ON POST-EMBRYONIC STAGES OF PHYLLOPOD CRUSTACEANS, TRIOPS (APUS), STREPTOCEPHALUS AND ESTHERIA

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CONTENTS

INTRODUCTION ........................................ 229
MATERIAL AND METHODS ................................ 230
OBSERVATIONS:
  (a) Triops ........................................... 231
  (b) Streptocephalus ................................. 236
  (c) Estheria .......................................... 240
DISCUSSION ........................................... 243
ACKNOWLEDGEMENTS .................................. 248
SUMMARY .............................................. 248
REFERENCES .......................................... 249
ABBREVIATIONS USED IN TEXT-FIGURES ............ 250

INTRODUCTION

CRUSTACEA, whose post-embryonic stages are described in this paper, viz., TRIOPS (APUS) orientalis, STREPTOCEPHALUS dichotomus Baird and ESTHERIA are found in pools and shallow reservoirs on the table-lands of the Deccan Plateau and round about Poona. Most of these pools and ponds dry for some months during summer but the eggs of these remain in the soil. They hatch after the first showers of rain in early June. Larvae in various stages of development can be collected during June. Adults are available up to the end of January.

The eggs of these animals are spherical and are provided with a hard coat which appears to be resistant to variations in external conditions. The
temperature of soil in Poona in summer varies from 94° F. to 124° F. (between 12 noon and 4 p.m.).

The occurrence of these phyllopods in Panchgani was noticed by several field workers. Cannon (1924) obtained a sample of dry soil containing eggs of *Estheria*, collected in the neighbourhood of Baghdad by Captain T. Buist, R.A.M.C. On placing the soil in water Cannon found that nauplii hatched out within about 24 hours and he observed that they fed on the green scum on the sides of the aquarium, on micro-organisms. He got adult *Estheria* in three weeks.

Gurney (1925) obtained specimens from Baghdad and identified the Estherid specimens as belonging to two genera. He examined about 20 specimens, two of which belonged to the genus *Leptestheria* and others to *Estheria* (=*Cyzicus* or *Eocyzicus*). He also observed that the two genera differed in rather minute details.

Gurney (1925) obtained specimens of *Apus*, some of which were from Panchgani. The Panchgani specimens were identified by him as *Apus asiaticus*. Specimens from Bulandhar in Kashmir were identified as *Apus cancriformis*. Both the Asiatic species showed many differences from the European species, *A. cancriformis*. Tiwari (1952) identified the Panchgani specimens as *Triops orientalis*, but Longhurst (1955) considered them and those collected from Rajasthan, *Apus maviensis* as *Triops granarius*.

As early as 1885, Claus worked on the morphology, development and secondary sexual characteristics of *Branchipus* and *Artemia*. Botnariuc (1947, 1948) described the development of some phyllopods (Conchostraca): *Cyzicus tetracerus* Kryn., *Eoleptestheria variabilis* Botn., *Lynceus andronachensis* Botn., *Leptestheria intermedia* Botn. and *Imnadia voitestii* Botn. and Orgh.

Reference to the occurrence of *Streptocephalus dichotomus* is found in the monograph by von Daday (1910). Coopey (1950) described the life-history of *Eubranchipus oregonius* and Cannon (1926) worked on the post-embryonic development of the shrimp (*Chirocephalus diaphanus*) and compared it with that of *Estheria*.

**MATERIAL AND METHODS**

There are various localities round about Poona where these animals are available. Dried mud or soil from Panchgani North Satara District (altitude 4296 ft. above m.s.l.) contains eggs of *Triops* and *Estheria*. Soil from a pond on the hill fortress at Panhala, Kolhapur District (altitude 2,772 ft. m.s.l.) contains eggs of *Triops, Estheria* and *Streptocephalus*. Soil from a pond at Sinhagad Fort, Poona District (altitude 4,320 ft. m.s.l.) contains eggs
Triops (Apus), Streptocephalus and Estheria of Streptocephalus and some cyprids. Adult specimens of Streptocephalus and Estheria are found in ponds in Katraj Ghat (Poona District).

