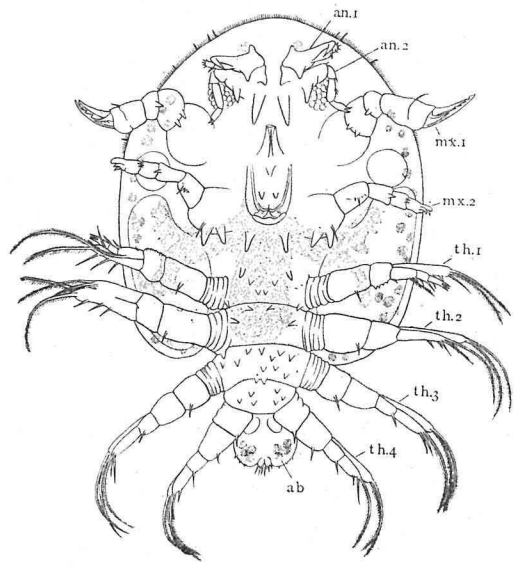
In 3–4 days after hatching, the first moulting is performed, and the larva approaches to the shape of the adult by losing the peculiar larval appearance. It is 0.9–1 mm. in length; the skin fold and the anterior marginal groove on the carapace are now distinguishable, but the joint of the dorsal ribs is scarcely seen (fig. 5). The margin of the carapace is fringed with ciliary processes, and reaches the level of the maxillulae.

In the antennule (fig. 5 A, an. 1 fig. 6 A) the proximal segment is defined faintly; it is provided with a backward spine, the third segment

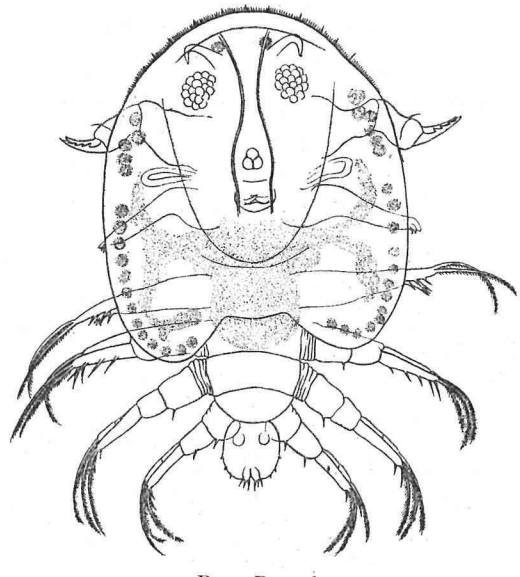
has a small process and two setae at the end.

The antenna (an. 2) is situated close behind the antennule; the palp as well as the spine on the posterior margin of the second segment is gone, while a seta is found at the antero-distal corner; the third segment is still small, the fourth is provided with two setae as in the first stage; the terminal segment is the longest, and ends in several strong setae.

The transverse chitinous bar has disappeared, leaving only a pair of large post-antennal spines. The mandibular palp is also missing, and the chitinous framework which has connected the palp to the mandible is changed to a simple outer longitudinal support; the junction of this rod to the mandible is still thickened into a spine; this spine becomes gradually smaller in the following stages and disappears entirely at last. A chitinous thickening occurs on each side of the anterior transverse bar along the buccal fold which foreshows the serrated margin of the adult. The labial processes are clearly seen, though very small,



A ♀ Ventral



B ♀ Dorsal

Fig. 5. Larva of the 2nd stage. × 50.

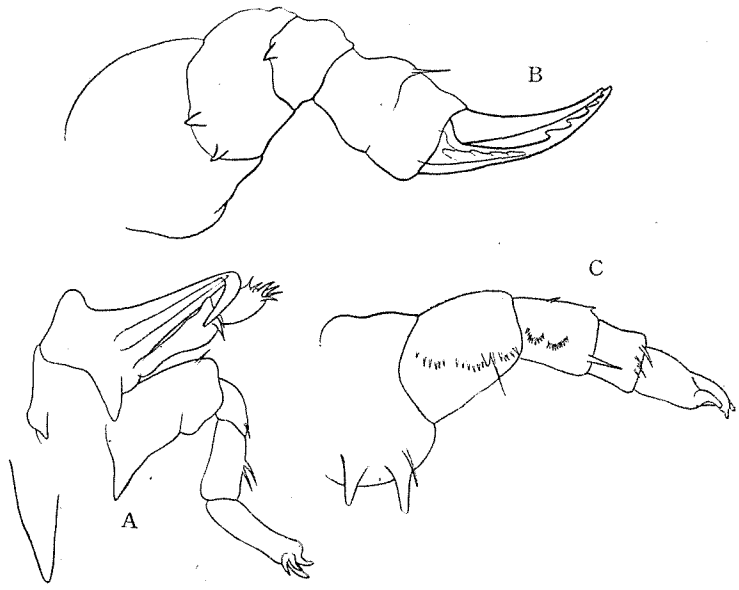


Fig. 6. Larva of the 2nd stage. A. Antennule and antenna, B. Maxillula, C. Maxilla. × 210.

but the labial spines are absent. A pair of spines are found in front of the mouth aperture.

