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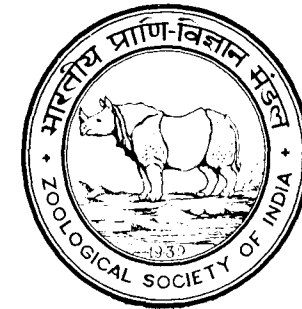
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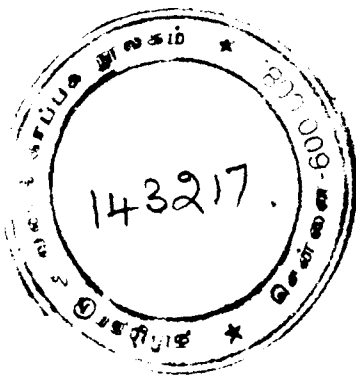
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Cytological Studies in Diplopoda (Myriapoda)

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Annamalainagar.

(Communicated by Prof. R. V. SESHAIYA, F.Z.S.I.)

(With 13 Text-figs)

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Introduction

The cytology of Myriapoda has been little studied in contrast to the other classes of Arthropoda. The accounts we have so far relate almost wholly to the group Chilopoda—the centipedes (Blackman, 1905, '07 & '10 Medes, 1905 and Bouin, 1920, '22 & '25). The more recent studies on these are those of Makino and Niiyama (1942), Ogawa (1950, '51 '52, '53, '54, '55, & '57), Ansley (1954) and Puttanna (1959).

The cytology of Diplopoda has suffered neglect excepting for the papers by Oettinger (1908, '09) and Sokoloff (1914, 1918). The investigations by Tuzet and Millot (1937), Tuzet and Bessier (1941 '43), Bessiere (1943, '48) and Tuzet Bessiere and Manier (1954) on many European species of Diplopoda, however, deal only with the cytoplasmic inclusions during spermiogenesis, any reference to chromosomes in these studies being only incidental. Bessiere's (1948) review of the previous investigations, as also his own observations on the representatives of the families Iulidae, Glomeridae and Polydesmidae indicate how incomplete and inadequate is our knowledge of the cytology of the Diplopoda.

With regard to the Indian species, excepting for the recently published observations of Puttanna (1959) on five species of Chilopoda, there have been no studies on the chromosomes of the Myriapoda. The only published work in India on the millepedes, by Nath and Sharma

(1952), relates to the cytoplasmic inclusions during spermatogenesis. In view of our complete lack of knowledge of the cytology of this group, I undertook, at the suggestion of Prof. R. V. Seshaiya, a study of the chromosomes and their behaviour during spermatogenesis in some of the South Indian millepedes viz., *Xenobolus acuticonus* Att. (Xenobolidae: Spirobolida, *Thyroglutus* sp., and *Phyllogonostreptus nigrolabiatus* Newp. Harpagophoridae: Spirostreptidae.)

Material and Technique

Xenobolus and *Phyllogonostreptus* are available locally during the cold season. *Xenobolus* measuring about 6 cm. in length and about 2 to 3 mm in breadth, occurs in large numbers near water sources, mostly haunting the green, cool and shady places. The adult specimens are dark with a bright mid-dorsal red line. *Phyllogonostreptus* is larger and a full grown specimen is about 12 to 15 cm in length and 1 cm. in breadth. The colour of the body is either bright tan or dark brown. These specimens also occur in large numbers in gardens and fields, mostly frequenting cool and green places and are easily collected in large numbers either in the cooler hours of the day or after a shower.

The specimens of *Thyroglutus* were collected from Karaikudi, South India. They were available in plenty in cold seasons. The adult specimen, which is greenish black in colour, is about 15 cm. in length and 5 mm. in width.

All the specimens were kept alive in the laboratory in wooden boxes having lids of wire mesh and containing moist sand and plenty of humus. The specimens thrive well under these conditions.

The testes are elongated whitish tubes, with a nodulated appearance and connected by a common duct. They occur in both sides of the body along the central nerve cord, running to the entire length of the body. It is very difficult to separate the testes completely from the surrounding tracheae and fat-bodies which cover the entire body-cavity.

For cytological studies, the animal was cut open immediately after decapitation and the gonad removed as quickly as possible to the fixatives. Allen's modification of Bouin's fluid, Sanfelice's mixture and Car-
noy's 1: 3 acetic alcohol proved excellent for the purpose. The material was later embedded in paraffin and sectioned at 8 μ . Heidenhain's iron haematoxylin, crystal violet and Schiff's reagent after Feulgen hydrolysis, were used for staining. Aceto-carmin and aceto-orcin squashes of the testes were also made and proved to be of very great help for the study of various stages.

Observations

I. *Phyllogonostreptus nigrolabiatus* Newp.

Spermatogonial metaphase: Fig. 1 is a photomicrograph of a spermatogonial metaphase of this form in a polar view. 25 chromosomes could be well observed and all of them are rod-shaped or stout and oblong. A karyogram (Text fig. 13) shows twelve pairs of homologous chromosomes and a rounded unpaired one which is the smallest of the spermatogonial complements. Further, six pairs of chromosomes appear long and rod-shaped while the remaining six pairs are rather short, stout and more rounded.

The anaphase and telophase stages of the spermatogonial division are normal.

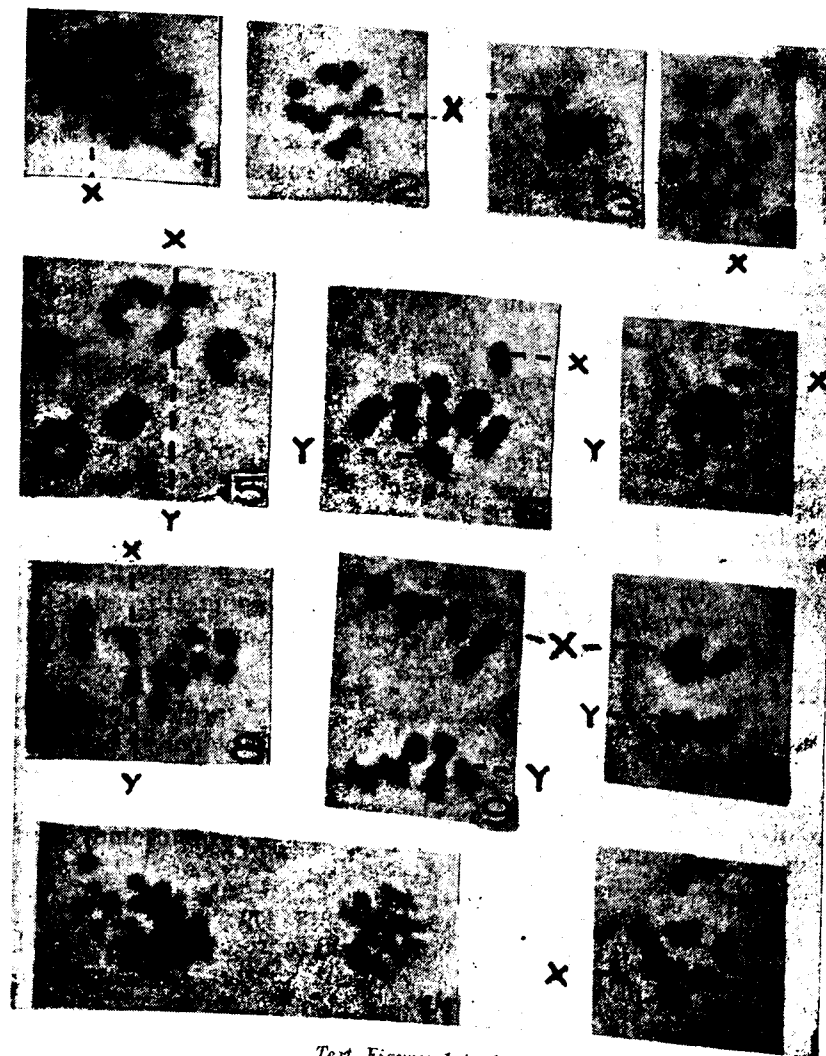
Meiosis: During leptotene, thin granular threads are seen traversing the nuclei in all directions. Towards one side of the nucleus and close to the nuclear membrane is seen a small condensed body which stains deeply with Feulgen. At zygotene also this more or less rounded heteropycnotic element is conspicuous towards the periphery of the nucleus, which now shows clearly the paired autosomal threads. No definite orientation of the threads or their ends could be seen within the nucleus.

The pachytene and diplotene stages in this species appear to be very diffuse as reported in some other Diplopods by Bessiere (1948). The chromosomes appear very lightly stained and show only blocks of chromatin connected by slender threads. So much so, neither the bivalents nor the heteropycnotic body (odd chromosome) could be detected.

During diakinesis, however, the bivalents emerge in characteristic shapes of rings and dumb-bells. The odd chromosome could also be made out as a small and rounded element. After the dissolution of the nuclear membrane the bivalents and also the single univalent chromosome are seen at the equatorial region of the cell (Fig. 2). During anaphase the univalent goes to one pole in advance of the disjoining halves of the bivalents (Fig. 3) and thus the first division is reductional for the unpaired element as well as the autosomes. The disjunction of the autosomal bivalents is normal.

The second division follows the first immediately without an interphase. Two types of secondary spermatocytes with 13 and 12 complements are clearly seen (Fig. 4). The second division is equational for all the chromosomes.

Another noteworthy point is the occurrence of polyploid cells in the testis of this species. Stray cells of this type are common but in one individual a cyst of polyploid cells was also met with. They are almost



Text Figures 1 to 13

Phyllogonistrepus nigrolabiatus Newp. Fig. 1. Spermatogonial metaphase polar view—aceto carmine squash. Fig. 2. I metaphase—polar view, Fig. 3. I metaphase side view—scx—chromosome can be clearly seen. Fig. 4. II metaphase polar view—aceto carmine squash. Fig. 11. Polyploid cells (Tetraploid) in the testis—crystal violet stained section.

Thyroglutus sp. Fig. 5. Diakinesis stage—aceto carmine squash—5 ring shaped chromosomes and two sex chromosomes are well seen. Fig. 6. First anaphase early—side view—the X and Y separate from each other precociously. Fig. 7. I anaphase early—side view—the X and Y reach the opposite poles along with the autosomes. Fig. 9. I anaphase late—the II metaphase—polar view—5 autosomes are seen surrounding the sex chromosome in the centre. X ca 5000.

Xenobolus acuticonus Att. Fig. 8. I metaphase—side view, aceto carmine squash—5 bivalents and the XY complex are well seen. Fig. 10. I anaphase early—the X and Y chromosomes separate precociously than the rest crystal violet section. Fig. 12. I anaphase late—the X and Y reach the opposite poles only along with the rest.—Feulgen section X ca 4000.

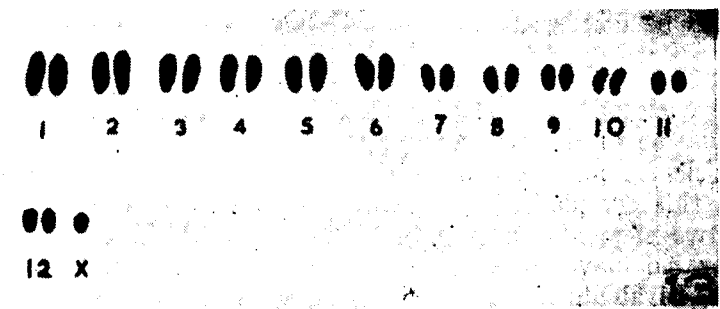


Fig. 13. Karyogram showing 12 homologous pairs of chromosomes and a single sex chromosome (X), arranged in order of their size. X ca 3500.

invariably in the I metaphase stage (Fig. 11) and are larger in size than the corresponding normal ones (c.f. figs. 2 & 11). From the chromosome counts these cells would appear to be at tetraploid level in having about 24 to 28 bivalents. However, the polyploid cells in other stages of development were never met with and it is therefore impossible to decide about their fate, although by analogy with somewhat similar instances in the animal kingdom, these might serve some nutritive function for the growing spermatozoa.

II. *Thyroglutus* sp., and *Xenobolus acuticonus* Att.

Although these species belong to different families, the number of chromosomes and also their behaviour during spermatogenesis are almost similar in both so that a common account is given below.

Meiosis: The meiotic stages are very clear in both the species. During leptotene there appears to be a slight polarisation of the ends of the chromosomal threads and two small heteropycnotic bodies could be clearly made out. At zygotene, the polarisation of the paired threads is more pronounced and a typical bouquet is also seen. The two heteropycnotic bodies which are small and rounded lie separately, close to the nuclear membrane.

As in the previous case, the pachytene and diplotene stages appear diffuse and the nuclei are light stained. The bivalents as well as the heteropycnotic bodies could not be made out clearly during these stages. During diakinesis, however, the bivalents are seen in the form of rings. They are five in number besides the two small slightly curved elements which appear to be connected to each other at one end (Fig. 5). These two elements, well condensed and deep-staining, are the heteropycnotic bodies. It also appears as though there is some sort of

association between the two heteropycnotic elements. This phenomenon will be discussed later.

At metaphase all the bivalents appear dumb-bell shaped which also show the enclosed space clearly (Fig. 8). A single element formed by the association of the two heteropycnotic bodies (as stated previously) could be clearly made out during this stage also. During anaphase, however, this complex of the two heteropycnotic bodies is dissolved and the two elements segregate to the opposite poles. (Figs. 6 & 7). The separated halves move polewards in advance of the disjoining halves of the bivalents but later they seem to wait as if they were on the spindle and reach the poles only along with the rest. (Figs. 9 & 10).

The second division follows immediately. In a polar view of the II metaphase (Fig. 12) five elements, appearing 'V'-shaped with equal arms are seen surrounding a smaller and rod-like chromosome situated in the middle of the spindle. All the chromosomes divide equationally in the II division. From the second metaphase it would appear that the karyotypes of these two species probably consist of metacentrics excepting of course the two elements which show positive heteropycnosis during the meiotic prophase stages.

Discussion

A study of the chromosomes of the males of three species of millipedes shows many interesting features, of which the most outstanding is the occurrence of sex-determining chromosomes and their behaviour.

As Wilson (1911) pointed out, the characteristic staining property of sex chromosomes is helpful in identifying and tracing them from generation to generation. Heteropycnosis of sex chromosomes is very widespread in the male meiotic prophase of animals and the sex chromosomes have on this account been referred to as heterochromosomes. The two heterochromosomes in *Thyroglutus* and *Xenobolus* which may be referred to as X and Y, with no size difference between them, and the single X chromosome in *Phyllogonostreptus*, are positively heteropycnotic and wholly so during the early stages of meiotic prophase. But in keeping with what appears to be a general feature with members of this order, the sex chromosomes also become indistinguishable along with the rest of the chromosomes or the autosomes during pachytene and diplotene. In later stages, however, their behaviour is indicative of their distinctive role, i.e., the genetic determination of sex. In all the species investigated presently, the sex chromosomes divide reductionally at the first meiotic division and equationally at the second, to give rise to two kinds of gametes.

Cytological investigations, especially chromosome studies, are extremely rare in Diplopoda, as stated earlier, and the only reference to sex

chromosomes is by Oettinger (1908, 1909) who reported that the male of *Pachyiulus varius* is the heterogametic sex with an XO type of sex determining mechanism. The presence of an "odd chromosome" during the first meiotic division in members of certain families of Diplopoda has been indicated by Bessiere (1948). The present finding of the unpaired sex chromosome in the males of *Phyllogonostreptus* thus adds one more example to this type of sex-determining mechanism in the group and also lends support to the findings by the earlier authors.

The present finding of an XY type of mechanism in the males of *Thyroglutus* and *Xenobolus* is the first instance of this type in Diplopoda and these, together with the other species studied, confirm the view that the male is the heterogametic sex in Diplopoda as in most groups of bisexual animals.