**Observations**

Soil or dried mud from these localities was brought to the laboratory and put in small aquaria, one containing distilled water, another chlorinated tap water and the third containing muddy water from a nearby canal. Separate aquaria were used for soils from each locality. Eggs from the soil put in the aquarium containing distilled water floated for about 5-7 days, those in tap and muddy canal water hatched in about 12-24 hours. Larvae in the muddy water hatched in about 12 hours but grew faster. Addition of bread powder and yeast did not affect relative growth, but addition of diatoms and protozoans accelerated growth. It was necessary to bubble air continuously in the aquaria.

The larvae were fixed in Bouin’s fluid at intervals and were stained with borax carmine and mounted. The following are the observations made from the whole mounts as well as from living specimens from the aquaria.

(a) Triops orientalis

Egg is spherical with a diameter of 0.2 mm. It has a chitinous covering. The eggs when immersed in water hatch in about 12 hours.

**Stage 1** (Fig. 1) 12 hours larva.—The larva at this stage is a nauplius and measures about 0.25 mm. in length. The body is broader at the anterior end and narrow at the posterior end. The trunk region is unsegmented and the anal plate is bifurcated into anal furca (an.f.). The cephalothorax (ce.th.) has three pairs of appendages, viz., antennules, antennae and mandibles. The antennule (anl.) is very small and not visible beyond carapace. The antennae (ant.) and mandibles (md.) are biramous and provided with long setae. Anterior portion of the body is covered with carapace. Median eye or ocellus is seen in a notch in the anterior region of the body. Ventrally the labrum (lbr.) is large, plate like and almost covering one-third the length of the body.

**Stage 2** (Fig. 2) 17 hours larva.—Nauplius larva at this stage measures about 0.3 mm. in length. The cephalothorax region is broadened and also increased in length. Three pairs of cephalic appendages are seen as in the previous stage; the antennæ and mandibles have increased in length and are supplied with long setæ. Each antenna is supplied with thumb-like endopodite and a conical exopodite. Dorsal organ (Fig. 2, d.o.) is visible and covers most part of the cephalic region and is yellowish brownish in appearance in living specimens due to the presence of yolk material. Below the
dorsal organ, is the space of cardiac cavity (c.c.). The median eye is well pigmented, but the two compound eyes on either side remain unnoticed as they are less pigmented. Carapace covers half the length of the body. Anal

Figs. 1–3. Fig. 1. *Triops orientalis*, Larva 12 hours, Lateral view. Fig. 2. *Triops orientalis*. Larva 17 hours, Dorsal view. Fig. 3. *Triops orientalis*. Larva 20 hours, Ventral view.

*Magnification:* Fig. 1. 18 x 10 x. Fig. 2. 18 x 10 x. Fig. 3. 10 x 10 x.
plate is very broad and ends in caudal furca. Mandible is more than one-third the length of antenna. It consists of a basal disc bearing a finger-shaped division, the palp, bearing a pair of setæ.

**Stage 3 (Fig. 3) 20 hours larva.**—Larva is about 0·4 mm. in length. The anterior end is very much increased and broadened. The three pairs' of cephalic appendages are increased in size of which the antennule is unsegmented, straight and blunt and with two setæ. Below the mandibles are seen a pair of maxillæ, bud of first thoracic foot and five buds of thoracic limbs protruding followed by an unsegmented trunk portion. Median eye is very prominent and the two sessile eyes becoming big and have a brownish tinge. Labrum is still broad and large. Carapace is broadened and almost covers the first two thoracic limbs in addition to the cephalic appendages.

**Stage 4 (Figs. 4 and 5) 24 hours larva.**—Larva is about 0·55 mm. in length. The carapace covers the first three trunk limbs (Fig. 4). In Fig. 5 seven buds of trunk limbs are followed by demarcation of four segments deeply marked and followed by faint transverse lines demarcating the segments. Digestive tube is seen with two digestive pouches at its anterior end as is very clearly seen due to the transparent exoskeleton. The food particles in the alimentary canal are seen in the form of suspended particles. The first thoracic foot is seen without its endites and the anal plate is bifurcated.