The maxillula (fig. 6 B) is four-jointed; the basal joint of the first stage has been divided into two segments, of which the distal one is provided with two spines on the ventro-proximal margin. The basal segment of the maxilla (fig. 6 C) has acquired one spine (the inner spine of the adult) on the posterior margin and a seta at the base of the outer spine. The second segment is fairly longer than the more distal segments.

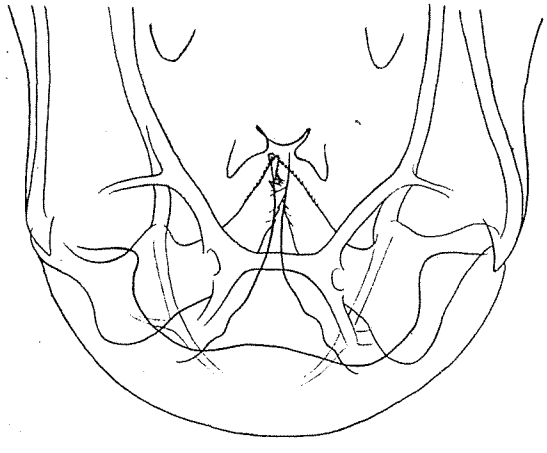


Fig. 7. Larva of the 2nd stage. Tip of proboscis, ventral. × 580.

The ramifications of the stomach have become slightly more complex. The thoracic segments are armed with some spinules on the ventral side.

Four pairs of swimming legs (th. 1–4) show-

ing the same segmentation as in the adult, occur, and serve as locomotive organs, by taking the place of the antennal and mandibular palps in the first stage. Each leg has several setae, plumose or simple; their average numbers are as follows:

	First pair					
	Coxa	Basis	Endopodite			Exopodite
			1st Seg.	2nd Seg.	3rd Seg.	
Plumose			0-1			2
Simple	1		2-1	1	3	4

	Second pair			
	Coxa	Basis	Endopodite	Exopodite
Plumose			1-2	2
Simple	1		2-1	3-4

	Third pair				
	Coxa	Basis	Endopodite		Exopodite
			1st Seg.	2nd Seg.	
Plumose				1	2
Simple	1		1	2	0-4

	Fourth pair				
	Coxa	Basis	Endopodite		Exopodite
			1st Seg.	2nd Seg.	
Plumose				1	2
Simple	1	1	1	2	0-3

The abdomen is still small, about 1/6-1/7 as long as the body. The abdominal lobes are projected slightly backwards, and are fringed with spinules on the margin and contain some gland cells.

The third larval stage

(Figs. 8—9)

The 5-7 day old larva enters the third stage by the second moulting. The differences between the second, the third, and the fourth stages are found mainly in the pattern of the maxillula and in the number of spines on the basal segment of the maxilla, besides smaller differences in size, in the number of setae and spinules, in the pattern of the branches of the stomach and so on.

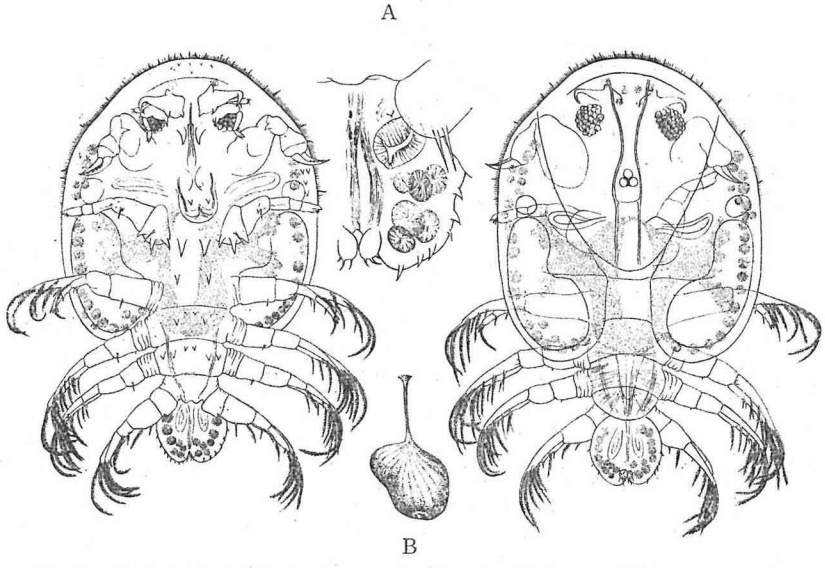


Fig. 8. Larva of the 3rd stage. ♂ × 40, A. Abdomen of female, ventral. × 160; B. Gland cell from the margin of carapace. × 320.