In this connection, it may be interesting to note that in Chilopoda, the other order of the class Myriapoda, simple sex-determining mechanisms with XY and XO and more complex ones with multiple sex chromosomes, have been claimed to occur (Makino, 1951; Ogawa, 1958 and Puttanna, 1959). The X and Y chromosomes in the Scolopendridae described by Puttanna (1959) and those in *Xenobolus* and *Thyroglutus* in the present study are heteropycnotic during early meiotic prophase. Such being the case, it may be interesting to consider the question of their association and "bivalent" formation prior to segregation. The association between X and Y and their subsequent segregation are normally conditioned by their pairing and chiasma formation during meiotic prophase, and in Mammalia and Diptera, where X and Y are heteropycnotic, there are pairing or homologous euchromatic regions though minute and crossing over occurs in them. This would imply that heteropycnosis prevents chiasma formation, although Pontecorvo (1943) would question such an assumption. Makino (1951) holds that the XY complex in *Apodemus* is due to 'heterochromatin cohesion' and that chiasmata play no role in holding together the sex chromosomes. In some species of earwigs which possess XY males (Asana and Makino, 1934; Misra, 1937) where the sex chromosomes are strongly heteropycnotic during meiotic prophase, the improbability of any chiasmata between the X and Y chromosomes has also been pointed out by White (1954).

The X and Y chromosomes described in the present study and also in the Scolopendridae described by Puttanna (1959) are entirely heteropycnotic and so far as could be made out there is no trace of any cytologically detectable chromatin other than heterochromatin. Further, their deep staining in Feulgen at the beginning of meiotic prophase indicates that they are heavily 'charged' with nucleic acid, and probably tightly spirals. In the present instances, these bodies were always seen to lie separately in leptotene and zygotene, while the autosomes are paired. Although their behaviour could not be traced in pachytene and

diplotene, like those of the autosomes, it is highly probable that they were not paired during these stages as well. These facts make it highly unlikely that any true pairing, chiasma formation and regular bivalent formation are involved. However, their regular segregation to the opposite poles require some mechanism which would bring them together and effect proper orientation on the spindle. As stated already, the heterochromatic cohesion described by Makino (1951) or some such mechanism would seem to be operative in the present instances also. Heitz (1929, 1933), McClintock (1933) and Schrader (1941) have considered possible a mutual attraction between heterochromatic elements resulting in a tendency to come together. The XY complex in various forms of Myriapoda so far described thus seem to be the result of a temporary association of the type indicated above at diakinesis and at first metaphase.

The earlier studies of Oettinger (1908, 1909) on *Pachyiulus* and of Sokoloff (1914) on *Polyxenus* (cited by Makino) are the only investigations so far on the chromosomes of diplopoda and the numbers reported are $2n = 25$ and $n = 13$, in *Pachyiulus*, and $n = 8$ in *Polyxenus*. The present observation that $2n = 25$ ($24 + X$) in *Phyllogonostreptus* is similar to that observed by Oettinger. But so far no reference to the critical morphology of the chromosomes is available in any diplopod. The karyogram of the mitotic chromosomes of *Phyllogonostreptus* has already been described and this attempt, which is the first in this direction, shows that the 24 chromosomes as well as X chromosome in this form are acrocentrics. In *Thyroglutus* and *Xenobolus* it was shown that $2n = 12$ ($10 + X + Y$) and $n = 6$ ($5 + X$ or Y). Although spermatogonial metaphase chromosomes of these forms were not available for the critical analysis of their morphology, it appeared from a study of the second metaphase chromosomes that all the autosomes are metacentrics, but nothing could be said of the sex chromosomes.

The diploid chromosome numbers of the various families of Diplopoda thus vary from 12 to 25 and both acrocentric and metacentric chromosomes are seen to occur in them. The occurrence of metacentric chromosomes in species with lower numbers and acrocentrics in species with higher numbers may prove to have some significance from the evolutionary point of view, although in the present state of our knowledge of the cytology of this order, any such conclusion would be rather presumptuous.

In India more than three hundred species of Diplopoda have so far been recorded (Attems, 1937), and a detailed cytological investigation of this order along the lines indicated in the present study promises to be very interesting and highly rewarding.

Summary

1. The chromosomes of three species of millipedes (Diplopoda: Myriapoda) viz., *Phyllogonostreptus nigrolabiatus* Newp., *Thyroglutus* sp. Harpagophoridae: Spirostreptida) and *Xenobolus acuticonus* Att. (Xenobolidae: Spirobolida) have been studied, especially with regard to sex determining mechanisms.

2. The chromosome numbers of all the three forms have been determined for the first time. $2n = 24 + X$ and $n = 12$ or $12 + X$ in *Phyllogonostreptus* while in the other two forms viz., *Thyroglutus* and *Xenobolus* it has been found that $n = 5 + X$ or Y .

3. The spermatogonial chromosomes of *Phyllogonostreptus* alone could be studied critically. In this form $2n = 24 + X$ as stated already and all the 25 elements of the complement are acrocentrics. Six pairs of them appear large and rod-shaped while the rest appear more rounded and stout. The X chromosome, which is unpaired and globular, is the smallest of all.

4. In all the three species studied, the male is the heterogametic sex. In *Phyllogonostreptus* is seen a XO type of sex determining mechanism while in the other two species studied it is of a XY type.

5. The sex chromosomes show positive heteropycnosis in all the three forms. In *Phyllogonostreptus* there is only a single heteropycnotic element but in the other two forms there are two such elements.

6. The pachytene and diplotene stages are diffuse in all the three forms. Consequently the formation of the chiasmata and also their terminalisation and other related phenomena could not be studied.

7. The X chromosome of *Phyllogonostreptus* and XY chromosomes of the other two species show a similar behaviour during meiotic divisions, i.e., they divide reductionally in the first division and equationally in the second.

8. The X and Y elements in both the species of *Thyroglutus* and *Xenobolus* do not vary much in their size, and during diakinesis and metaphase, they form a temporary and non-specific association. This temporary association between the sex elements is presumably only to facilitate their regular segregation.

9. In all the three species the sex elements show precession but the autosomes also join them before they reach the poles.

10. In *Phyllogonostreptus* because of the XO type of sex determining mechanism, two kinds of spermatocytes are seen—one with 13

complements and the other with 12 only. In the other two species the secondary spermatocytes are found to be either $5A + X$ or $5A + Y$.

11. In the diploid testis of *Phyllogonostreptus* polyploid cells at the tetraploid level are of common occurrence. In one individual a cyst of such cells was noticed, whereas normally only stray cells are common. Moreover, these cells were observed always at the first I metaphase stage only and never at any other stage.

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(For previous work on Myriapoda see Bessiere, 1948).

Abnormal Development in the Temperature Treated
Eggs of *Gasterosteus aculeatus* (L.): IV Microcephaly

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(With 7 Text-Figures)

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Introduction

Malformations of the head may be obtained by over-ripeness of eggs (Witschi 1952), centrifugation of uncleaved eggs (Pasteels 1940) and by cultivation of the germs at high temperatures (Hoadley 1938). More-over similar abnormalities result from a treatment of blastulae and gastrulae with lithium chloride solutions (Lehmann 1937; Pasteels 1945) and with butyric acid and acetone (Werber 1916). Somewhat less extensive are the disturbances that follow application of a large variety of other chemical substances, salts and organic compounds (Dawson 1938; Hertwig 1895; Holtfreter 1933).

When the freshly fertilized eggs of *Gasterosteus aculeatus* are subjected to temperature treatments, various types of abnormalities are produced (Swarup 1958, 1959a, 1959b). In the present paper an account is given of those abnormalities which are produced in the head region causing microcephaly.

Material and Methods

G. aculeatus, a small fresh water fish, was made to breed in the laboratory and its eggs used for the present work. A fuller account of the material used is given in earlier papers of the series.

Temperature treatment to the freshly fertilized eggs was provided by immersing them in water of the requisite temperature.

Observations

Production of abnormalities:

The temperatures used and the types of head deformities produced are given in Table I. The malformations here are the defects in the brain, eyes, olfactory and otic regions. Since a defect of the eyes is very easily detectable, it has been taken as a criterion for the classification of the microcephalic forms.

Table 1—Showing the microcephalic abnormalities

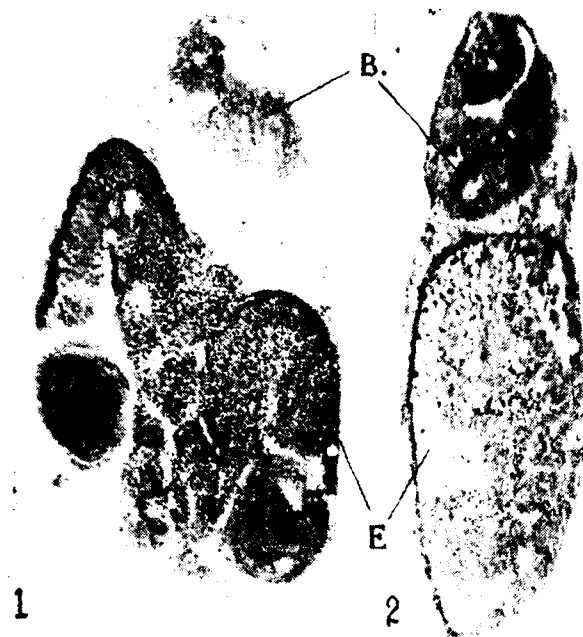
Treatment	Eggs treated	Gastru- lated	Synoph- thalmia	Monoph- thalmia	Microph- thalmia	Anoph- thalmia
32.5° to 37.0°C. for 5 minutes	936	437	23	0	77	0
0°C. for ½ to 3 hours	6069	1597	60	9	117	9

The types of microcephaly produced are *Synophthalmia*, *Monophthalmia*, *Microphthalmia* and *Anophthalmia*. *Synophthalmia* and *Microphthalmia* are the most frequent both in hot as well as cold treatments. *Monophthalmia* and *Anophthalmia* have been observed with less frequency in cold treatment while in hot treatment, these abnormalities were not observed at all.

Synophthalmia:

Under *Synophthalmia* are included those cases in which the two eyes show various degrees of ventral approximation. In the extreme case

both eyes fuse but their composite character remains externally recognisable. The terms *Synophthalmia Bilentica* and *Synophthalmia Unilentic* are used when the two lenses remain distinct or are fused, respectively. When the two eyes are fused in such a way that their composite nature is not discernable externally, the terms *Cyclopia* or *Monophthalmia*



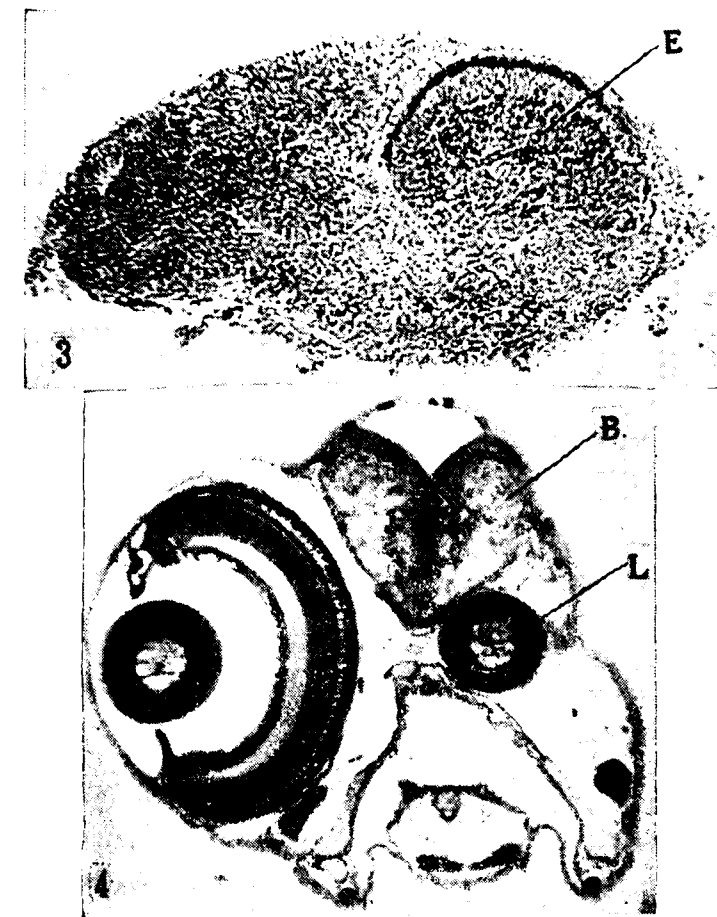
Text-Figs. 1 & 2: Sections through the eye region of synophthalmic embryos; 1. *Synophthalmia Bilentica*; 2. *Cyclopia Synophthalmia*. B = brain, E = eye; X162.

media Mediana are used. If, however, during a microscopic examination of sections, an eye is found to consist of two blended eye components the term *Cyclopia Synophthalmia* is used. *Cyclopia Perfecta* is a condition in which the composite nature cannot be made out even in sections. Most of the *Synophthalmia* abnormalities are either *Synophthalmia Bilentica* or *Cyclopia Synophthalmia*. These two cases are shown in figures 1 and 2.

Monophthalmia:

This is a condition in which only one eye is present. It lies on one side, the other eye being absent. To distinguish this type from *Cyclopia* or *Monophthalmia Mediana*, the term *Monophthalmia Asymmetrica*

is also used. Apart from the lack of one eye on one side, the embryos appear almost normal. Sections of early stages confirm the conditions observed in the living state (fig. 3). In one advanced embryo sections revealed however that a lens had also developed on the other side (fig. 4).



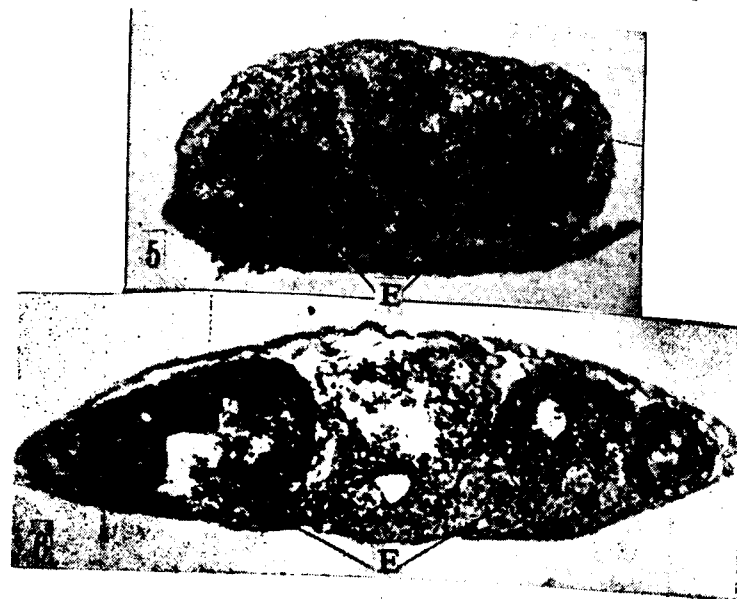
Text-Figs. 3 & 4: Sections passing through the eye region monophthalmic embryos; 3. early stage; 4. late stage B = brain, E = eye, L = lens developing without the eye cup. Magnifications X162 and X108 respectively.

Such a self-differentiation of a lens without the presence of an eye cup is not common among vertebrates. This second lens is only slightly smaller than the normally induced one of the other side.