**Stage 5 (Fig. 6) 36 hours larva.**—Larva is 0·65 mm. in length; appendages on the cephalothorax are the same as in previous stages, except that there is now the beginning of maxilla. Instead of the median eye two sessile eyes slightly pigmented are seen on either side gradually becoming larger in size and receding from the median eye. The caudal furca have increased in length and bear setæ. The carapace is very broad and covers almost the first two trunk segments. The first thoracic foot is seen to be segmented.

**Stage 6 (Figs. 7 and 8) 48 hours larva.**—Larva is now 0·85 mm. in length. The first three cephalic appendages show the highest growth and are supplied with long setæ. The first and second maxilla are present but usually covered by the thoracic feet. The median eye in the notch is very conspicuous and the two sessile eyes take a bean-shaped structure and are with more pigmentation than in the previous stages. In Fig. 7 (D.V.) the dorsal organ and cardiac cavity are noticeable. In Fig. 9 though the larva is of the same age shows the typical phyllopodian nature of the trunk limbs and as such deserves to be included in the next stage. The caudal styles have increased in length and end into fine setæ. Ventrally, tubular digestive gland is noticeable.
Figs. 4–7. Fig. 4. *Triops orientalis*. Larva 24 hours, Dorsal view. Fig. 5. *Triops orientalis*. Larva 24 hours, Ventral view. Fig. 6. *Triops orientalis*. Larva 36 hours, Ventral view. Fig. 7. *Triops orientalis*. Larva 48 hours, Dorsal view.

Magnification: Fig. 4. 10 x x 10 x. Fig. 5. 10 x x 10 x. Fig. 6. 10 x x 10 x. Fig. 7. 18 x x 10 x.
Stage 7 (Fig. 9) 68 hours larva.—Larva is about 1.1 mm. in length. Of the first three cephalic appendages the antennule is of the same size as in the preceding stages but the antenna and mandible are smaller in size. The mandible is smaller, is a pouch-like structure with hard brownish spines on it. The first thoracic foot is with five endites and as such the animal can crawl on these feet. Six other feet are also noticeable on the thorax. Number of trunk segments is now 20. The length of the caudal styles almost equal the length of the body. Carapace has become very broad and within it the rudiments of shell gland are visible. The coils of the gland are very well seen under the carapace. The digestive gland has become very much tubular and almost fills the anterior region of the body.

Stage 8 (Fig. 10) 96 hours larva.—The larva is about 1.2 mm. in length. Seen ventrally the labrum is very much reduced. Antenna is still biramous;
mandible is drawn out into a pouch showing further reduction. It has com-
pletely lost its setae. The first thoracic foot with its endites is seen on either
side. The carapace is now covering 11 thoracic appendages. Flabellae are
present on the first eight thoracic appendages.

Stages 9 (Fig. 11) 108 hours larva.—Larva is about 1.4 mm. in length
and resembles almost an adult. Ventrally the respiratory bracts are seen
on first thoracic appendages and also their endites. Labrum is very much
reduced and the digestive gland is very much tubular than before. Anal
furca are segmented and bear fine setae. Larva is now almost an adult and
can swim on its back or crawl on its abdominal feet.

(b) Streptocephalus dichotomous Baird.

Eggs are very minute in size, about 0.2 mm. in diameter with a wrinkled
sculptured coat.
Stage 1 (Fig. 12) 12 hours larva.—The larva at this stage is a nauplius. Its anterior end is broader than the posterior. The larva is 0.2 mm. in length with unsegmented trunk, two anal setae and three pairs of cephalic appendages. The antennule is uniramous, unsegmented and is provided with two setae at its anterior extremity; the antenna and mandible are both biramous and bear long setae. The median eye (Ocellus) is a tiny red spot in between the two compound eyes which are not pigmented. Below the eyes is a dorsal organ or nuchal organ very swollen up with yolky material. Ventrally the labrum covers a considerable area of the body. It is distinguished from the other part of the body by its dark orange colour. This colour is due to the yolky material as seen in living specimens.