The body is 1–1.2 mm. in length. The joint of the dorsal ribs is shown clearly; the posterior transverse bar of the proboscis can be distinguished; the buccal fold has a process on its free margin.

The maxillula (fig. 9, B) which has developed best in the second stage as a clasping organ, now enters the course of degeneration. The boundary between the basal and second segments becomes somewhat indistinct; the two spines found in the second segment have vanished and the round framework of the sucker is faintly seen on the basal segment.

In the maxilla (fig. 9, C), a small spine is added to the basal segment at the postero-distal corner, this corresponds with the outer spine of the adult. Moreover, some minute spinules appear on this segment.

A few backward spinules emerge for the first time on the ventral surface in the part in front of the anterior marginal groove and along the margin of the carapace adjacent to the anterior respiratory area. Rudiments of flagella (fig. 9 D) are formed at the postero-dorsal corner at the base of the exopodite of the two anterior pairs of legs. The setae on the swimming legs are as follows:

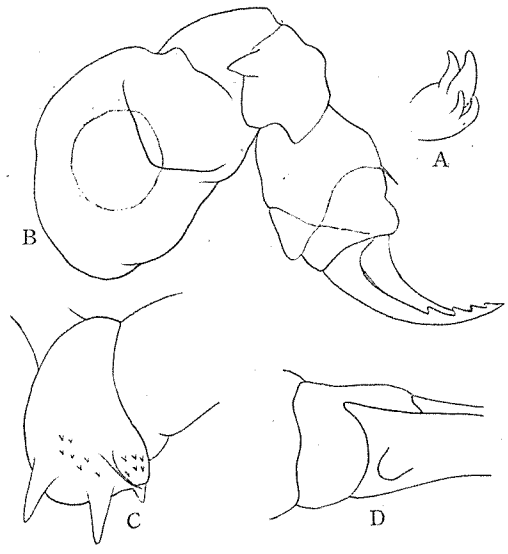


Fig. 9. Larva of the 3rd stage.
A. Tip of antenna. × 260, B. Maxillula, C. Basal segment of maxilla, D. 2nd leg, dorsal. B-D. ×210.

	First pair					
	Coxa	Basis	Endopodite			Exopodite
			1st Seg.	2nd Seg.	3rd Seg.	
Plumose			1			5-6
Simple	1		2	1	3	1

	Second pair			
	Coxa	Basis	Endopodite	Exopodite
Plumose			3	6
Simple	1		2-3	1-2

	Third pair				
	Coxa	Basis	Endopodite		Exopodite
			1st Seg.	2nd Seg.	
Plumose			1	2	5
Simple	1			1	1-2

	Fourth pair				
	Coxa	Basis	Endopodite		Exopodite
			1st Seg.	2nd Seg.	
Plumose		1	1	3	3-5
Simple	2	1	1	1	1-0

The ratio of the length of the abdomen to the body length is about 1 : 6. In the female, a minute chitinous spine appeares at the point of the extremity of the duct from the seminal receptacle (fig. 8. A).

The fourth larval stage

(Figs. 10—11)

The 7-8 day old larva enters the fourth stage by the third moulting. It is 1.2-1.4 mm. long, and has the lateral lobes still short, covering barely the second legs (fig. 10). The inward branches of the lateral groove limiting the cephalic area are faintly seen; the anterior end of the dorsal rib shows the rudimentary outer branch; the ciliary ornament of the margin of the carapace reaches the level of the maxilla. The two pairs of antennae (fig. 11 A, B)