Microphthalmia:

In this category are included all those forms of abnormalities in which eyes are in their normal place but are reduced in size and may then possess other defects. The two examples illustrated in figures 5

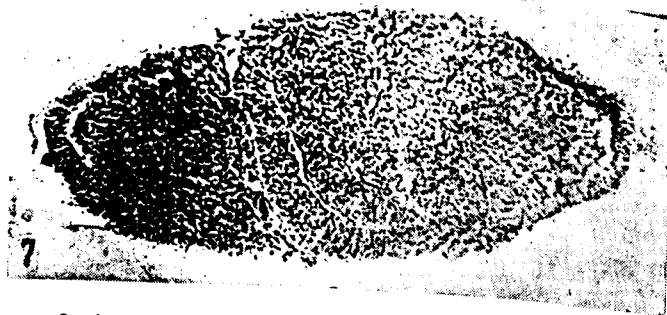
and 6 represent one case in which both the eyes are rudimentary (fig. 5) and one in which one eye is normal and the other rudimentary (fig. 6). In both these cases, the presence of pigment in the eye epithelium is



Text-Figs. 5 & 6: Sections through the eye region of microphthalmic embryos; 5. both eyes rudimentary; 6. one eye normal, the other rudimentary. E = eyes; X162.
noticable although the eyes were arrested in their morphological development at a stage in which normal embryos do not exhibit any such histological differentiation as pigment.

Anophthalmia:

The microphthalmic condition in its extreme is characterised by the absence of any eye. My anophthalmic embryos usually possess poorly



Text-Fig. 7. Section through the eye region of anophthalmic embryo. X162.
differentiated and deeply buried eye rudiments (Fig. 7) although external examination gave the impression of a total absence of eye anlagen.

Discussion

Very many interpretations have been offered to explain the abnormalities of this type but none is satisfactory. Werber (1916) and Wright (1934) assume that teratogenesis follows from differential destruction or inhibition of dominant regions, which are most susceptible to damaging influences. On the other hand Harrison (1945) and Lehmann (1937) believe that the malformations are expressions of defects in corresponding regions of the head organisers in the roof of the archenteron. Pasteels (1937, 1938) has postulated a chemical gradient concept. According to him all embryonic tissue differentiations are caused by one and the same hypothetical agent ('organisine') and that quantitative differences between the inductions are due to different concentrations of this agent.

A possible explanation for the development of microcephalic forms in the present experiments might be given on the basis of weak secondary inductions. Differentiation is determined not only by interaction between different germ layers, but is modified also by the action of surrounding cells which limit the type of a structure formed by any particular cell group. Such secondary effects may be responsible for the selective reduction which is sometimes seen in the head region. It is possible that the appearance of fluid filled spaces ('oedema') between the inducing and reacting tissues, may be responsible for the inhibition of or unequal differentiation of head organs. It may be mentioned here that many fish, which developed from the temperature treated eggs, later suffered from oedema and ultimately died.

The interesting case of monophthalmia in which a lens did develop in the absence of an eye cup, is similar to Spemann's and also Ten Cate's observations in *Rana esculenta* (Ten Cate 1956). The possible causes of an abnormality of this type have already been discussed by the author (Swarup 1959).

Summary

1. Microcephalic forms are produced when freshly fertilized eggs of *G. aculeatus* are subjected to heat and cold treatment.
2. The malformations include *Synophthalmia*, *Monophthalmia*, *Microphthalmia* and *Anophthalmia*.
3. The production of microcephalic forms is related to weak secondary inductions.

Acknowledgements

It is a pleasure to thank Sir Alister Hardy F.R.S. and Dr. M. Fischberg of the University of Oxford, with whom the author worked, for facilities and help.

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Taxonomy of the Lugworm Found off Bombay

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With 1 Text-Fig.

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Introduction

Fauvel (1953) states that occurrence of lugworms is rare in the tropical parts of the Indian ocean and no species of lugworm has yet been recorded. However, Ranade (1952) discovered for the first time the occurrence of lugworms from Bombay, the taxonomy of which is of considerable interest, since some of the external and internal features reveal deviation for the species already described (Ashworth, 1912).

Material and Methods

The lugworm in Bombay is found in a muddy flat, in the intertidal zone. Live specimens were collected and brought to the laboratory, where they were narcotised in sea-water, using either menthol or 7.5 per cent magnesium chloride. The latter was found more effective. For the relaxation and distension of the worms, the method adopted by Wells (1950) was used. They were then preserved in 4 per cent formalin.

Description

The largest specimen collected so far measured 250 mm. in length, including the tail length of 55 mm. The fresh live specimens are reddish-brown in colour. The region of the trunk is very deeply coloured, showing little variation from the other parts.

The body consists of a prostomium, peristomium, an achaetous segment, chaetiferous segments and tail segments (Fig. 1, a). There are 17 chaetiferous segments and this number was found to be constant in all the specimens examined. Variation was, however, observed in the total number of tail segments, the number varying from seven to ten. The annulation formula of the lugworm is i 2. ii 3. iii 3 or $3\frac{1}{2}$. iv. 4 v 4 vi 4

Prostomium is a tri-lobate structure. The middle lobe is more prominent and larger than the lateral lobes which are hidden in the nuchal groove.

The notopodia are present on the dorso-lateral aspect of all the chaetiferous segments only. Each notopodium consists of a cylindrical elevation—the chaetal sac, from the mouth of which the tips of chaetae project. The chaetal sac extends into the body cavity. The chaetae are capillary and laminate, with their margins typically dentate and tips sharply pointed (Text-fig. 1, c).

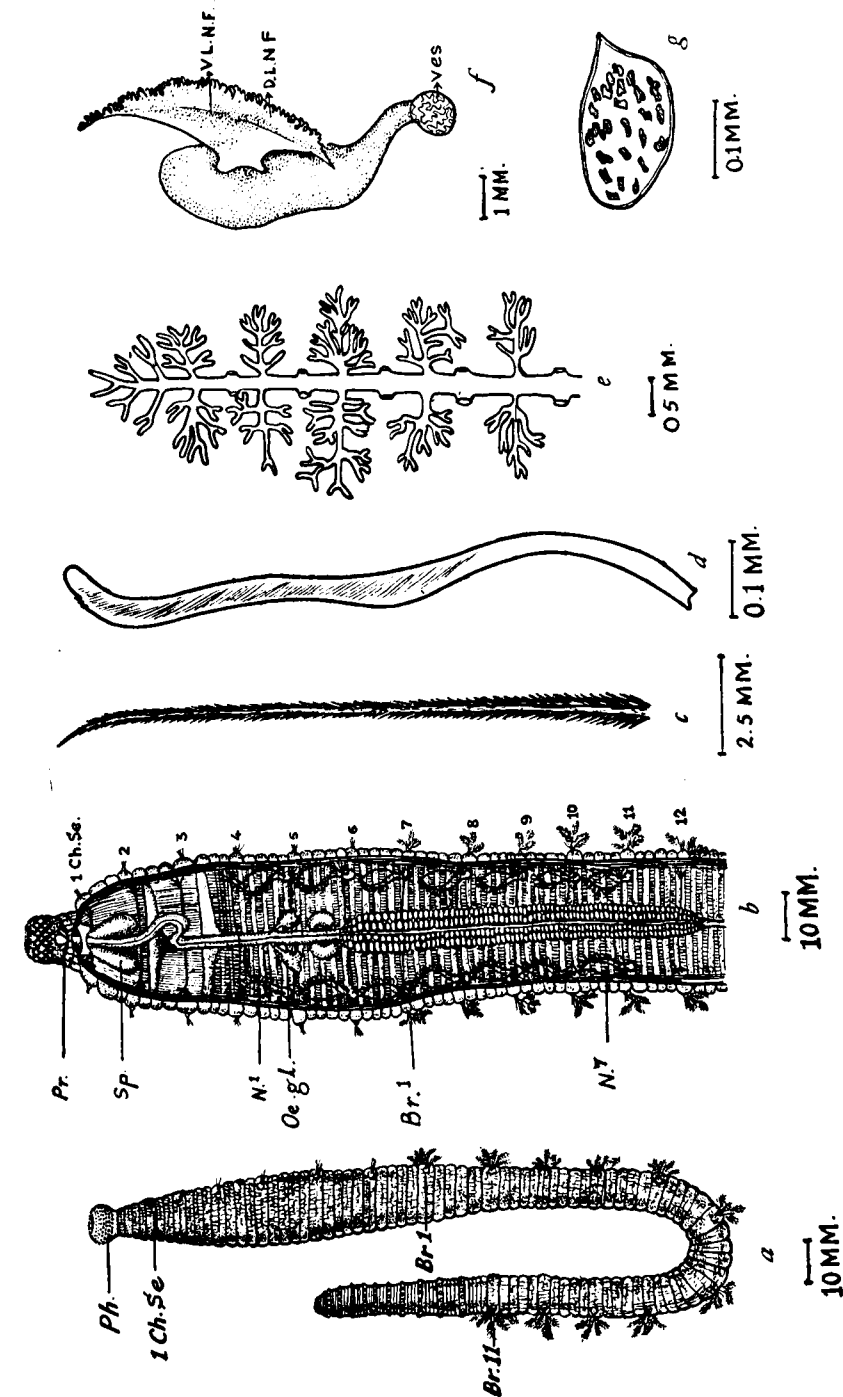
The neuropodia which appear as muscular ridges are situated on the ventro-lateral sides of the animal. These are clearly visible in all the chaetiferous segments, except in the first two. In the neuropodial ridge there is a row of crotchets. Each crotchet (Text-fig. 1, d) is made up of a shaft and a rostrum, both of which appear to be more or less in the same axis.

There are eleven pairs of gills, first pair being situated on the seventh chaetiferous segment. Each gill exhibits a number of pinnate-type stems or axes (Text-fig. 1, e) which radiate from a common basal trunk. The first pair of gills are the smallest, each consisting of only six to seven axes. The number of axes increase posteriorly. The gills in the last segment have nearly 14 axes.

A pair of septal pouches, situated in the anterior margin of the first chaetiferous segment, extend in between the first and the second transverse septa (Fig. 1 b). The average length of the septal pouch is approximately 8 mm.

There is a pair of oesophageal glands which are conical in shape and with a curved base (Text-fig. 1, b).

There are seven pairs of nephridia and this number was found constant in all the specimens examined. The nephridia open in the segments between the fifth and eleventh (Fig. 1, b). The dorsal lip of the funnel of each nephridium is frilled and the middle region of the ventral lip is slightly thicker than the anterior and posterior portions



a. Entire distended lugworm. Ph.—Proboscis; 1 Ch. Se.—1st chaetiferous segment; Br. 1—1st gill; Br. 11—11th gill. b. Internal Anatomy. Pr.—Prostomium; 1 Ch. Se.—1st chaetiferous segment Sp.—Septal pouch; N. 1—1st Nephridium Oe. gl.—Oesophageal gland; Br. 1—1st gill; N. 7—7th nephridium. c. Tip of an unworm chaeta. d. An unworm crotchet. e. Dorsal axis of the gill (pinnate type). f. Nephridium. V.L.N.F.—Ventral lip of the nephridial funnel; D.L.N.F.—Dorsal lip of the nephridial funnel; Ves.—Vesicle. g. Statocyst (Closed type) with statoliths.

(Text-fig. 1 f). All the nephridia open behind the upper terminal ends of the corresponding neuropodia.

The statocyst is a closed bag-like structure, situated on the dorso-lateral side of the oesophageal connectives, and contains many statoliths. (Text-fig. 1, g).

Discussion

Comparison of the characters of the Bombay lugworm with those of the other species of *Arenicola* already described (Ashworth 1912) shows that the Bombay lugworm comes near to either *A. cristata* (Simpson) or *A. glacialis* (Murdoch) or *A. glasseli* (Berkeley and Berkeley), but does not fully conform, as can be seen from the following table, to any one of these three species.

	Number of chaetiferous segments	Number of gills	Number of nephridia	Statocyst
<i>A.cristata</i>	17	11 pairs	6 pairs 1st on the 5th segment	closed with a single statolith
<i>A.glacialis</i>	17	11 pairs	6 pairs 1st on the 4th segment	Open with many statoliths
<i>A.glasseli</i>	16	10 pairs	7 pairs 1st on the 5th segment	Closed with a single statolith
Bombay lugworm	17	11 pairs	7 pairs 1st on the 5th segment	Closed with many statoliths

The number of chaetiferous segments, the number of gills and the number of nephridia have been considered as three main distinguishing characters in identifying different species belonging to the genus *Arenicola*. Berkeley and Berkeley (1939) state "the smaller size (of the sexually mature) individuals, the presence of only 16 setigerous segments and 10 pairs of branchiae and particularly, the presence of seven pairs of nephridia, all of which are constant in the material examined, seem

to sufficiently differentiate it from *A. cristata* to necessitate the establishment of a new species".

Since the Bombay lugworm also does not conform to any of the three species in the combination of all the three distinguishing characters, there is sufficient justification, in assigning to it the independent status of a new species. Moreover, it also differs from *A. cristata*, *A. glacialis* and *A. glasseli*, in the type of the statocyst and the number of statoliths in it.

The authors, therefore, propose to name the Bombay lugworm *A. bombayensis* (sp. nov.). The chief distinguishing features of the Bombay lugworm are as follows:—

Caudate *Arenicola* with 17 chaetiferous segments. Even pairs of pinnate type of gills, first pair smallest and situated on the seventh segment. Median lobe of the prostomium much larger than the lateral lobes. Neuropodia clearly visible in each chaetiferous segment. The rostrum and the shaft of each crotchet appear to be in the same axis. Seven pairs of nephridia opening on the fifth to the eleventh segments. A pair of oesophageal glands conical in shape and with a curved base. A pair of septal pouches, extending between the first and the second transverse septa. A pair of closed staocysts, with numerous statoliths.

Revised key to the species of *Arenicola*

- I Caudate species.
1. 19-20 chaetiferous segments; 13 (or 12) pairs of gills, the first on the 7th or 8th segment. ... 2

16-17 chaetiferous segments; 10 (or 11) pairs of gills, the first on the 6th or 7th segment. ... 6

2. One pair of oesophageal glands. ... 3

More than one pair of oesophageal glands. ... 4

3. 6 pairs of nephridia, 1st opening on the 4th segment; statocyst open, with many statoliths. ... *A. marina* (L)

- 5 pairs of nephridia, 1st opening on the 5th segment; statocyst closed, with a single large statolith. ... *A. loveni* (Kinberg)
4. 20 chaetiferous segments; 6 pairs of nephridia, 1st pair opening on the 4th segment. ... *A. assimilis* (Ehlers)
- 19 chaetiferous segments ... 5
5. 6 pairs of nephridia, 1st opening on the 4th (or 5th) segment, statocysts open with many statoliths. ... *A. assimilis* var. *affinis* (Ashworth)
- 5 pairs of nephridia, 1st opening on the 5th segment. Statocyst absent. ... *A. clapedii* (Levinsen)
6. 6 pairs of nephridia ... 7
- 7 pairs of nephridia. ... 8
7. Gills pinnate; 1st pair of nephridia opening on the 5th segment; Septal pouches larger; Statocysts closed containing single large statolith. ... *A. cristata* (Stimpson)
- Gills bushy; 1st pair of nephridia opening on the 4th segment; Septal pouches small; statocysts open, with many statoliths. ... *A. glacialis* (Murdoch)
8. 10 pairs of gills; 16 chaetiferous segments; statocyst closed, with a single statolith. ... *A. glasseli* (Berkeley & Berkeley)
- 11 pairs of gills; 17 chaetiferous segments; statocyst closed, with many statoliths. ... *A. bombayensis* (Sp. Nov.)

II. Ecaudate species.

1. 13 pairs of nephridia; 1st pair of gills on the 16th segment. ... *A. ecaudata* (Johnston)
2. 5 pairs of nephridia; 1st pair of gills on the 12th segment. ... *A. branchialis* Audoin & Edwards)

Acknowledgment

We are greatly indebted to Dr. C. V. Kulkarni, Director of Fisheries, Bombay, for his encouragement and suggestions. We are also grateful to Dr. G. P. Wells for his helpful criticism.