Stage 2 (Fig. 13) 17 hours larva.—The larva at this stage measures 0.25 mm. in length, average being 0.32 mm. The three pairs of cephalic appendages are seen as in the previous stage. In addition to this the rudiments of maxilla are seen below the mandibles. The trunk region is commencing to segment and ends in two anal setae. The median eye becomes more pigmented and is very conspicuous at this stage. The compound eyes attain a slight brownish tinge. Each compound eye becomes larger and migrates away from the median eye. The dorsal organ occupies a larger portion of the cephalic region and does not show any change in the shape (not seen in Fig. 13 which is a ventral view). The antennule is very short and straight due to the increase in length of the body. The antenna is six segmented and supplied with long setae. Ventrally the labrum covers the mouth. All the appendages seem to arise from the mid-ventral line of the body. The trunk region shows as many as five segments and also traces of caudal setae (c.s.) at the posterior end.

Stage 3 (Fig. 14) 20 hours larva.—The larva is about 0.35 mm. in length. All the three body regions such as head, thorax and abdomen are well differentiated. The compound eyes are as prominent as the median eye but still with brownish tinge. There is an increase in the length of the maxillary region and the development of maxillae. There is also increase in the length of the antennae and mandibles.

Stage 4 (Fig. 15) 24 hours larva.—The larva is now 0.45 mm. in length. The antennule is short, straight, unsegmented and supplied with two bristles. The antennae and mandibles have increased in length. The endopodite of the antenna is thumb-like and is supplied not only with setae but with setules. The maxillary region is very much larger since the maxillary gland (excretory gland) is very much developed in the larval stages. The bud of first thoracic limb is also noticeable. In the trunk region buds of trunk appendages
Figs. 12-15. 
Fig. 12. Streptocephalus dichotomus. Larva 12 hours, Dorsal view.
Fig. 13. Streptocephalus dichotomus. Larva 17 hours, Ventral view.
Fig. 14. Streptocephalus dichotomus. Larva 20 hours, Dorsal view.
Fig. 15. Streptocephalus dichotomus. Larva 24 hours, Dorsal view.

Magnification: 
Fig. 12. 18 x 10 x.  
Fig. 13. 15 x 10 x.  
Fig. 14. 10 x 10 x.  
Fig. 15. 10 x 12.5 x.
numbering five protrude out followed by markings of two segments and finally there is an unsegmented portion. The alimentary canal is seen with two digestive pouches below the transparent exoskeleton and the food is seen in the form of suspended particles. The compound eyes become pigmented at their anterior end.

Stage 5 (Fig. 16) 48 hours larva.—The larva is about 1.1 mm. in length. The compound eyes are elevated above the cephalic region and are borne on stalks. The antennæ and mandibles are reduced in size. In front of the eyes the frontal organs are also noticeable. Mandible is now in the form of a pouch. Maxillary gland is well developed below the mandibles. Eleven pairs of thoracic appendages are seen, out of which the first four are seen with endites and the remaining are in the form of protuberances. The bracts of the first four limbs are clearly formed. The flabellæ are also dis-

**Figs. 16-17.** Fig. 16. *Streptocephalus dichotomus*. Larva 48 hours, Dorsolateral view. Fig. 17. *Streptocephalus dichotomus*. Larva 96 hours (female), Lateral view. **Magnification:** Fig. 16. 10 × 10 x. Fig. 17. 10 × 3.2 x.
tinctly formed and show the clear demarcation from the last endite at one end and the bract at the other. The first thoracic limb is smaller in size than the second. The thoracic and the abdominal region are more clearly marked than in the previous stages. The abdominal region is without any appendages. The caudal furca with caudal setae is noticeable. The head region has increased in size and breadth. The antennules and antennae become more ventral in position. In the case of antenna there is a constriction at the basal region and this is probably due to the bending of the antenna ventrally, which is slowly attained during the process of reorientation.