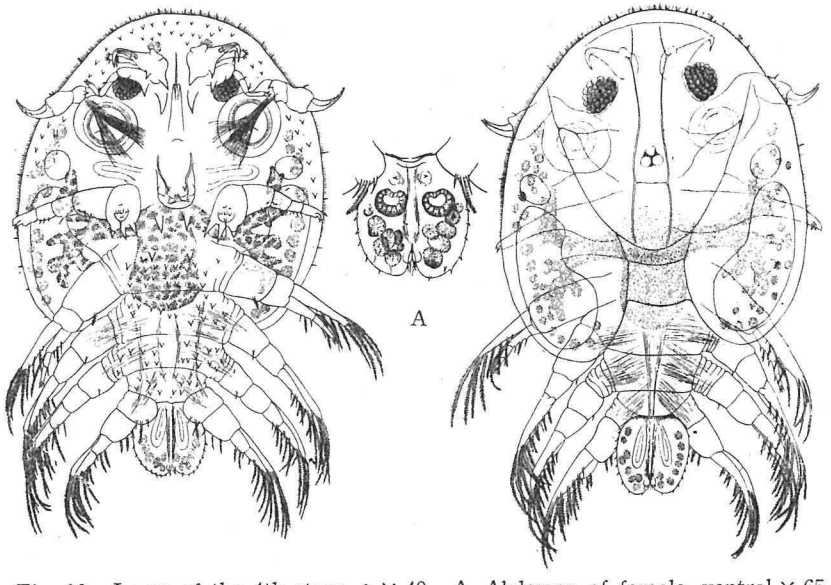


Fig. 10. Larva of the 4th stage. ♂ × 40, A. Abdomen of female, ventral × 65.

are the same as in the preceding stage; the buccal fold of the proboscis has two teeth on the free margin; the basal segment of the maxillula (fig. 11 C) is expanded considerably by the formation of the sucker within. The circular margin of the sucker is fringed with minute triangular processes; and the muscles attached to the sucker are seen through the chitinous exoskeleton. The backward spinules on the ventral surface of the carapace have increased.

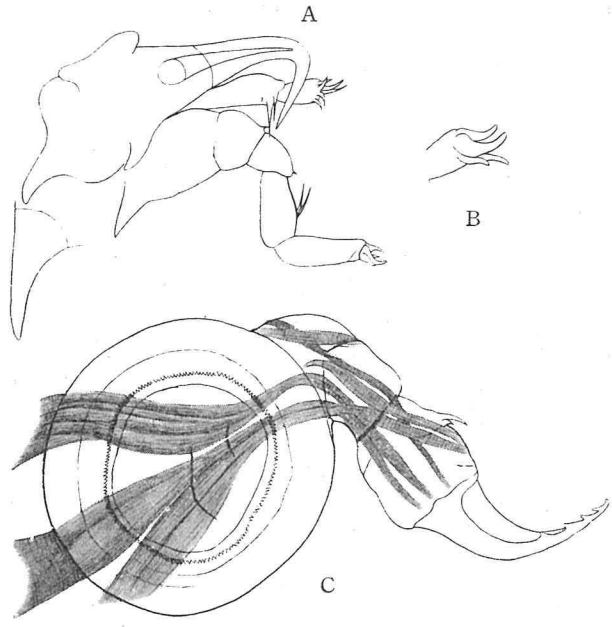


Fig. 11. Larva of the 4th stage. A. Antennule and antenna. × 210, B. Tip of antenna. × 300, C. Maxillula × 210.

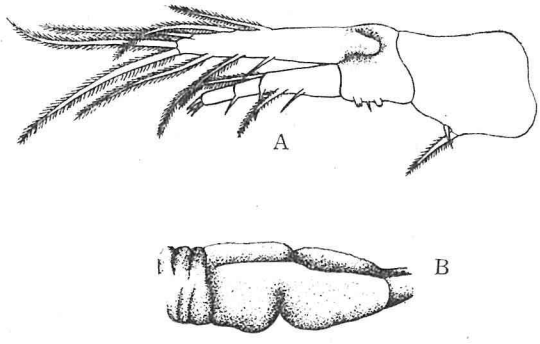


Fig. 12. Larva of 4th stage. A. 1st leg, dorsal, B. 3rd leg of male, dorsal. × 130.

The buds of the flagella (fig. 12 A) are still very small and without any setae. In the male the posterior side of the joint between the coxa and the basis of the third leg is deeply cut in, and foreshadows the semen capsule of the adult (fig. 12 B). The numbers of the setae of legs are as follows:

	First pair					
	Coxa	Basis	Endopodite			Exopodite
			1st Seg.	2nd Seg.	3rd Seg.	
Plumose	1		2			5-7
Simple	0-1		1-2	1	3	1

	Second pair			
	Coxa	Basis	Endopodite	Exopodite
Plumose			4-5	7-8
Simple	1		2-1	1-0

	Third pair				
	Coxa	Basis	Endopodite		Exopodite
			1st Seg.	2nd Seg.	
Plumose			1	3-4	6-7
Simple	1		1-2	1	1

	Fourth pair				
	Coxa	Basis	Endopodite		Exopodite
			1st Seg.	2nd Seg.	
Plumose	1	2	2	3-4	7
Simple	2	1	1	1-0	1

The abdomen is about 1/6 as long as the body. The abdomen is slightly smaller in the female than in the male (fig. 10 A).