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Saurida tumbil (Bloch): Development and Feeding Habits

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Introduction

The binomics of the foreign species of *Myctophoidea* or lizard fishes belonging to *Callionymus*, *Synodus* and *Saurus* have been studied by Raffaele (1888), Ehrenbaum (1909), Lebour (1922) and others. The feeding habits of the Indian species of *Harpodon*, *Synodus* and *Saurus* have been studied by Hora (1934), Gopinath (1946) and Chacko (1949a). Vijayaraghavan (1953) collected eggs of *S. tumbil* from the plankton and reared them for forty-eight hours after hatching. He also collected from fishermen's nets the post larvae and analysed their food. But the age of the larvae could not be definitely determined. The present author was able to artificially fertilize eggs and follow the development upto identifiable juvenile stage. A brief general account of the early development of the eggs and the feeding habits of the larvae and juveniles is given in this paper.

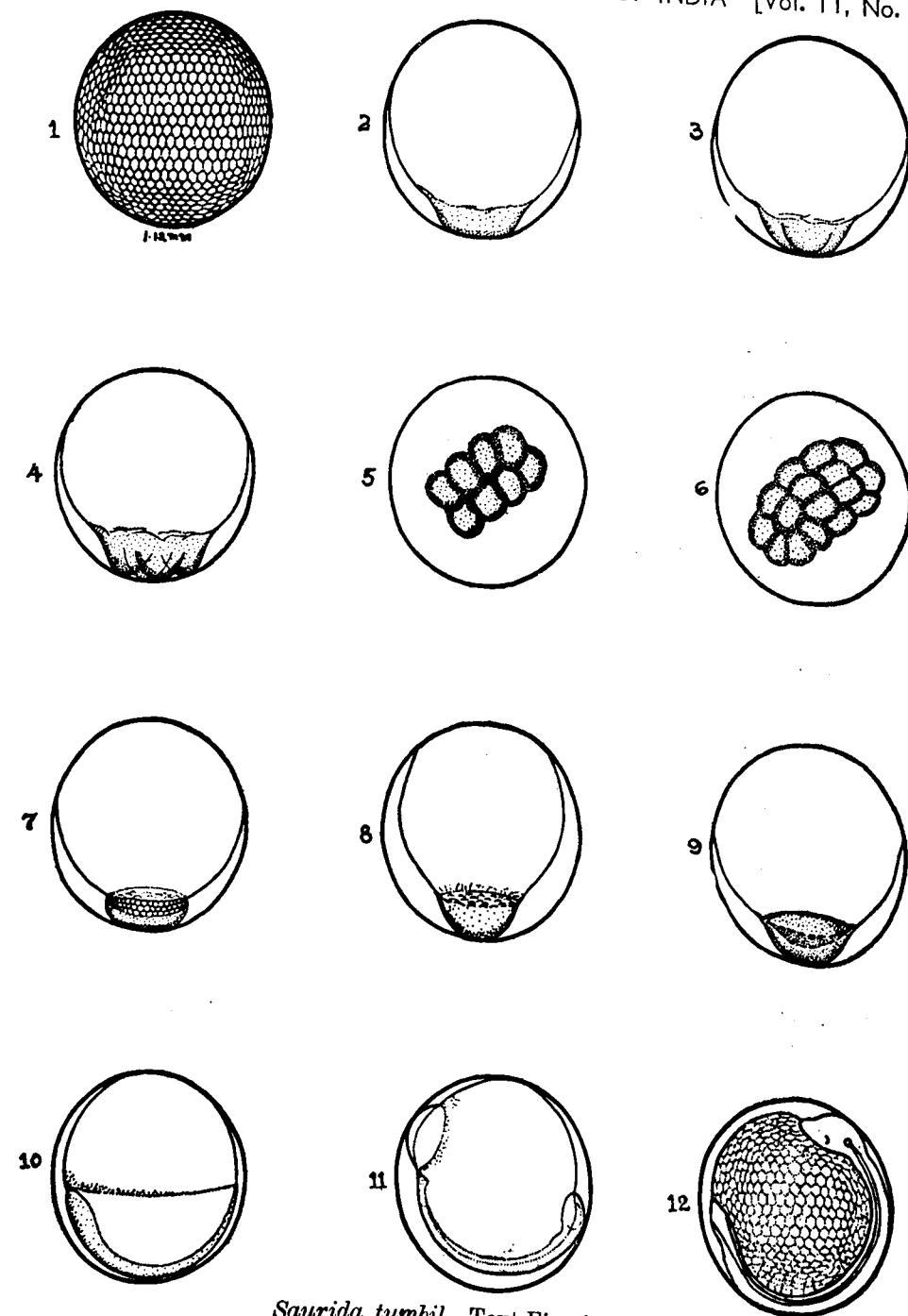
On 18th December, 1956, two males and two females were separated from a large number of live fishes brought to the laboratory. These mature fishes were left in a large glass tank and were kept under observation for about three days. Later they were cut open and the milt and the eggs were mixed in a small glass bowl of sea water. A few eggs were pipetted on to a slide and observed under the microscope.

Eggs:

They are pelagic, perfectly spherical and have an average diameter of 1.12 mm. Examination under microscope shows that the egg membrane is thin and marked by hexagonal areas of approximately equal size, measuring about 0.034 mm. across. The yolk is clear and transparent and contains no oil globule (Fig. 1).

A few minutes after fertilization the blastodisc is formed by the protoplasm accumulating at the lower pole of the egg, the yolk becoming whitish and less transparent. The gathering of the protoplasm at the animal pole results in the compression of the yolk in that region bringing the perivitelline space into evidence. The actual streaming motion of the protoplasm so well described by Ryder (1884) could not be seen in the case of *Saurida tumbil*. The completion of the blastodisc took about forty-five minutes at the end of which it had a lenticular shape with the protoplasm merging into an extremely thin peripheral layer that continued to surround the entire yolk sphere (Fig. 2).

The first cleavage begins about sixty-five minutes after fertilization. The first sign of division is initiated by a slight lengthening of the blastodisc on either side of the egg axis resulting in a groove at the animal pole of the egg. Into the deepening transverse furrow the yolk extends as a plug and helps the separation of the two halves of the blastodisc. Above this blastodisc the transverse furrow extends through the thin layer of protoplasm surrounding the yolk without however dividing the yolk. Segmentation is limited to the blastodisc. In about an hour and fifteen minutes, the segmented blastodisc becomes dome-shape and distinct from the rest of the egg (Fig. 3). After the completion of the first cleavage there is a resting period of about ten minutes. The second division is completed in fifteen minutes, in the same manner, being also meridional but at right angles to the first. (Fig. 4). After the second cleavage there is an interval of about five minutes, and the third cleavage was completed within an hour and fifty-five minutes. It is accomplished by two lateral furrows appearing simultaneously one on either side and parallel to the first plane of cleavage. This results in eight cells. (Fig. 5). The fourth cleavage follows immediately after the third and is in the form of two simultaneous furrows producing a sixteen-celled blastoderm (Fig. 6). The fifth cleavage which results in thirty-two cells takes place approximately after five hours and is followed by the sixth and subsequent cleavages resulting in 64, 128, cells etc. The blastoderm consisting of two layers of cells in the eight-hours-old egg (Fig. 7), exhibits a well rounded blastodermal cap. By about the 10th hour this becomes further pronounced and is conspicuous on the lower surface of the yolk (Fig. 8). The blastodermal cap of *Saurida tumbil* is smaller in size than that of *Parophrys vetula* (Paul 1940).



Saurida tumbil—Text-Figs 1 & 19.

1. Unfertilized egg, 2. Blastodisc, 3. Two cells, 4. Four cells, 5. Eight cells, 6. Sixteen cells, 7. Early blastodermal cap, 8. Completed blastodermal cap, 9. Segmentation cavity, 10. Germ ring approaching equator, 11. Blastopore nearing closure, 12. Advanced embryo.

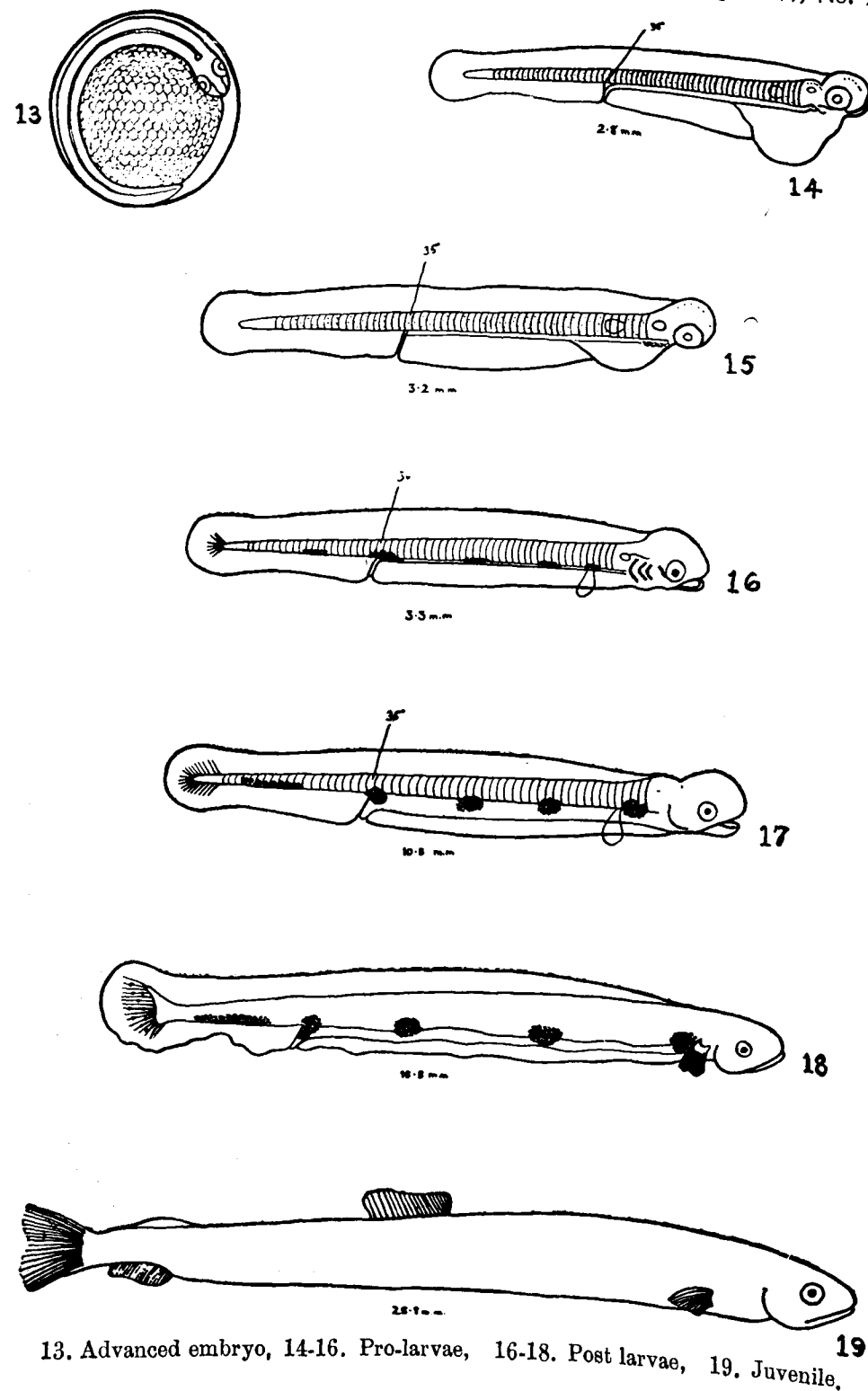
When sixteen hours old, the eggs show a distinct well-marked area at the base of the blastodermal cap which becomes marked with black dots. This indicates the formation of the segmentation cavity within the blastoderm (Fig. 9). The floor of the cavity is concave and the roof convex. With the blastodermal cap this cavity is pushed towards one side by the occurrence of a group of cells on the opposite side. This group of cells becomes a thickened mass destined to form the head rudiment of the embryo. By about the 20th hour (Fig. 10) the blastodermal cap had become so large that its lower limits extends very near the equator of the egg. The roof of the segmentation cavity becomes so thickened along the mid-line that the outline of the body of the future embryo can be made out. By about the 22nd hour (Fig. 11) this thickening on the roof of the segmentation cavity appears continuous with the group of thickened cells mentioned before to form the body and the head of the embryo. In the 33 hours old egg (Fig. 12) the embryo nearly encircles the whole of the egg and has eyes and auditory vesicles. In such an embryo pigment cells can be seen and a pulsating heart can also be discerned. Fig. 13 shows the embryo forty-eight hours after fertilization. The embryo lies coiled almost into a ring and is more superficial to the yolk, but close beneath the egg membrane. The myotomes as well as the unpigmented eyes can be seen clearly through the egg membrane. The tail end of the embryo twitches periodically 20 minutes after this, i.e., two days and twenty minutes after fertilization, the embryo hatches, the tail being thrust out of the membrane and lashing about.

Just hatched larvae (Fig. 14):

On the second day at about 7-20 a.m. when the larvae hatch out, they measure about 2.8 mm and are seen to dart from place to place when the bowls in which they are contained are disturbed. The yolk is not completely absorbed and the dorsal and ventral fin-folds are continuous and entire round the caudal region. There is no indication of the mouth or gill-slits. The gut is narrow and long and the anus is situated under the 35th myotome and nearly nineteen post-anal myotomes were counted. Under high power the muscle fibres in the myotomes show crossed arrangements characteristic of the clupeids. Black pigment spots are seen scattered irregularly all over the body.

Larvae 3 days old (Fig. 15):

On the third day morning they were 3.2 mm. long. The mouth is not formed, and the eyes are still unpigmented. The rudiments of the pectoral fins are seen below the 3rd myotome and behind the enlarged auditory vesicle. There is no change in pigmentation of the larvae, nor the number of myotomes or the condition of the median fins. The yolk is much reduced.



13. Advanced embryo, 14-16. Pro-larvae, 16-18. Post larvae, 19. Juvenile.

By the evening of the third day, at about 5 p.m. the yolk is completely absorbed and the post-larvae grow to 3.3 mm. (Fig. 16). The eyes are pigmented. The black pigment spots on the body are concentrated into nine patches, four paired and one unpaired, along the ventral border of the myotomes. Of these, three paired ones are in front of the anus, one is just above it and the single unpaired patch is on the lower side of the tail. The post-anal myotomes are now clearer and twenty can be counted. The fin-folds are still continuous, but pectoral fins are very prominent. Gills begin to appear and four are clearly visible. The mouth is in communication with the alimentary canal.

Out of a total of 384 pro-larvae hatched in the laboratory sixty-nine died at this stage and the remaining became post-larvae. The larvae were separated into lots of twenty-five and reared in separate dishes. Some lots were supplied with copepod (eggs, nauplii and adults), a few were supplied with cirripede larvae a few others with diatoms, molluscan larvae, polychaete larvae, and species of *Diatomaceae* and few others with other items of planktonic food. The different lots of larvae were kept under close observation. It was found that the larvae feed only on copepod eggs, nauplii and adults. Thereafter all the fish larvae in the different dishes were supplied with only this item of food. Daily observation showed that the post-larvae feed upon *Oithona* sp. *Acartia* sp, *Eucalanus* sp, *Pontella* sp, *Corycaeus* sp, *Pseudodiaptomus* sp, and *Acrocalanus* sp, till they are fourteen days old and grew to a length of 10.8 mm.

Larvae 15 days old (Fig. 17):

The mouth is wide and minute teeth can be seen on the lower jaw. The median fins are still continuous. The pectoral fins are considerably enlarged in size and are devoid of fin-rays. There is no change in the number of pre-anal myotomes and the myotomes are slightly broader than in the previous stage.