Stage 6 (Fig. 17) 96 hours larva.—The larva is 3·3 mm. in length. The appendages of the thoracic region very well developed and are followed by several abdominal segments without appendages. The 1st eight appendages of the thorax have well marked endites, flabellae and bracts. The first limb appears distinctly smaller than the 2nd limb. The antenna at this stage is completely rotated on the ventral side and is very much reduced and knob-like thereby indicating the female sex. At the same time at the “Analage” of 11th and 12th thoracic appendage a thickening in the form of a paired rounded elevation is developed which goes to form the egg-pouch of the female. The caudal furcae are elongated, plate-like and with setae.

Stage 7 (Fig. 18) 10th day larva.—The larva is almost adult now, measuring about 5·1 mm. in length. The abdominal segments are all well marked and the last is the longest of all. Development of all thoracic limbs except the last is complete. The mandibular and maxillary regions are very much reduced. The antenna has become very much plumose and prehensile. At the very “Analage” of the 1st and 2nd abdominal segment a raised pouch in which the male retractile penis is developing is noticeable. The frontal organs have become plumose and sensory. The caudal furcae have five setae on them. The larva is almost an adult now.

(c) Estheria

Eggs resemble those of Streptocephalus; they are very minute in size, 0·2 mm. in diameter.

Stage 1 (Fig. 19) 17 hours larva.—The larva is a nauplius, 0·25 mm. in length with no trace of segmentation in the post-mandibular region. The carapace is bivalve and almost covers the entire body. Three pairs of cephalic appendages are seen of which the antennule is uniramous, unsegmented and is supplied with two setae. The antenna and mandible are biramous. Ventrally, labrum is large and covers one-third the length of the body. Median eye is pigmented and is found in the anterior notch in the cephalic region.
Labral glands are very prominent at the margin of the labral plate. The anal plate is not bifurcated.

Stage 2 (Fig. 20), 20 hours larva.—Larva is now a metanauplius, 0·3 mm. in length. About 9 segments are seen in the post-mandibular region. Carapace is folded on one side of the cephalic appendages, the antennule is stumpy and blunt. The antenna has increased in size and is supplied with very long setæ. The mandible is also biramous and with long setæ. The anal plate is bifurcated into hooked claws. Ventrally the labrum is a long plate covering one-third the portion of the body.

Stage 3 (Fig. 21) 48 hours larva.—Larva is now 0·65 mm. in length. In front of the eyes are sensory papillæ. Each thoracic segment bears a curved
spine on its dorsal side. The carapace is well marked bearing very small spines at regular intervals at its margin and covers first eight thoracic appendages.

Within the carapace rudimentary shell gland is noticeable. The digestive tube is seen with the digestive pouches and is encircled by tubular digestive gland. Seven trunk appendages with rudiments of buds of two more trunk appendages are noticeable. The caudal hooked claws are longer and are supplied with spines at their extremity.

Stage 4 (Fig. 22) 68 hours larva.—The larva is about 1·4 mm. in length. The antenna and mandible are reduced in size. Mandible is reduced to a pouchlike structure. Thoracic appendages are with bracts and the typical phyllopodian nature of limbs is noticeable in first eight thoracic limbs. Four buds of thoracic appendages are present. Two sessile prominent black eyes are seen on either side of the antennule.

Stage 5 (Fig. 23) 96 hours larva.—Larva is 1·3 mm. in length. The shell gland, which is the excretory organ, is well developed within the carapace.
Six endites are seen to each thoracic appendage. Number of hind segments is increased to 9. The carapace is seen with "lines of growth" on it. Larva almost looks like an adult Estheria.

**Fig. 21.** Estheria. Larva 48 hours, Lateral view.

*Magnification:* Fig. 21. 10 x x 10 x.