The fifth larval stage

(Figs. 13—16)

The fourth moulting is performed in 3-4 days after the third ecdysis. The larva of this stage is about 1.3-1.7 mm. in length. The lateral lobes cover the first pair of legs and the basal portion of the second pair (fig. 13). The trapezoidal areas on the carapace appear indistinctly, the outer branches of the dorsal ribs at the

anterior ends are still short (fig. 14); the ciliated margin of the carapace reaches almost the level of the first thoracic segment. The basal two segments of the antenna (fig. 15 A) have several setae at each distal end; the third segment is small; the fourth is twice as long as the third; the two setae on this segment found in the preceding stages are moved to the distal end; the last segment is as long as the fourth and ends in a few rather thick setae.

The labial spines are found distinctly on the anterior floor of the buccal cavity. The maxillula has undergone important changes, namely, the basal segment has been broken and the sucker exposed, but the remaining segments are still preserved (fig. 15 B); the third segment has a spine on its proximal margin as before; the terminal segment has a seta at the middle of its anterior margin and two claws at the tip, of which one is still stout, while the other is slender, curved slightly, and without any teeth on its anterior margin.

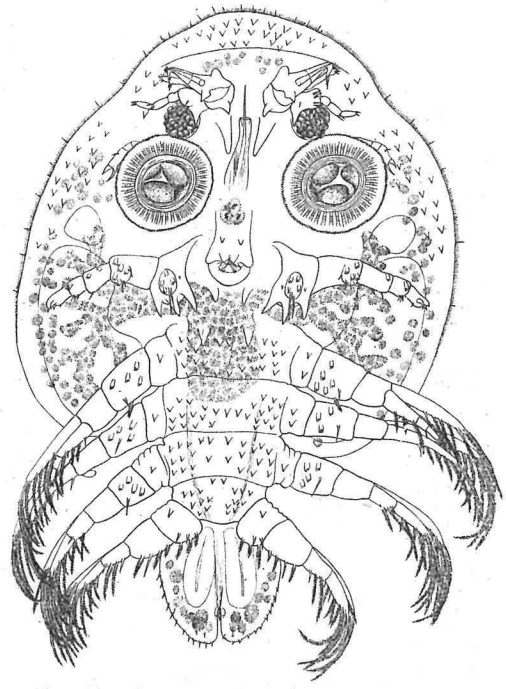


Fig. 13. Larva of the 5th stage. ♂ × 40.

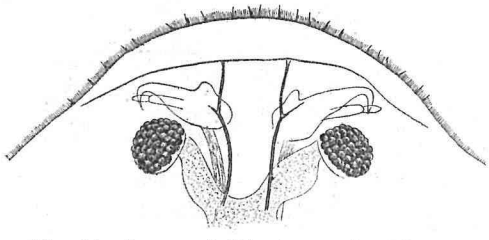


Fig. 14. Larva of 5th stage. Anterior portion of carapace, dorsal. × 53.

The sucker is exactly the same as that of the adult, except the number of the segments of the chitinous ribs supporting the flexible marginal portion being smaller. Each rib consists of one longer and two shorter segments, of which the distal one is only faintly defined. The basal segment of the maxilla has two long

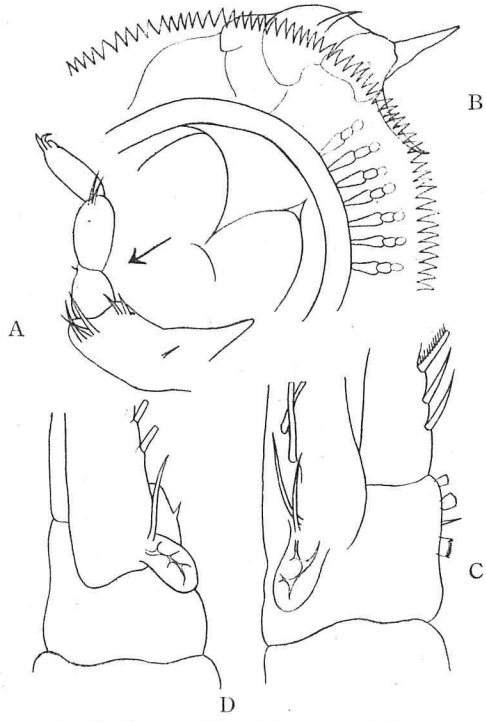


Fig. 15. Larva of the 5th stage. A. Antenna, The arrow points anteriorly. B. Maxillula, C. 1st leg, dorsal, D. 2nd leg, dorsal. × 210.