In the matter of feeding there is a change. They do not feed any longer on copepods which form the diet during the preceding days. Into one dish a small quantity of unsorted plankton was introduced. After an interval of two hours, the post-larvae were killed and their stomach contents teased out and examined under the microscope. It was found that they had fed upon 32% of molluscan larvae, 30.4% of polychaete larvae and 37.6% of diatoms. This experiment was repeated in each dish and the results show that the post-larvae at this stage prefer a mixed diet of vegetable and animal matter.

It cannot be however concluded that they avoided crustacean food, for Vijayaraghavan (1953) who had collected post-larvae 10.2 mm—14 mm long from the sea, had found that they fed on cirripede larvae and copepod nauplii. He had also observed that the diet included *Dinophyceae*

like *Ceratium* sp, *Procentrum* sp, echinopluteus larvae, etc. It is probable that the larvae reared in the laboratory rejected these items offered to them preferring the diatoms in the dish. That the fifteen days old post-larvae show a preference for a mixed diet is however clear since they thrive on such a diet till they are thirty-three days old.

Larvae 26 days old (Fig. 18):

The larvae have grown to 18.8 mm. and the operculum is well formed and prominent. The larvae have become opaque and the myotomes and the alimentary canal cannot be made out. The region of the head in front of the orbit becomes a prominent snout. The mouth was very wide and the angles of the jaws extended beyond the hind ridge of the orbit. The lower jaw is longer than the upper and there are numerous minute sharp teeth on both the jaws. Pigmentation is similar to that of stages described above except in the caudal region where the black branching chromatophores become more scattered, but arranged along the mid-ventral line. The caudal fin-rays can now be seen more clearly and there is a slight indication of forking.

Larvae 34 days old:

Though the post-larvae have grown to 22.4 mm. in length on the 34th day, there is not much change in the external features. But during the next eight days, the growth of the larvae is slower, though all the features of the juvenile stage develop.

As on the previous days other items of food principally crustaceans were introduced to see if the diet changed. It was found that these larvae which grew to a length of 24.8 mm. were able to feed upon chiefly *Lucifer*, larval *Acetes*, and larvae of fish genera like *Leiognathus* sp, *Stolephorus* sp, *Clupea* sp, *Upeneus* sp, and *Sciaena* sp. The small sized copepods were neglected.

Juvenile 42 days old (Fig 19):

Adult features are fairly well defined in these, though the second dorsal fin is not fully developed. Two kinds of teeth can be distinguished in the jaws, one short and conical and the other long and narrow. These two types of teeth occur alternately in the same row. The nostril is prominent and is placed in front of the eye. The median fins are well differentiated and the fins have developed rays. The first dorsal has eleven rays and the second one is membranous with backwardly directed lobe which subsequently develops into adipose fin in the full grown adult fish. The anal fin is placed immediately below the adipose fin and has ten rays. The pectorals are situated above the first pair of abdominal spots and has fifteen rays in each. The ventrals are present only as two stumps, but have nine rays as in the full grown fish and are placed below the second pair of spots.

Feeding experiments conducted show that the juveniles feed chiefly on a variety of animals. Though *Lucifer*, *Acetes*, and *Mysis* formed the major item of food, copepods (*Pseudodiaptomus* sp, *Oithona* sp, *Eucalanus* sp, *Acartia* sp, *Temora* sp, *Euterpina* sp) larval decapod and cirripede larvae are occasionally found in the stomach. In the juvenile stage also a predominant portion of the food consists of fish like (*Leiognathus* sp, *Stolephorus* sp, *Gazza* sp, and *Clupea* sp) as in the previous stage.

A total of 218 adult fishes were examined. Prawns (*Penaeus* sp) formed the major item of food. Teleostean larvae and adults (*Stolephorus* sp, *Engraulis* sp, *Trichiurus* sp and *Leiognathus* sp) were often found in the stomach. Small amounts of copepods (*Acartia* sp, *Oithona* sp, *Eucalanus* sp and *Paracalanus* sp), cirripede larvae, larval decapods and *Sagitta* spp also were found in the stomach.

Summary

1. Brief account of the previous work on the bionomics and feeding habits done both in India and abroad is reviewed.
2. The various stages in the life history of *Saurida tumbil* are described with notes on the artificially fertilized eggs and the changes taking place during the development are added.
3. Feeding begins invariably with the transformation of the pro larvae into post larvae. The fish begins on a diet of copepod eggs, Nauplii and adults during larval stages, but gradually changes over to larger pelagic organisms as it grows and finally subsists on planktonic as well as nectonic organisms when they become adults.

Acknowledgements

I wish to thank Professor C. P. Gnanamuthu M.A., D.Sc., Director, University Zoology Research Laboratory, Madras, for suggesting the problem and for his guidance throughout the course of investigation. I am indebted to Dr. M. V. Lebour for offering valuable suggestions. I am also thankful to Dr. S. Krishnaswamy for help in identifying the copepods.

In conclusion I wish to thank the syndicate of the Madras University for the award of a Research Fellowship during the tenure of which the present investigation was conducted,

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The Apical Tibial Spur Formula in the Termite Genus *Coptotermes*

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(With 1 Table and 4 Text-figures)

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Introduction

The distal end of the tibia of each of the three throacic legs, i.e., the fore-middle-and hind-legs, of termites (Insecta: Isoptera) carries a number of large spurs, called the “apical tibial spurs”, which are readily distinguishable by their larger size, stronger build and darker colour from the numerous spines on the remaining portion of the tibia. The number of the apical tibial spurs on each tibia usually varies from 2 to 3, and it is sometimes possible to use them for the separation of genera, and of species within a genus. This number is generally expressed in a definite order, viz., those on the fore-tibia,

middle-tibia and hind-tibia, and the expression is then called the “apical tibial spur formula” or simply “tibial spur formula”. Thus, the formula 3: 3: 2 would mean that the number of apical tibial spurs is 3 in the fore-tibia, 3 in the middle-tibia and 2 in the hind-tibia.

While carrying out a revision of the oriental members of the termite genus *Coptotermes* Wasmann (family Rhinotermitide, subfamily Coptotermitinae), we found that while the older authors (Wasmann, 1896; Desneux, 1904; Holmgren, 1913) gave no indication of the number of apical tibial spurs in *Coptotermes*, the more recent ones (Hill, 1942; Ahmad, 1950) gave the tibial spur formula as 3: 3, (which differed from our own observations (3: 2: 2). Consequently, we carried out the examination of a large number of species of *Coptotermes*, and of all the castes (*viz.*, the imago or alate, the soldier and the worker), from all over the world available to us, and the results are presented here.

Number of Apical Tibial Spurs in *Coptotermes*
(Table 1 and Text-figs. 1-4)

We examined (Table 1) a total of 32 out of about 45 known species from all over the world, *viz.*, Africa, Asia, Australia, New Zealand, Papua (New Guinea), South America, Central America (Mexico and Panama) and the Pacific islands (Hawaii, Palau and Solomon). The various castes examined were as follows:—Imagos (alates), 17 species; soldiers, 32 species; and workers, 28 species. The tibiae, and their apical spurs, of *Copototermes heimi* (Wasmann), from India (Text-figs. 1-3, imago, soldier and worker respectively) and *C. acinaciformis* (Froggatt), from Australia (Text-fig. 4, soldier) are illustrated.

In all species and in all the castes examined by us the number of apical tibial spurs were invariably as follows:—Fore-tibia 3; middle-tibia 2; and hind-tibia 2. The spur formula, thus, is 3: 2: 2.

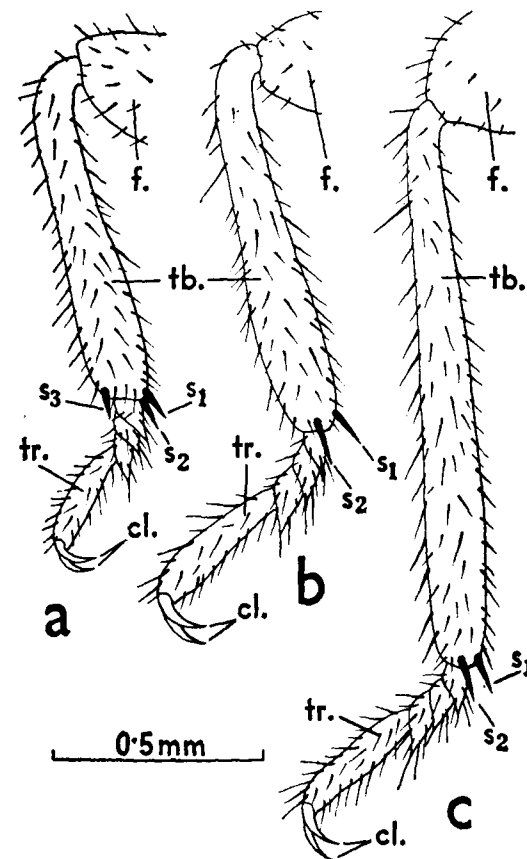
TABLE 1.—Apical tibial spurs in the genus *Coptotermes* Wasmann.

Note:—The number of apical tibial spurs is mentioned in the following order: Fore-tibia, middle-tibia and hind-tibia.

Serial No.	Species of <i>Coptotermes</i>	Locality of specimens examined	Castes examined, and tibial spur formula		
			Imago	Soldier	Worker
1	<i>acinaciformis</i> (Froggatt)	Australia ; New Zealand	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
2	<i>amanii</i> Sjöstedt	Tanganyika (Africa)	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
3	<i>boetonensis</i> Kemner	Java	—	? : ? : 2	3 : 2 : 2
4	<i>ceylonicus</i> Holmgren	Ceylon ; India	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
5	<i>crassus</i> Snyder	Mexico	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
6	<i>curvignathus</i> Holmgren	Indonesia; Philippines	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
7	<i>dregghorni</i> Hill	N. Queensland (Australia)	3 : 2 : 2	3 : 2 : 2	—
8	<i>formosanus</i> Shiraki	S. Africa ; Formosa ; Ceylon ; Hawaii	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
9	<i>frenchi</i> Hill	Australia ; New Zealand	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
10	<i>gaurii</i> Roonwal & Krishna	Ceylon	—	3 : 2 : 2	3 : 2 : 2
11	<i>gestroi</i> Wasmann	India	—	3 : 2 : 2	3 : 2 : 2
12	<i>grandiceps</i> Snyder	Solomon Is. (Malanesia, Pacific Ocean)	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
13	<i>harrisi</i> Emerson	Uganda (Africa)	—	3 : 2 : 2	—
14	<i>havilandi</i> Holmgren	Java	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
15	<i>heimi</i> (Wasmann)	India	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
16	<i>hyaloapex</i> Holmgren	Papua (New Guinea)	—	3 : 2 : 2	3 : 2 : 2
17	<i>intermedius</i> Silvestri	Gold Coast (Africa)	—	3 : 2 : 2	3 : 2 : 2
18	<i>kishori</i> Roonwal & Chhotani (sp. nov.)	India	—	3 : 2 : 2	3 : 2 : 2
19	<i>lacteus</i> (Froggatt)	Australia	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
20	<i>michaelsenii</i> Silvestri	Australia	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
21	<i>niger</i> Snyder	Barro Colorado Is. (Canal Zone, Panama)	3 : 2 : 2	3 : 2 : 2	—
22	<i>obiratus</i> Hill	Port Morsley (Papua)	—	3 : 2 : 2	3 : 2 : 2
23	<i>peregrinator</i> Kemner	Saleier Is. (Celebes group, Indonesia)	—	3 : ? : ?	3 : 2 : 2
24	<i>raffrayi</i> Wasmann	Australia	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
25	<i>reductus</i> Sjöstedt	Gold Coast (Africa)	—	3 : 2 : 2	3 : 2 : 2
26	<i>remotus</i> Hill	Palau Is. (S. Pacific Ocean)	—	3 : 2 : 2	3 : 2 : 2
27	<i>sinabangensis</i> Oshima	Malaya	—	3 : 2 : 2	—
28	<i>sjöstedti</i> Holmgren	Belgian Congo (Africa)	—	3 : 2 : 2	3 : 2 : 2
29	<i>testaceus</i> (Linnè)	British West Indies ; Brazil	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2
30	<i>travians</i> Haviland	Borneo; Burma; India; Singapore (Malaya)	—	3 : 2 : 2	3 : 2 : 2
31	<i>truncatus</i> Wasmann	Madagascar	—	3 : 2 : 2	3 : 2 : 2
32	<i>vastator</i> Light	Philippines	3 : 2 : 2	3 : 2 : 2	3 : 2 : 2

Discussion

Neither Wasmann (1896, pp. 628-629), the original author of the genus *Coptotermes*, nor the subsequent revisers, namely, Desneux



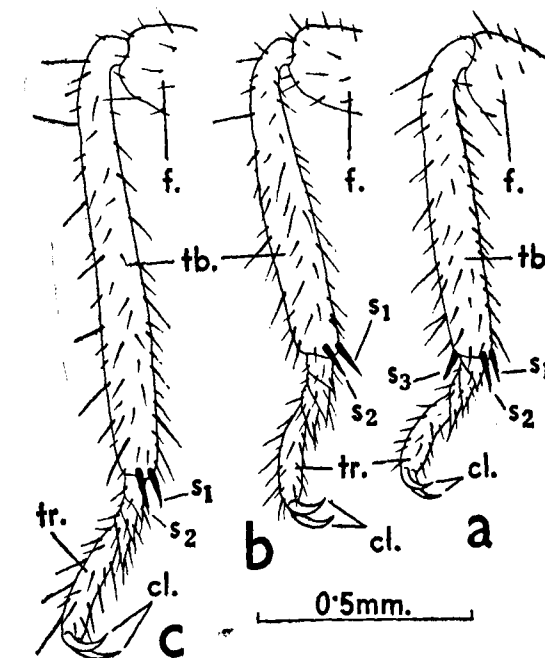
Text-fig. 1. *Coptotermes heimi* (Wasmann), from India. Fore-, middle-, and hind-tibiae of imago (alate).

(a) Fore-tibia. (b) Middle-tibia. (c) Hind-tibia.

cl., claws; f., femur; s_1 , s_2 , s_3 , apical tibial spurs; tb., tibia; tr., tarsus.

(1904) and Holmgren (1913) made any mention of the number of apical tibial spurs in the representatives of this genus. In his account of the Australian termites, Hill (1942, p. 141), while giving the characters of the soldier caste of the genus *Coptotermes*, stated as follows:—"Tibial spurs 3 : 3 : 3, as in other castes." Ahmad (1950, p. 53) also assign-

ed the same formula to the subfamily Coptotermitinae and sought to distinguish it on that ground from the allied subfamily Heterotermitinae. He wrote as follows:—"The Heterotermitinae, though close to the Coptotermitinae, possess several distinct higher revolutionary features, such as the reduction of antennal articles, pronotum, anterior wing



Text-fig. 2. *Coptotermes heimi* (Wasmann), from India. Fore-, middle-, and hind-tibiae of soldier caste.

(a) Fore-tibia. (b) Middle-tibia. (c) Hind-tibia.

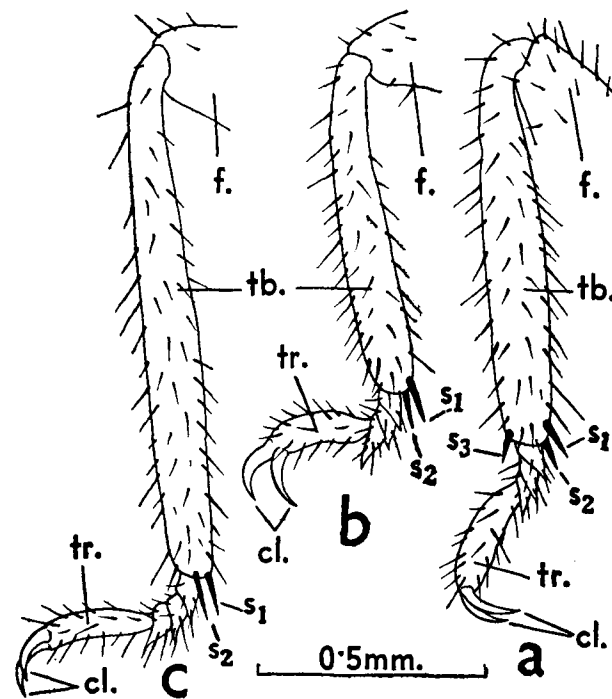
cl., claws; f., femur; s_1 , s_2 , s_3 , apical tibial spurs; tb., tibia; tr., tarsus.

scales, and the 3 : 2 : 2 tibial spurs (3 : 3 : 3 in the Coptotermitinae)."