**DISCUSSION**

The newly hatched larva is either a true nauplius without any segmentation in the trunk region, but possessing a median nauplius eye in the notch in the anterior part of head (seen ventrally) and three pairs of cephalic appendages or a metanauplius showing segmentation in the post-mandibular region. They show phototrophic movements and tend to move to the top of the aquarium to feed on the scum deposited on its sides. Scum when examined is full of protozoa, diatoms and algae. Longhurst (1955), Hall (1933), Cannon (1924 and 1926) obtained larvae of various phyllopods from mud samples by placing them in tanks of clean water.

The time taken for hatching after the immersion of mud containing eggs is about 12 hours. This period is likely to vary. If only a small quantity of mud is placed in a deep petri-dish, the larvae hatch in 12 hours but in a large aquarium with a larger quantity of mud, the larvae hatch in about 24–48 hours. Most workers have obtained nauplius larvae in 24–48 hours.
The larvæ also hatch out more quickly in hot season than in winter. All these observations are made at room temperature which is different in both the seasons.

Figs. 22-23. Fig. 22. *Estheria*. Larva 72 hours, Lateral view. Fig. 23. *Estheria*. Larva 96 hours, Lateral view.

*Magnification*: Fig. 22. 10 x × 10 x. Fig. 23. 10 x × 5 x.

The larvæ of the three crustaceans can easily be distinguished from each other immediately at hatching. The larvæ of *Triops* have a carapace covering
the anterior part of the body, bifurcated anal plate, three pairs of cephalic appendages and a median pigmented nauplius eye seen ventrally. The larva of *Streptocephalus* has no carapace, no segmentation in the post-mandibular region but possesses three pairs of cephalic appendages, two anal setae, a prominent sessile median eye in the notch in the anterior part of the head (seen ventrally). The larva of *Estheria* has carapace in the form of a bivalve shell without any striation. The shell covers almost the entire body. The larva possesses three pairs of cephalic appendages, a median nauplius eye (seen ventrally) with pigmentation and a large labrum overlapping one-third the length of the body. In the metanauplius stage of *Estheria* the trunk shows segmentation and an anal plate without paired hooked claws. The shell does not cover the whole body but keeps the head and telson free. These observations are in agreement with those of Botnariuc (1947) on the phyllopod conchostraca (*Leptestheria intermedia* Botn.), *Eoleptestheria variabilis* Botn. and *Imnadia viotestii* Botn. (1948).

**Carapace.**—*Streptocephalus* has no carapace at all. The carapace of *Estheria* is not moulted during ecdysis but seems to be retained and shows "Lines of growth" and from these lines one can conclude the age of the animal (Lankester). In the case of *Triops*, moulting takes place together with the carapace. This was well noticed while observing the various larval stages in the cultures. Longhurst (1955) while working on the individuals of *Triops cancriformis* and *T. granarius* noticed that the ratio of the carapace length to the total length of body remained the same throughout the growth. The basic variation is seen in the size of the carapace relative to the total length of the body. While observing the various larval stages of *Triops*, it is noticed that when the carapace is small in size, it is rounded in outline and is stronger in structure but when it is broad, it is flat and less strong.

**Segmentation and appendages.**—External appearance of segmentation in all these animals is noticeable 20 hours after hatching when along with trunk segments, 4–5 buds of appendages of the trunk are seen to protrude. This is the condition in *Triops* and *Estheria*. But in *Streptocephalus* buds of trunk appendages commence 24 hours after hatching though the cultures are at the same room temperature. The first thoracic appendage with its endites is seen in the larvae of *Streptocephalus* and *Estheria*, 36–48 hours after hatching and the distal endite of this appendage develops into a respiratory bract. But in the case of *Triops* the distal endite of the first thoracic appendage forms the respiratory bract as late as 4th day after hatching. Lankester (1909) stated that the epipodites are richly supplied with blood and he called them "Branchiae".
Linder (1952) working on the North American Notostraca elucidated the relationship between the number of segments, the number of appendages and the number of posterior apodous segments. He concludes that the number of appendages is the result of two quite separate processes: the production of segments and appendages in the larvae proceed at different rates. The boundaries of the appendages bearing segments are not complete ventrally; no correlation could be found between the number of appendages and the segments bearing them. The appendages may have no relation to the length of segment.