between the coxa and the basis (fig. 16 C) ; the segments forming the two lateral folds of the capsule and the projection on the ventral side forming the median fold. The precoxa and coxa of each leg has small spinules or scales on the ventral side. The legs are armed with setae in the following manner :

setae at the middle of the posterior margin of the scaled area besides many scales on its surface.

The branches of the stomach are fairly complex. The rudimentary flagellum (fig. 15 C, D) of the first leg has two setae, while that of the second leg has a seta. The ventro-posterior edge of the coxa of the second leg of the male foreshows two backward protuberances found in the adult (fig. 16 A, B). The third leg of the male has an incomplete semen capsule on the postero-dorsal side

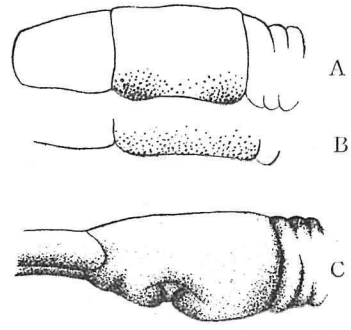


Fig. 16. Larva of the 5th stage. A. 2nd leg of male, ventral, B. The same of female for comparison, C. 3rd leg of male, dorsal. × 130.

	First pair					
	Coxa	Basis	Endopodite			Exopodite
			1st Seg.	2nd Seg.	3rd Seg.	
Plumose	1		4-3			6-9
Simple	1		1-2	1	3	3-1

	Second pair			
	Coxa	Basis	Endopodite	Exopodite
Plumose			6-7	7-9
Simple	1		1	3-2

	Third pair				
	Coxa	Basis	Endopodite		Exopodite
			1st Seg.	2nd Seg.	
Plumose			2	6	8-6
Simple	1		1		0-2

	Fourth pair				
	Coxa	Basis	Endopodite		Exopodite
			1st Seg.	2nd Seg.	
Plumose	3	3	2	5	8
Simple	2	1	2	1	1

The abdominal lobes have grown rather considerably; the anal sinus reaches 1/4–1/3 of the length of the abdomen. The ratio of the length of the abdomen to the body length in the male is about 1 : 5.3.

The sixth larval stage

(Fig. 17)

The differences between the fifth, the sixth, and the seventh stages are found in respect to the residual portion of the maxillula and in the degree of development of the accessory part of the male sexual organ. The length of the animal is so variable that the decision of the stage in the female is

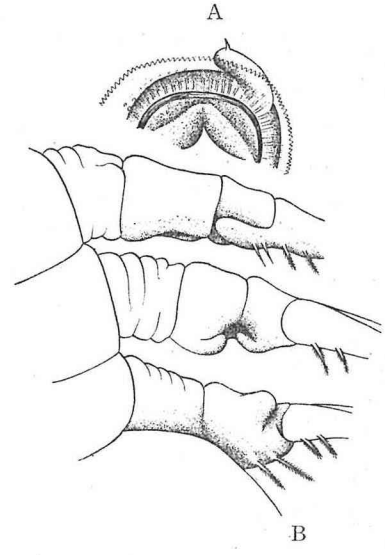


Fig. 17. Larva of the 6th stage. A. Maxillula, B. Three posterior legs of male, dorsal. × 100.

somewhat difficult. This is especially so in the distinction of the sixth and seventh stages.

The length of the animals is about 1.6–2.0 mm. The residual of the maxillula shows no segmentation and has a spine at the tip (fig. 17 A). The spines on the proboscis situated in front of the mouth aperture in the foregoing stages have disappeared. As to the accessory sexual structures (fig. 17 B), the second and the third legs are the same as in the preceding stage, while the antero-distal corner of the basis of the last leg is protruded into a round process —the rudiment of the peg in the adult. The abdominal processes are faintly defined at the base of the abdomen in the female.