As shown above, the tibial spur formula in the genus *Coptotermes* (the sole genus in the subfamily Coptotermitinae is 3 : 2 : 2 and not 3 : 3 : 3. Thus, on this basis alone it is not possible to separate the Coptotermitinae from the Heterotermitinae, although there are other grounds to justify the separation.

Summary

1. The number of apical tibial spurs was studied in 32 species of the genus *Coptotermes* Wasmann (Isoptera, family Rhinotermitidae, subfamily Coptotermitinae) from all over the world, viz., Africa, Asia, Australia, New Zealand, Papua (New Guinea), South America, Central America (Mexico and Panama), and various island in the Pacific Ocean. All the three available castes were examined as follows:—Imagos (alates), 17 species; soldiers, 32 species; and workers, 28 species.



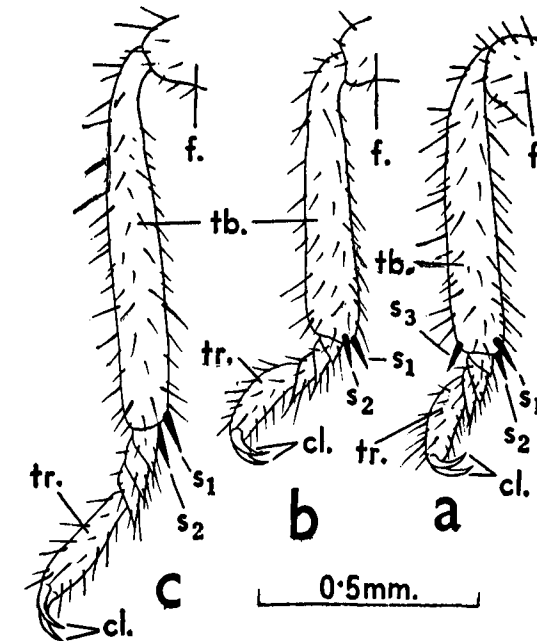
Text-fig. 3. *Coptotermes heimi* (Wasmann), from India. Fore-, middle-, and hind-tibiae of worker caste.

(a) Fore-tibia. (b) Middle-tibia. (c) Hind-tibia.

cl. claws; f., femur; s_1, s_2, s_3 , apical tibial spurs; tb., tibia; tr., tarsus.

2. In all the species and in all the castes examined, the number of tibial spurs were as follows:—Fore-tibia 3; middle-tibia 2; and hind-tibia 2. The "tibial spur formula", thus, is 3 : 2 : 2. This is in contrast to the findings of some authors who gave the formula as 3 : 3 : 3.

3. The tibiae, and the apical spurs, of *Coptotermes hiemi* (Wasmann), from India (Text-figs. 1-3, imago, soldier and worker respectively, and *C. acinaciformis* (Froggatt), from Australia (Text-fig. 4, soldier) are illustrated.



Text-fig. 4. *Coptotermes acinaciformis* (Froggatt), from Australia. Fore-, middle- and hind-tibiae of soldier caste.

(a) Fore-tibia. (b) Middle-tibia. (c) Hind-tibia.

cl. claws; f., femur; s_1, s_2, s_3 , apical tibial spurs; tb., tibia; tr., tarsus.

4. Thus, on the basis of the tibial spur formula alone, it is not possible to separate the subfamily Coptotermitinae from the allied subfamily Hetertotermitinae, as has been done by some authors, although there are other grounds to justify the separation.

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New Grass Gall Midge (Itomididae Cecidomyiidae) From India

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With 16 Text-figures.

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Introduction

The midge described in this article differs from all the known Indian midges from grasses (Felt, 1921). This midge was first noticed in October, 1958 on grass under a huge tree in the lawns of the Zoology Department. On subsequent dates it was noticed that these insects produced small galls on the stems of the grass.

The type slides are for the time being retained in the collections of the senior author.

Dactylodiplosis indica Sp. Nov.

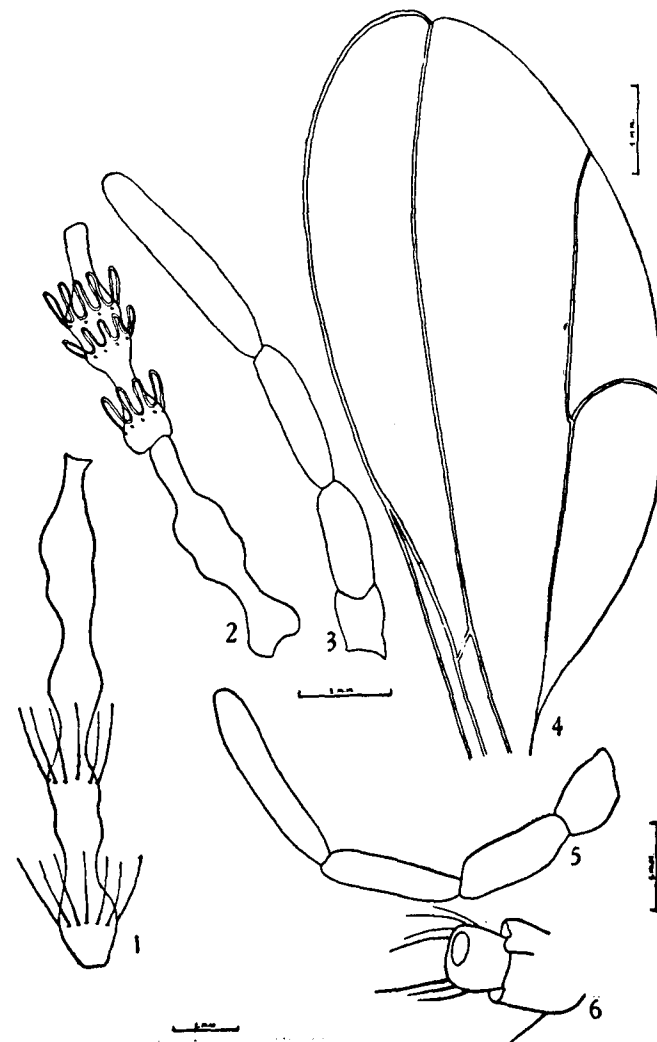
Subfamily Itomidinae.

Tribe Triflini.

Dactylodiplosis indica, sp. nov.

♂ Length 2.4 mm. Body blackish-yellow. Eyes confluent above. Antenna shorter than body, pale yellow, with 14 segments, flagellate segments cylindrical with very short stems with two whorls of long hairs and three whorls of circumfila; first antennal segment longer than broad, light brown, length one and one-fourth times the maximum breadth, nearly oval, broader apically than at base; second antennal segment oval, light brown, broadest in middle, length one and one-fourth times the maximum breadth; third antennal segment confluent with the fourth, cylindrical, with a very slight constriction in middle, length nearly thrice the maximum width, stem broader

than long (4 : 5); fourth segment nearly as long as third segment, length three and one third times the maximum width, stem broader than



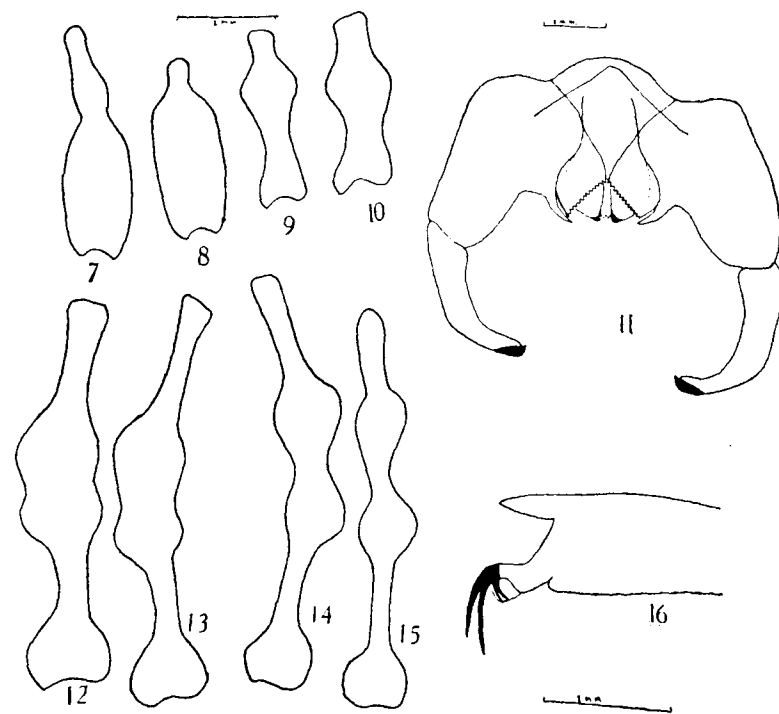
1. Third and fourth antennal segments of female
2. Fifth and sixth antennal segments of female
3. Palpus of female
4. Wing of male
5. Palpus of male
6. First and second antennal segments of male

long; sixth antennal segment as in figure 10; seventh antennal segment cylindrical, with a slight constriction in middle; length two and three-fourths the maximum width, stem one and half times as long as broad;

ninth segment nearly equal to seventh segment, length of enlargement nearly two and a half times its diameter, stem nearly one-fourth the length of segment, length one and two-thirds the maximum width; twelfth segment as in figure 9; thirteenth segment (Text-fig. 8) cylindrical with an enlargement two and two-thirds as long as thick, stem one and one-third as long as thick; terminal segment (Text-fig. 7) cylindrical, with an oval stem tapering at apex, length three and one-fourth times the thickness. Palpi (Text-fig. 3) quadriarticulate, long, sparsely setose; first segment nearly oval, length one and one-third times its diameter, second segment longer than first, cylindrical, two and one-third times as long as thick, third segment slightly longer than second, cylindrical, ends slightly tapering, length four times the maximum thickness, fourth segment longest of all, cylindrical, with the apices tapering, maximum thickness as in third segment, length six times the maximum thickness. Mesonotum dark brown, darker than rest of thorax; scutellum and postscutellum brown, paler than mesonotum. Abdomen pale brown. Wing hyaline, nearly four times as long as broad, vein *R*_s distinct but incomplete, vein *Sc* joining costa much before middle of wing, vein *R*₅ evenly curved and reaching wing margin a little beyond apex vein, *M*₁ 2 wanting, vein *M-m-Cu* forked. Halteres pale brown. Legs pale brown, densely hairy, metatarsus half the length of terminal tarsal segment, second tarsal segment longest, longer than rest of tarsal segments combined. Claw bifid on all legs, bent at right angles, brown, empodium nearly less than one fourth the length of claw. Ovipositor short, exerted with two oval lobes and a third triangular lobe.

♂ Length 1.23 mm. Body pale-brown. Eyes confluent above. Antenna slightly longer than body, with 14 segments, flagellate segments cylindrical, apical segments being narrower, trinodose, with long apical stems, with two whorls of long hairs, one on basal and another on apical enlargements, with three whorls of circumfila, middle whorl slightly shorter than rest. First antennal segment (Text-fig. 6) yellow, widest at apex, with long hairs, nearly globular; second antennal segment (Text-fig. 6) nearly as long as thick, globose, slightly darker and smaller than first segment; third segment Text fig. 1 confluent with fourth, very slightly longer than fourth, basal enlargement with a small basal stem nearly one third the length of segment and nearly one and one-fourth times as long as broad (15 : 11), basal stem a little less than half the length of basal enlargement, very slightly longer than broad, apical enlargement one-third the length of segment and one and a half times as long as broad (15 : 10), apical stem longer than basal stem, two-thirds the length of apical enlargement and two and a half times as long as broad; fourth segment (Text fig. 1) very slightly shorter than third segment, basal enlargement nearly one-fourth the length of segment, as long as broad (10 : 11), basal stem nearly two-thirds the length of basal enlargement and one and two-fifths as long as broad, apical enlargement a little

less than one-third the length of enlargement and one and three-fifths as long as broad, apical stem shorter than basal enlargement, three-fourths the length of apical enlargement and nearly thrice as long as broad; fifth and sixth antennal segments as in Text fig. 2; seventh segment as long as fourth segment, basal enlargement one-sixth the length of the segment, broader than long, length four-fifths the maximum breadth, basal stem a little longer than basal enlargement, length two and a half times the maximum breadth, apical enlargement one-third the length of the segment and one and a half



- | | |
|---|--|
| 7. Terminal antennal segment of female | 12. Seventh antennal segment of male |
| 8. Penultimate antennal segment of female | 13. eleventh antennal segment of male |
| 9. Twelfth antennal segment of female | 14. Penultimate antennal segment of male |
| 10. Sixth antennal segment of female | 15. Terminal antennal segment of male |
| 11. Genitalia | 16. Hind claw of male |

times as long as broad, apical stem shorter than apical enlargement, four times as long as broad; ninth segment longer than seventh segment, basal enlargement one-sixth the length of segment, broader than long, basal stem longer than basal enlargement and four-fifths the length of segment, length three and one-third times its maximum thickness, apical enlargement a little over one-third the length of segment and twice as long as broad, apical stem as long as apical enlargement, five times as long as broad; eleventh segment longer than ninth, basal enlargement one-seventh the length of segment, broader than long

(7 : 9), basal stem longer than basal enlargement, length nearly one-fifth the length of segment and three and one-third times the length of maximum breadth, apical enlargement half the length of segment and nearly twice as long as broad, apical stem longer than apical enlargement, length nearly six times its breadth; thirteenth segment longer than eleventh, basal enlargement one-seventh the length of segment, broader than long (7 : 8), basal stem longer than basal enlargement, length three and two-thirds the maximum breadth, apical enlargement longer than basal enlargement, length two and a half times the breadth, apical stem longer than basal stem, length nearly four times the breadth; terminal segment as long as the penultimate, basal enlargement one-fifth the length of segment, length one and three-sevenths the maximum breadth, basal stem as long as basal enlargement, length three and one-third times the maximum breadth, apical enlargement twice as long as basal enlargement and two-fifths the length of segment, nearly thrice as long as broad, apical stem as long as basal stem but half the length of apical enlargement and similar to basal stem. Palpi (Text-fig. 5) quadriarticulate, long, sparsely setose, first segment smallest of all, length two and a half times the maximum breadth, second segment longer than first, broadest at basal one-third, length two and two-thirds the maximum breadth, third segment longer than second, cylindrical, thinner than second segment, length a little more than thrice the thickness, terminal segment longest of all, as broad as third segment, cylindrical, length six times the maximum thickness. Mesonotum dark brown. Slightly darker than rest of thorax. Scutellum and postscutellum brown, slightly paler than mesonotum. Abdomen light brown, paler than mesonotum. Wings as in female. Halteres pale yellow. Legs pale yellow, long, densely hairy; metatarsus shorter than terminal tarsal segment, second tarsal segment longest but shorter than rest of tarsal segments combined, hind claw (Text-fig. 16) bifid on all legs, bent at right angles, dark brown, empodium less than one fourth the length of claw. Genitalia (Text-fig. 11): dorsal plate deeply and broadly incised in middle, lobes broadly angulated at tips, margins beset with short stiff setae, ventral plate nearly as long as dorsal plate, one and a half times as long as broad, broadest subapically, slightly incised in middle, lobes nearly subtriangular, apices thickly chitinised in the form of blunt short teeth, style slender, as long as ventral plate, a little shorter than dorsal plate, five times as long as thick, basal clasp segment stout, twice as long as broad, with a pointed and slightly curved spine at base, terminal clasp segment evenly curved at base, gradually tapering at apex and ending in a blunt tooth.