The three cephalic appendages, viz., the antennules, antennae and mandibles show interesting variations in the three phyllopods studied. The antennule is almost constant in size. It is uniramous, unsegmented and supplied with sensitive bristles at its upper extremity. The antennae and the mandibles are typically biramous and supplied with long setae in early larval stages. They increase in length with age; maximum length is attained in larvae 36–48 hours old. Later these appendages undergo reduction. The antenna becomes small in size except in *Streptocephalus* male where it is plumose and, by the time metamorphosis is complete, almost vestigial. The mandible loses its biramous character and develops into a cup-shaped structure with spines. The first trunk appendage by this time is fully developed and is provided with endites and it functions as a swimming and crawling appendage. As early as 1886, Claus observed that the loped leaf-like appendages suggested the primitive form of crustacean appendage inasmuch as the branchiopod limb resembles the early phylogenetic stage before the evolution of the biramous type.

Eyes.—The median pigmented nauplius eye seen in early larval stages (12 and 20 hours) is seen in a notch in the anterior part of the head. In the case of *Streptocephalus* there is a median eye in the nauplius stage and it persists up to 36 hours and then paired sessile eyes appear which are pigmented. Slowly, in larvae 48 hours old the eyes are borne on stalks. In the case of *Triops* and *Estheria*, there is a median eye with pigmentation and the two sessile eyes on either side of the dorsal organ in larvae 36 hours old, but pigmentation is less marked. Seventy-two hours old larvae of these animals show two sessile eyes on either side of the dorsal organ with dark pigmentation.

Maxillary gland.—The maxillary gland of *Streptocephalus* which is found below the 2nd maxilla makes its first appearance in a 36 hours old larva. It becomes conspicuous in 48–68 hours and more prominent in 72 hours. The shell gland in the case of *Triops* and *Estheria* makes its appearance in 48 hours old larva and is very well developed by the 4th day. The digestive
gland in all these animals is first seen at the 48 hours stage and becomes much more tubular during 72–96 hours stages and thereafter is very prominent in the animal.

**Sex differentiation.**—The larvae develop into adults, but the adult forms survive under laboratory conditions just for one and a half month. Sex differentiation is particularly well noticed in *Streptocephalus*. As early as the 10th day in a larva with 11 pairs of appendages and with the appearance of 12th segment, the “Analage” of either a double penis or egg-pouch could be seen. The penis is retractile and is beset with curved spines when everted. The egg-pouch of the female has a red patch on its ventral surface and bears an opening controlled by a sphincter at its distal end. The antenna of the female is plate-like. The male has a twisted plumose prehensile antenna used as “sexual clasper” (Lankester, 1909).

Some of the females of *Streptocephalus* were isolated and kept in another aquarium full of water and with ordinary dried mud. These laid eggs which were without chitinous covering and they soon decomposed and did not germinate. It appears, therefore, there is no parthenogenesis in these animals.

In *Estheria*, during the third week of development the male develops hooked claws to the first two endites of the first thoracic appendage. These claws are also used as sexual claspers with which the female is held. The female shows continuous rhythmic movement of the abdomen. The male and female are seen attached to each other lengthwise one behind the other, for many days. Later, they bury themselves in the mud with periodical spurting movements in the aquarium. After copulation, the animals become whitish in colour and look very sluggish in their activity. The whole life-cycle of the animal is completed within 40 days. Eggs extruded from the egg-pouch were placed on a filter-paper and the paper was kept to dry for about 24 hours. On immersing the filter-paper in water, larvae hatched in 4–5 days or even as early as 48 hours. It is a remarkable fact that the eggs laid in an aquarium did not germinate in the same aquarium, but if it was emptied, dried for a week and then refilled, the eggs germinated in about 48 hours. A period of desiccation appears to be necessary for the eggs to germinate under natural or normal conditions. Eggs do not hatch in pools or ponds where they are laid unless the pool or pond dries and new showers fall in the next monsoon. Heath (1924) while summarising his observations on the Indian Anostraca remarks that both specimens of *Branchinecta orientalis* and *Branchipodopsis affinis* have eggs requiring freezing and certainly that of *Branchipus* and of the *Streptocephali* require drying.
Evidence of sex differentiation is not so readily obtainable in *T. granarius* except in the second week of development when males look pale and brownish and the females deep green. The males possess long caudal styles. The females possess a broad carapace beneath which an egg-pouch is formed to the 11th appendage.