The seventh stage

(Figs. 18—22)

About 2–2.2 mm. in length. The carapace covers the third legs barely, the anterior ends of the dorsal ribs are now clearly forked; the residual of the maxillula is only a small process provided with a minute spinule (figs. 18, 19 A). To each of the supporting ribs on the margin of the sucker is added a short segment (fig. 19 B). The flagella are elongated and reach beyond the proximal margin of the basis and are provided with several plumose setae (fig. 20 A). In the male the backward protuberances of the coxae of the second legs are fairly conspicuous and the semen capsule of the third pair is almost completed; but the small papillated processes in front of the aperture are not yet found; the peg of the last leg is almost the same as that of the adult: it is provided with a thumb-like process at the base of the

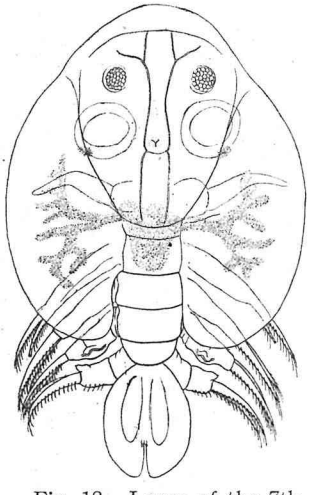
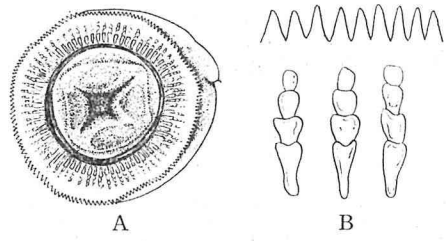


Fig. 18. Larva of the 7th stage. ♂ × 30.



A B

Fig. 19. Larva of the 7th stage. A. Maxillula (sucker), × 85, B. A part of flexible marginal portion of sucker. ×420.

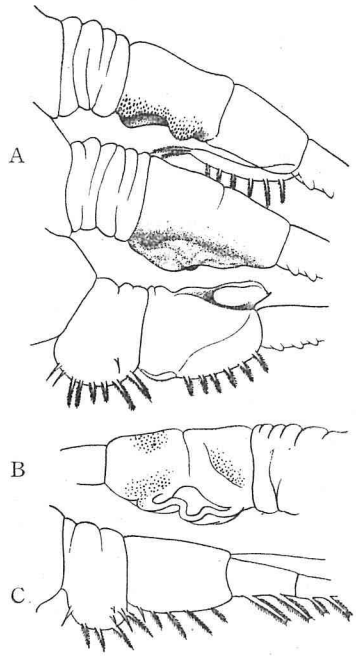


Fig. 20. Larva of the 7th stage. A. Three posterior legs of male, ventral, B. 3rd leg of male, dorsal, C. Last leg of female, ventral. × 85.

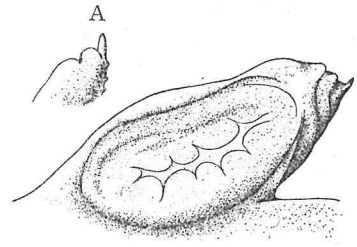


Fig. 21. Larva of the 7th stage. Peg of male. ×420, ventral. A. Tip of the same, dorsal.

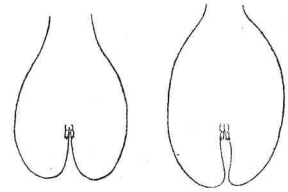


Fig. 22. Larva of the 7th stage. A. Abdomen of ♀, B. of ♂. × 40.

ventral side and the tip ends in a terminal process and a small spinule (fig. 21). The chitinous framework supporting the peg continues to the postero-proximal edge of the basis across the dorsal side of the segment, where the chitin is thickened conspicuously. In the female the posterior portion of the coxa of the last leg is protruded posteriorly—this is the basal lobe of the adult (fig. 20 C).

The shape of the abdomen (fig. 22) differs slightly in the sexes: the abdominal lobes of the male have bluntly pointed tips, while those of the female end in round tips. It is to be noted that the abdominal lobe in the female resembles closely that of *A. foliaceus* which is found commonly in Europe. Generally the abdomen is larger in the male than in the female. The ratio of the length of the abdomen to the body length is about 1 : 4.2 in the male. The sixth and seventh stages are attained in about 10–18 days after hatching.

The subsequent development

(Figs. 23, 24)

The lateral lobes of the carapace grow somewhat. All the grooves on the dorsal surface become distinct, while the longitudinal groove appears in a later stage. The ramification of the stomach becomes complicated with the succeeding stages. The pigment spots deposited on the oviduct appear on the dorsal side of the thorax on about the 20th day after hatching (fig. 23). These pigment spots (fig. 24) are stellate in shape, and as large as those on the branches of the stomach, but they have somewhat longer processes than in the latter. The pigment spots are symmetrically arranged on each side.