Holotype: one female dissected and mounted on slide labelled "Midges collected and reared from grass—*Andropogonis* sp. in Gulba's enclosure, Nov. 1958, S. N. R. Coll., Nagpur"

Allotype: one male dissected and mounted on slide and labelled as above.

Paratypes: Large number of males and females dissected and mounted on slides in the collections of the senior author.

This species differs from the only known Indian species of this genus *Dactylodiplosis? menoni* Mani in the structure of the genitalia and wing venation. This is probably the first definite species from India under this genus.

Acknowledgments

We take this opportunity of recording our deep gratitude to Dr. N. G. Shabde, Principal and Dr. S. M. H. Khatib, professor of Zoology, College of Science, Nagpur, for all the facilities

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On the Insect Pests of Paddy in Orissa

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Introduction

The State of Orissa had about 9,361,000 acres of land under cultivation of paddy in 1955-56, yielding 2,068,464 tons. It is one of the major paddy growing States in the Indian Union and exports surplus rice to the neighbouring areas. So far there is no consolidated account of the various insect pests of paddy, their local names their geographical distribution within the State, extent of damage to the crop and measures of their control, etc. The authors recently referred to some of the points briefly in an annotated list of crop pests in the State (Sengupta and Behura, 1957). The present paper is a continuation of the same and embodies the result of observations made during 1950-58.

In the State of Orissa, paddy is grown in three seasons, viz: autumn, winter and summer and are respectively known in Oriya as *Biali dhana*, *Sarada dhana* and *Dalua dhana*. During 1955-56, the autumn paddy was cultivated over an area of 1,256,300 acres, winter paddy 8,077,300 acres and summer paddy 27,400 acres. The summer paddy is grown in the coastal districts of Puri and Ganjam. Very few pests are found to attack the winter paddy.

Major Pests

SPODOPTERA MAURITIA BOISDUVAL. THE PADDY SWARMING CATERPILLAR.

(Lepidoptera, Agrotidae)

Local name: Leda poka.

Stage Causing Damage: Larva.

Nature of Damage: The caterpillars appear in large numbers and feed voraciously on the leaves at night. In case of severe attack the entire field looks barren.

LIFE-HISTORY:

Egg stage: 3-6 days.

Larval stage: 3-5 weeks.

Pupal stage: 10-15 days.

Life-cycle: 30-40 days.

Period of Incidence: There is only one generation during June to September.

Peak Period of Infestation: July to September.

Zonal Distribution in Orissa: Cuttack, Puri, Balasore, Balangir and Ganjam districts.

Distribution in India: A pest in all the States of India, but occurs as a major pest in Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bombay, Kerala, Madhya Pradesh, Madras, Manipur, Orissa, Rajasthan and West Bengal; and as a minor pest in Bihar, Himachal Pradesh, Mysore and Uttar Pradesh.

World Distribution: Burma, Ceylon, Hawaii, India, Java, Malaya and the Phillipines.

Notable Outbreaks in Orissa:

1950—*Cuttack district:* Kendrapara, Ali, Bhinjharpur and Jagatsingpur.

1951—*Balasore district:* Jaleswar, Remuna and Dhamnagar.

1955—*Puri district:* Balighai, Nimapara and Kakatpur.

1958—*Balangir district:* Some areas near the bank of Tel river.

Extent of Damage: 70% of crop on an average.

Control: Dusting 10% BHC at 15-20 lbs. per acre; or spraying with Folido! 0.08% or Endrin 0.04%.

SCHOENOBIVUS INCERTELLUS WALKER. THE RICE STEM-BORER.

(Lepidoptera, Pyralidae).

Local name: Ganthi bindha poka.

Stage Causing Damage: Larva.

Nature of Damage: The caterpillars bore into the stem. The central shoot dies and turns yellow.

Symptoms of Damage: In the early stages of attack, the plants turn yellow, later grain formation is prevented and the ear-heads turn yellow and chaffy. Small punctures at the lower portion of the stems exhibit the path of entrance of the caterpillars.

LIFE-HISTORY:

The eggs are deposited on the lower surface of the leaves.

Egg stage: 5-6 days.

Larval stage: 4-5 weeks. Larvae pupate inside the stem.

Pupal stage: 10 days (Ayyar and Anantanarayan, 1937).

Period of incidence: From November to December on autumn paddy and from February to April on summer paddy. Altogether two broods have been noted in Orissa with considerable overlapping of generations.

Peak period of Infestation: January to March.

Zonal Distribution in Orissa: This is a pest of regular occurrence in the districts of Cuttack, Puri and Ganjam.

Distribution in India: Throughout India and a major pest in Andhra Pradesh, Assam, Bihar, Bombay, Jammu and Kashmir, Kerala, Madhya Pradesh, Madras, Mysore, Orissa and West Bengal; and minor pest in the Punjab, Manipur and Rajasthan.

World Distribution: Asia and Japan.

Notable Outbreak in Orissa:

1955—*Puri district:* Balighai (on summer paddy); Samagra pata and Sara pata near Puri.

Extent of Damage: Variable. Highest damage noted was 80% of the crop.

Control: Light traps should be set up after dusk upto midnight to capture the moths. Ploughing of the rice stubbles destroys the pupae.

Light dusting with 5% BHC twice in the nursery is sufficient to ensure insect-free seedlings.

Spraying on the transplanted crop should be directed against the ovipositing moths and newly hatched larvae. Folidol 0.08% or Endrin 0.04% was found most effective for the purpose.

DICLADISPA (HISPA) ARMIGERA OLIVER. THE PADDY HISPA.

(Coleoptera, Chrysomelidae).

Local name: Biriha poka.

Stages Causing Damage: Adult and larvae.

Nature of Damage: The adults scrape out the green matter of the leaves, while the larvae mine the leaves by feeding on the tissue between the layers of epidermis.

Symptoms of Damage: The affected leaves turn whitish and membranous and appear like straw. In heavy infestations, the field appears as if burnt up.

LIFE-HISTORY:

The eggs are deposited inside the leaf tissues.

Egg stage: 3-4 days.

Larval stage: About a week.

Pupal stage: 3-4 days (Sen, 1921).

Period of Incidence: From July to October on autumn paddy. In 1955, the brood on autumn paddy lasted upto March and was also found infesting summer paddy. There are three to four generations a year.

Peak Period of Infestation: July to September.

Zonal Distribution in Orissa: Throughout the State except the Agency tracts.

Distribution in India: A major pest in Andhra Pradesh, Assam, Bihar, Kerala, Madhya Pradesh, Manipur, Orissa and West Bengal; and a minor pest in Bombay, Himachal Pradesh, Jammu and Kashmir, Madras, Mysore, the Punjab and Uttar Pradesh.

Notable Outbreak in Orissa:

1948—In all coastal districts of the State.

Extent of Damage: In the years of severe infestations the damage was 25% of the crop on an average.

Control: Dusting with 5% BHC, DDT or Endrin or spraying with 0.2% BHC is effective in killing the adult insects. Spraying with 0.08% Folidol or 0.04% Endrin was found effective in controlling both the adults and the mining grubs.

Remarks: The infestation of the paddy hispa is sporadic.

LEPTOCORISA ACUTA THUNBERG AND *L. VARICORNIS* FABRICUS. THE RICE BUGS.

(Hemiptera: Coreidae).

Local name: Gandhi poka.

Stages Causing Damage: Adult and nymph.

Nature of Damage: When the grains are in the 'milk stage', the bugs suck the 'milk' and prevent grain formation.

Symptoms of attack: The affected earheads stand erect unlike the normal ones. They also bear a very small punctures caused during the feeding of the bugs. Infestation by the bugs is further characterised by the presence of empty grains, ill-formed grains and some ripe grains in a panicle.

LIFE-HISTORY:

Egg stage: 4-8 days.

Nymphal stage: 16-23 days during which 5 moults occur.

Nymphal stage: 16-23 days during which 5 moults occur.

Period of Incidence: From May to October. In 1953 infestation by the bugs continued upto the middle of December. So far, only one brood has been recorded in Orissa.

Peak period of Infestation: September.

Zonal Distribution in Orissa: Cuttack, Puri, Sambalpur, Balangir, Sundergarh and Kalahandi districts.

Distribution in India: *L. acuta* occurs as a major pest in Kerala, Madhya Pradesh, Madras, Orissa and West Bengal; and as a minor pest in Bombay, Himachal Pradesh, Mysore, Rajasthan and Uttar Pradesh.

L. varicornis occurs as a major pest in Assam, Bihar, Delhi, Kerala, Madhya Pradesh, Madras, Orissa, Rajasthan and Uttar Pradesh; and as a minor pest in Himachal Pradesh, Jammu and Kashmir and the Punjab.

Notable Outbreaks in Orissa:

1953—Cuttack, Puri, Sambalpur, Balangir, Sundergarh and Kalahandi districts.

Extent of Damage: Usually 5 to 10% of the crop on an average, but in the year of severe epidemics, the damage was as high as 40 to 60%.

Control: Dusting with 5% BHC, DDT or Aldrin in the early morning hours at the rate of 15 lbs. per acre.

Remarks: A minor pest becoming a major one in particular years

NYMPHULA DEPUNCTALIS GUENEE. THE PADDY CASE
WORM.

(Lepidoptera, Pyralidae),

Local name: Nali poka.

Stage Causing Damage: Larva.

Nature of Damage: The caterpillars feed on the leaves and form tubular cases around them by cutting the apical portion of the leaves. In severe infestations earhead formation is retarded.

Syptoms of attack: The apical portions of the leaves are clipped off. Papery whitish areas are also found on the leaves due to scraping of chlorophyll by the larvae. The cases of the larvae remain attached to the stem, a little above the surface of water.

LIFE-HISTORY:

Egg stage: 2-6 days.

Larval stage: 14-20 days.

Pupal stage: 4-7 days.

The adults live for 2-8 days and the females oviposit 1-4 days after emergence (Sisam, 1938).

Period of Incidence: August to October. Infestation by this pest has also been noticed on summer paddy in February and March.

Peak Period of Infestation: From the last part of August to the middle of September.

Zonal Distribution in Orissa: Cuttack, Puri, Balasore, Dhenkanal, Sambalpur, Balangir and Sundergarh districts.

Distribution in India: A serious pest in the Andaman and Nicobar Islands, Andhra, Assam, Bihar, Bombay, Madras, Manipur, Mysore and Orissa; and minor in Kerala, Madhya Pradesh, Uttar Pradesh and West Bengal.

Notable Outbreaks in Orissa:

1954—Dhenkanal district: Gadasila.

1955—Balangir district: Patnagarh and Sonapur.

Extent of Damage: In case of severe infestations the damage was 25% of the crop on an average.

Control: Spraying with Folidol 0.08% or Endrin 0.04%. Cover the surface of the standing water with a thin film of kerosine oil and dislodge the cases of the pest by rope dragging.

HIEROGLYPHUS BANIAN FABRICUS. THE PADDY
GRASSHOPPER.

(Orthoptera, Acrididae).

Local name: Jhintika.

Stages Causing Damage: Nymphs and adults.

Nature of Damage and Symptoms of Attack: Both nymphs and adults feed on the leaves. When they nibble at the lower portions of the ear stalks, the latter hang down and turn whitish. In case of severe infestations, the plants are entirely eaten up.

LIFE-HISTORY:

Eggs are laid in masses under the soil usually between October and December. Hoppers emerge towards the last week of June. It takes about 70 days in case of males and 80 days in case of females to reach maturity (Fletcher, 1913).

Period of Incidence: From late June to September.

Peak Period of Incidence: From the last part of July to September.

Zonal Distribution in Orissa: The incidence of this pest has so far been noted in the districts of Ganjam, Puri and Dhenkanal.

Distribution in India: A major pest in the Punjab, Uttar Pradesh, Rajasthan, Madhya Pradesh, West Bengal, Orissa, Madras and Bombay; and minor in Assam, Himachal Pradesh, Jammu and Kashmir, Uttar Pradesh and West Bengal.

Notable out-breaks in Orissa:

1952—Ganjam district.

1953—Ganjam district.

Extent of Damage: About 25% of the crop on an average.

Control: Dusting with 5, 7 and 10% BHC at the rate of 15-20 lbs. per acre.

HIEROGLYPHUS NIGROREPLETUS BOL. THE PHADKA
GRASSHOPPER

(Orthoptera, Acrididae).

Local name: Jhintika.

Stages Causing Damage: Nymphs and adults.

Nature of Damage: Both the nymphs and adults feed on the leaves. They also infest millet and sugarcane.

LIFE-HISTORY:

Eggs are laid in masses under the soil between October and November. Hoppers emerge about the first week of July.

Period of Incidence: September-October.

Peak period of Incidence: September.

Zonal Distribution in Orissa: The pest has so far been reported from Khariar in the Nawapara sub-division of the district of Kalahandi.

Distribution in India: Assam, Bihar, Bombay, Madhya Pradesh, Madras, Mysore, Orissa, the Punjab, Rajasthan, Uttar Pradesh and West Bengal.

Notable out-breaks in Orissa:

1954—Kalahandi district: Nawapara sub-division: Khariar.

Extent of Damage: About 25% of the crop on an average.

Control: Dusing with 5% and 10% BHC at the rate of 15-20 lbs. per acre

Minor Pests**NEPHOTETTIX BIPUNCTATUS FABRICUS. THE PADDY LEAFHOPPER**

(Hemiptera, Jassidae).

Local name: Dipabali poka.

Stages Causing Damage: Nymphs and adults.

Nature of Damage and Symptoms of Attack: The jassids suck the sap of the plants. In severe infestations, the plants turn yellow and have stunted growth and earhead formation is retarded.

LIFE-HISTORY:

Egg stage: 4-6 days.

Nymphal stage: 13-21 days during which 5 moults occur (Misra, 1920).

Period of Incidence: From the first week of August to the second week of October.

Peak Period of Incidence: Mid-August to mid-October.

Zonal Distribution in Orissa: Cuttack, Puri, Balasore, Ganjam, Sundergarh, Sambalpur, Balangir, Koraput, Kalahandi and Dhenkanal districts.

Distribution in India: Andhra, Madhya Pradesh, Madras, Orissa, Uttar Pradesh and West Bengal.

Notable out-breaks in Orissa: Wide-spread outbreak of the pest was noted in 1952 and 1955, the following localities being badly affected:

Puri district: Balugan, Nayagarh, Khurda and Bhubaneswar;

Ganjam district: Chatrapur and Khallikote;

Cuttack district: Salepur and Kendrapara.

Extent of Damage: 20% of the crop on an average.

Control: Dusting with 5% BHC or Aldrin or spraying with 0.08% Folidol or 0.04% Endrin; better drainage.

Remarks: Along with *N. bipunctatus*, *N. apicalis* Mots. also occurs.

RIPERSIA ORYZAE GREEN. THE PADDY MEALY BUG.
(Hemiptera, Coccidae).

Local name: Jau poka. Dahia.

Stages Causing Damage: Nymphs and adults.

Nature of Damage: The small bugs suck the sap of the host-plants. Normal growth of the plants is thereby hampered and in severe infestations the earheads fail to appear. They are found in colonies between the leaf sheath and the stem

Symptoms of Attack: The leaves turn yellow within the sheaths of which may be found the coccids coated with white mealy powder. The leaves also appear curled and dried.

LIFE-HISTORY:

Number of eggs per female: 126-319 (Banerjee, 1957).

Period of incubation: From a few minutes to 24 hours. Subsequent development 18-34 days (Cherian, Krishnaswamy, Ramachandran and Sundaram, 1935).

Period of Incidence: July to September.

Peak Period of Incidence: August to September.

Zonal Distribution in Orissa: Ganjam, Cuttack and Puri districts.