All the three animals can be kept in an aquarium for about 2 months. In about 40 days the life-history of the animals is completed. After copulation the animals become senile and die. The conditions in the aquarium retard their growth.

*Movement of light and food.*—Cannon (1924) described the larvæ of *Estheria* as showing phototropic movements and it was noticed during the course of the work, that during night if a light from a torch was thrown on the aquarium, the larvæ showed a very spurtng movement. During the day they now and then congregated at the surface on the top of the aquarium towards the bright side and fed on protozoa and diatoms.

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**Summary**

1. Eggs from mud take 12-48 hours to hatch.
2. The newly hatched larva in *Estheria* is a nauplius or a metanauplius.
3. It shows phototrophic movements and feeds on diatoms and minute micro-organisms. Scum when examined was full of diatoms, algæ and protozoans.
4. Three pairs of cephalic appendages show maximum growth in length within 36-48 hours after hatching but after 72 hours progressive reduction takes place so that the antenna becomes almost vestigial except in male *Streptocephalus* and the mandible changes into a cup-shaped structure with spines on it, the antennule, however, persists.
5. Segmentation of trunk region increases progressively leaving in all cases a posterior unsegmented region.
6. Buds of appendages on the trunk segments increase in regular antero-posterior order.
7. During the formation of appendages the distal endite of the thoracic appendage in the case of *Streptocephalus* and *Estheria* develops into a respi-
ratory bract early, 48 hours after hatching, but in the case of *Triops* as late as on the 4th day.

8. In *Streptocephalus* sexual difference is noticeable during 2nd week of larval life, when 11 pairs of appendages are developed, either in the form of a penis or an egg-pouch. In male antennæ become plumose and rep- hensile. In male *Estheria* the first two endites of the first thoracic appendage develop hooked claws on them.

9. The caudal appendages show variations in the three larvae. It is long, rod-like, segmented and supplied with bristles in *Triops*; plate-like and supplied with very fine bristles in *Streptocephalus* and in the form of hooked claws in *Estheria*.

10. Median sessile eye degenerates and the two compound eyes on either side remain sessile in *Triops* and *Estheria* but become stalked in *Streptocephalus*.

11. The eggs extruded in an aquarium do not germinate in the same aquarium but require a period of desiccation.

12. Females when isolated produce naked eggs (without shell) which decompose after a time thereby showing that parthenogenesis does not take place. The naked eggs dried on a filter-paper and immersed in water do not germinate.

**References**


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**ABBREVIATIONS USED IN TEXT-FIGURES**

*abd.*, abdomen; *a.f.*, anal furca; *an.*, anus; *an.pl.*, anal plate; *anl.*, antennule. *br.*, bristle; *ce.th.*, cephalothorax; *cp.*, carapace; *c.c.*, cardiac cavity; *c.s.*, caudal seta; *d.o.*, dorsal organ; *d.gl.*, digestive gland; *d.p.*, digestive pouch; *eg.p.*, egg-pouch; *e.*, eye; *h.cl.*, hooked claws; *l.br.*, labrum; *m.*, mouth; *md.*, mandible; *max.*, maxilla; *max.gl.*, maxillary gland; *o.*, ocellus (median eye); *p.*, pouch to denote male sex; *res.br.*, respiratory bracts; *se.*, seta; *seg.*, segment; *sp.*, spine; *u.p.t.*, unsegmented portion of the trunk.