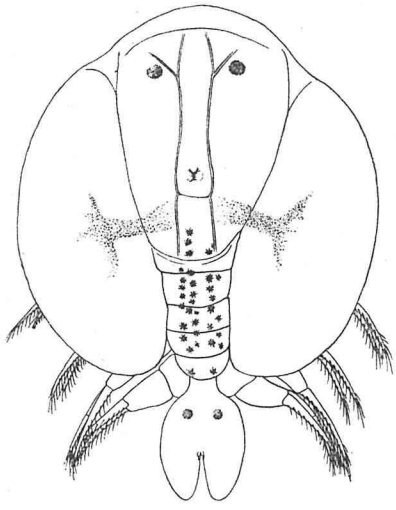


Fig. 23. ♀ of 22–23 day old. × 20.

The sucker loses the residual of the maxillula after the 7th moulting, except a tiny seta remaining for a long time (frequently even 18–19 day old larvae retain this seta). The spine at the antero-proximal edge of the coxa of the second leg, the papillated process on the anterior margin of the precoxa of the third leg, and small processes in front of the aperture of the semen capsule of the male are formed in the later stage.

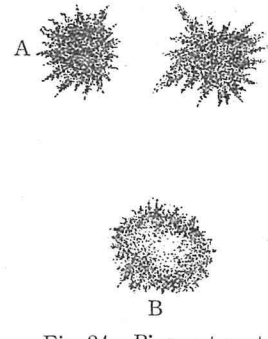


Fig. 24. Pigment spots from ♀ of 22–23 day old. A. from oviduct, B from branches of stomach. × 130.

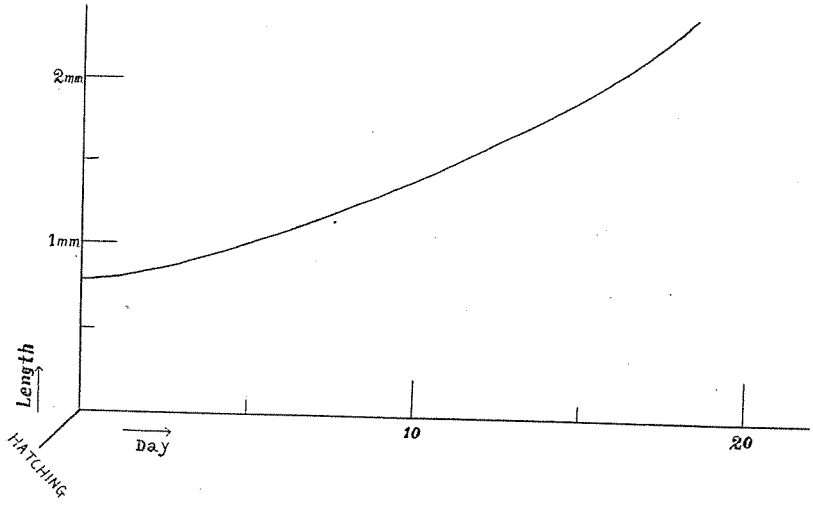
The abdominal lobes also grow somewhat.

After this stage the animals become sexually mature and begin to copulate in about a month after hatching. I have observed 22 day old animals copulate; but it is somewhat doubtful whether both of them have become mature or not.

Some additional notes

Newly hatched larvae and the larvae in early stages are strongly photopositive. In swimming they use antennal and mandibular palps and perform jerking movements as in copepods. When they come across a host, they immediately cling to it.

The earlier stages go on very regularly, but the later stages after the fourth stage become irregular. The larvae may live 3–5 days without being attached to the host. They may perform moulting meanwhile; but such ill-fed animals are smaller than the normal and their growth is very slow. In the natural environment, it is very probable that such differences in the nutritive condition make the duration of each stage and also the size of the animal very variable. For this reason the duration of each stage and the size of the animal at a certain stage can hardly be stated definitely; but roughly speaking, the growth goes on as shown in the graph.



The animals after the seventh stage have no well-defined characteristic. The change brought about by moulting is merely in grade. The animals just after the moulting has a very delicate exoskeleton especially in earlier stages. The animals in such a state are not suited for description, for the setae and spines appear very indistinct.

The moulting has been observed in *A. japonicus* as well as in *A. caecus*. The ventral surface of the skeleton ruptures along the mid-line from the anterior marginal groove to the anterior thoracic

segments and the animal draws out the thorax and abdomen first through this slit. Next comes out the anterior portion of the carapace, and lastly the lateral lobes. The exuviae have the sheaths of all appendages except those of suckers. The coat of each sucker comes off one after the other after the moulting of the other portions is all through.

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