Distribution in India: A serious pest in Madras and minor in Andhra, Madhya Pradesh, Mysore, Orissa and West Bengal.

Notable outbreaks in Orissa:

1950—*Puri district:* Balugan and Bhubaneswar.

1955—*Ganjam district:* Bhanjanagar and Hinjli.

1956—*Cuttack district:* Salepur and Kendrapara.

Puri district: Bhubaneswar and Khurda.

1959—*Cuttack district:* Athagarh.

Extent of Damage: About 10% of the crop on an average. In the year of severe drought the extent of damage goes upto about 15% of the crop on an average.

Control: Spraying with 0.08% Folidol.

Remarks: Occurrence sporadic.

PACHYDIPLOSIS ORYZE (WOOD-MASON) MANI. THE PADDY GALL-FLY.

(Diptera, Cecidomyidae)

Local Name: Kahalia tuturi.

Stage Causing Damage: Larva.

Nature of Damage: The maggots bore into the stems causing the formation of long silvery tubular galls called 'Silver shoot' instead of the normal earheads. The longitudinal margins of the leaf sheath are glued together to form a silvershoot, at the top of which is a small leaf blade.

Symptoms of Attack: Appearance of white, greenish white or greenish violet tubular galls in place of the growing shoot.

Life-History:

Egg stage: 3-5 days.

Larval stage: 14-28 days.

Pupal stage: 4-5 days (Yen, Liu and Kuo, 1941). The number of broods varies from six to eight with considerable overlapping of generations.

Peak period of incidence: September to mid-November.

Zonal distribution in Orissa: The incidence of the pest is restricted to the districts of Dhenkanal, Cuttack, Puri, Balasore and Ganjam districts.

Distribution in India: Andhra, Assam, Bihar, Bombay, Madhya Pradesh, Madras, Mysore, Orissa and West Bengal.

World distribution: French, Sudan (Africa), Ceylon, Burma, China, Siam, Dutch East Indies and Indochina.

Notable out-breaks in Orissa:

1949—Dhenkanal district: Talcher sub-division.

1952—Dhenkanal district: Poipal in Talcher sub-division; Ganjam district: Bhanjanagar, Aska and Hinjli; Puri district: Nayagarh, Khurda and Bhubaneswar

1954—Dhenkanal district: Angul and Talcher,

1956—Cuttack district: Jagatsingpur, Salepur and Jajpur.

Dhenkanal district: Kamakhyanagar and Poipal.

Extent of damage: About 15% of the crop on an average.

Control: Use of light trap is recommended. Spraying with 1.6 lbs Parathion (as an emulsion) or 8 lb Chlordane per acre effectively reduces the infestation (Patel and Bhat, 1954).

LEUCANIA (CIRPHIS) UNIPUNCTA HAWORTH. THE PADDY CUT WORM

(Lepidoptera, Agrotidae)

Local name: Patrakata leda poka.

Stage causing damage: Larva.

Nature of damage: The caterpillars cause damage at the seedling stage. They feed mainly at night.

Symptoms of attack: Sudden destruction of leaf blades. The symptoms of attack and habits of this pest are similar to those of *Spodoptera mauritia* but the larvae of the former attack the earheads also.

Life-history:

Eggs are laid in batches and thrust into the shelter of the leaf sheath.

Egg stage: 8-10 days.

Larval stage: 3-4 weeks.

Pupation takes place in the soil.

Total life-cycle: 7-8 weeks.

Period of Incidence: July to September.

Zonal distribution in Orissa: This is a sporadic pest distributed in all parts of the State.

Distribution in India: A serious pest in Assam, Andhra, Manipur and West Bengal; and minor in Himachal Pradesh, Madhya Pradesh, Madras, Orissa and Uttar Pradesh.

Extent of damage: In case of severe infestations the damage was about 10% to 15% of the crop on an average.

Control: Spraying with 0.20% DDT or dusting with 5% BHC or DDT controls the pest.

Remarks: A minor pest but assumes the role of a major one in speradic outbreaks. *Leucania (Cirphis) albistigma* Mo. also occurs along with *L. unipuncta*. The life-histories and habits of both the species are similar.

NILAPARVATA LUGENS STAL (= *SORDESCENS* LINNAEUS)

(Hemiptera, Fulgoridae)

Stages causing damage: Nymphs and adults.*Nature of damage:* The nymphs and adults suck the sap of the leaves.*Period of incidence:* July to September.*Zonal distribution in Orissa:* Ganjam and Puri districts.*Distribution in India:* A serious pest in some years in Andhra and Madras; and minor in Bihar, Madhya Pradesh, Mysore, Orissa and Uttar Pradesh.*Control:* Dusting with 5% BHC or Aldrin.*CNAPHALOCROSIS MEDINALIS* GUENEE. THE PADDY LEAF ROLLER

(Lepidoptera, Pyralidae)

Local name: Dhana patra moda poka.*Stage causing damage:* Larva.*Nature of damage and symptoms of attack:* The caterpillar rolls up the tips of the leaves, lives inside them and feeds on the leaf tissue. The margins of the leaf blades are folded and fastened with a few silk leaves turn whitish and sticky. In case infestation is severe, leaf margins and tips appear entirely dried up.*Life-history:**Period of Incidence:* August to September.*Zonal Distribution in Orissa:* Distributed in all parts of the State.*Distribution in India:* This is a sporadic minor pest in Andhra, Bihar, Bombay, Kerala, Madras, Mysore, Orissa and West Bengal.*Control:* Spraying with Folidol 0.08% or Endrin 0.04%.*PARANARA MATHIAS* FABRICUS. THE PADDY SKIPPER

(Lepidoptera, Hesperidae)

Stage causing damage: Larva.*Nature and Symptoms of damage:* The larva feeds on the leaves and lives in the longitudinally rolled leaves.*Life-history:**Egg stage:* 4-5 days.*Larval stage:* 21-28 days.*Pupal stage:* 10-15 days (Li, 1937).*Period of incidence:* July to September.*Peak period of incidence:* September.*Zonal distribution in Orissa:* Distributed in all parts of Orissa.*Distribution in India:* Andhra, Assam, Bihar, Bombay, Jammu and Kashmir, Kerala, Madhya Pradesh, Madras, Mysore, Orissa, Uttar Pradesh and West Bengal.*Control:* Dusting with 5% BHC.**Acknowledgment**

The authors are indebted to Dr. C. Misra, Deputy-Director of Statistics, Orissa for valuable information incorporated in the body of the paper.

Summary

A list of major insect pests of paddy in Orissa together with their local names, nature and symptoms of damage, salient features of their life-history, period of incidence, zonal distribution in the State, distribution in India, notable out-breaks in the State extent of damage and suitable measures of control so far found effective are given.

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Studies on the Marine Leech *Branchellion plicobranchus* Raj, (Family Piscicolidae) from India

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(with 7 Text-figures)

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Introduction

Of the Piscicolidae, the marine genus *Branchellion* Sav. was recorded for the first time from Indian waters by the author (Sanjeeva Raj, 1953) on the basis of a single specimen obtained from a fish market in Madras. In view of its extremely folded, lobed gills and certain other characters the author (Sanjeeva Raj, 1953 and 1954), assigned it to a new species, *Branchellion plicobranchus* (Syn. *plicusbranchus* loc. cit.). It closely resembled the specimen of the genus collected by Hornell in 1936 from the Assumption Island and described as a species *inquirendae* by Moore in 1944.

Recently a few specimens of *Branchellion* were obtained from the nostrils of "*Carcharias* sp." at Vizagapatam on the coast of the Bay of Bengal by Dr. P. N. Ganapathy, who kindly allowed me to examine the material. Another specimen collected at Quilon on the coast of the Arabian sea and supplied to the museum of the Women's Christian College, Madras was also examined through the kind permission of Miss Rachel Philip. Mr. Ranade of the Taraporevala Marine Biological Station, Bombay has informed me that he had also collected a number of specimens of this genus from Bombay. But unfortunately, I have not had the opportunity to examine these specimens from Bombay.

Some time back when I visited Adhirampatnam, a coastal village on the Bay of Bengal, 37 miles South east of Tanjore, I was able to collect fifteen specimens of *Branchellion plicobranchus* from *Dasyatis uarnak*. Some of these could be kept alive for nearly three hours in small glass tubes containing sea water. These were killed and preserved in 40% formaldehyde solution. The present account deals with a detailed diagnosis of the species, together with observations on living specimens.

Bionomics

Branchellion plicobranchus maintains a firm grip on the host mainly with its posterior sucker, and the adhesion seems to be reinforced by the copious amount of mucus present on the body of the host and that of the leech. When transferred to sea water in glass tubes, or while still on the body of the host, it is not as extensile as *Haemadipsa*, *Hirudinaria* or *Glossiphonia*. The pulsation of the vesicles was not noticeable, as the bushy gills completely hid them. In life, the lobes of the gill spread out fan-wise and showed slight wavy movements.

The leeches were found almost all over the body of the host *Dasyatis uarnak*, both in young and adult specimens. They were present on the eyes, in front of the eyes, in the notch of the pelvic fins, on the disc in front of the tail and on the edges of the mouth. In one instance, three large individuals were attached one above the other in front of the eyes. When separated, they left no scratch or tear on the skin of the host, except in one case, where the leech was adhering to the soft parts of the spiracle and on removal left a small reddened spot with slight bleeding. The posterior sucker is more adherent than the anterior and considerable force has to be used in releasing it.

No sooner were the hosts (*Dasyatis uarnak*) brought to the shore than the leeches tried to crawl away from their bodies probably in search of water. This may be the reason why most specimens of *Dasyatis uarnak* caught off shore during the night and brought ashore dead the next morning, did not bear any leeches. Only fresh and live hosts dragged ashore in the fish nets are likely to harbour live leeches.

Although rays and skates are the usual hosts of *Branchellion*, it is probable that other elasmobranchs may also serve occasionally as hosts. Richardson (1953) recorded *Branchellion* from *Callorhynchus milii* (Holocephali) whereas the specimen collected at Vizagapatam was from *Carcharias* sp. At Adhirampatnam other elasmobranchs, namely *Pristis*, *Narcine* and *Scoliodon* were abundant along with *Dasyatis uarnak* which was infested with *Branchellion plicobranchus*. The other elasmobranchs were free from the leech infection. However, in a lot of about

fifty specimens of *Dasyatis uarnak*. examined, only eight were infested with *Branchellion*.

Body Measurements

Of the fifteen specimens collected from Adhirampatnam coast, fourteen were found suitable for detailed study. These specimens varied from 10.00 to 40.50 mm. in total length, the largest specimen being thus much smaller than the holotype (Sanjeeva Raj 1954) which measures 64 mm. The range of variation in the different body measurements of the specimens from Adhirampatnam, from Quilon and the holotype from Madras are given below:—

Total length (including suckers)	...	10.00—64.00 mm.
Length of neck (including anterior sucker)	...	2.50—10.00 "
Length of abdomen (including posterior sucker)	...	7.50—54.00 "
Width of neck	...	1.00— 3.50 "
Width of anterior sucker	...	2.00— 5.50 "
Width of abdomen	...	1.50—14.00 "
Width of posterior sucker	...	3.00—10.00 "
Length of gill	...	0.70— 3.50 "

Colouration

B. plicobranchus when alive is dark coloured above, and can be spotted out easily on the body of the host. In the young, both the suckers and the gills are pale and translucent without any spots, the abdomen and neck are blackish, and the whole of the ventral surface is pale. In older specimens a darker tint develops on the dorsal side. (including the suckers and the gills), with white irregular streaks throughout. Only one individual was completely dark with no white streaks. Perhaps a larger series may indicate all gradations in colour from the pale to dark with or without white streaks or spots. The preserved specimen from Quilon had completely lost its natural colouration, but indications of irregular white streaks over the body were visible still. Thus it would appear that colouration cannot have any diagnostic value in *B. plicobranchus* unlike in *B. torpedinis* (Harding 1910).

Suckers

The suckers, particularly the posterior sucker, in the hitherto known species of *Branchellion* have been described as cupiliform (Leigh-sharpe 1933, Harding 1910) deeply hooded (Moore 1944) and shallow or cup-like (Baird 1869). In the present collection nine specimens have deeply hooded suckers and the rest have perfectly flat ones. I find that the hooded nature of a sucker is an artifact brought about as a result of

the slow death of the animal or by faulty preservation. In live condition the suckers are always flat and this shape is retained, if the specimens are properly killed and preserved. It may be pointed out that the functional efficiency of the sucker is best possible only if the sucker is flat and not hooded.

(a) Anterior Sucker

The anterior sucker is an almost circular, ventrally directed organ, attached to the neck eccentrically on its dorsal side. Its posterior rim is usually folded downwards on itself so that the sucker appears to be elliptical.

In no earlier record is the anterior sucker of *Branchellion* described as tuberculated, except in *B. punctatum* in which it is minutely granulated inside (Baird 1869) and in *B. parkeri* in which it has "low papillae" (Richardson 1949). In *B. plicobranchus*, the ventral surface of the anterior sucker in all specimens including the holotype is minutely tuberculated, but the tubercles, unlike the papillae of the posterior sucker (*vide infra*) are neither prominent nor confined to the superficial membrane lining the sucker. They are minute, epidermal projections of almost uniform size, arranged in an irregular closely packed manner near the centre and in radial rows towards the periphery. At the centre they are so closely juxtaposed that they together form a continuous base with only their summits distinct. On magnification, each tubercle looks like a hemispherical knob.

None of the specimens examined showed eyes. Young specimens up to a length of 15 mm. are perhaps the best for verifying the absence of eyes, as they have a translucent anterior sucker in which the dark eye spots if any, would be clearly visible. The absence of eyes was also noticed in the holotype specimen.

The mouth is a small transverse slit, situated on the ventral surface in the posterior part of the anterior sucker at a distance of about one-third the sucker-diameter from the posterior rim.

(b) Posterior Sucker

The posterior sucker in the living condition is rather flat ventrally and convex dorsally. It is attached to the abdomen by the middle of its dorsal surface. In well spread out specimens, it is broader than the broadest part of the abdomen excluding the branchiae. If the leech dies slowly, the posterior sucker like the anterior, attains a deeply hooded form, but if the specimen is killed instantaneously, the sucker retains its more or less flat appearance.

In the various species of *Branchellion*, hitherto known, the posterior sucker bears on its ventral surface alveoli (MacDonald 1877), granules (Baird 1869), subsidiary suckers (Harding 1910), cupules or secondary suckers (Meyer 1941), minute pedunculate suckers (Richardson 1949) or papillae (Moore 1944 and Sanjeeva Raj 1954). The papillae in *B. pilcobranchus* (Fig. 1) are rather large near the centre, becoming gradually smaller towards the periphery. There are 16-18 rows at the centre and

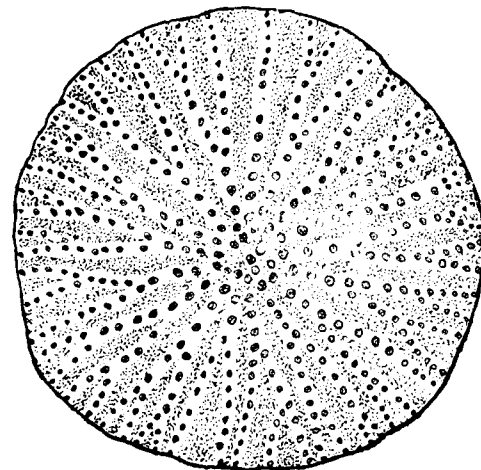


Fig. 1. Ventral view of the posterior sucker showing the distribution of papillae-X 7.

60-70 near the periphery. Each row has 9-10 papillae before it bifurcates and each of the branches, thus formed, has 5-6 papillae. If a row does not branch, it has 15-16 papillae from the centre to the periphery. Thus, the total number of papillae varies from 450 to 600 according to the size of the sucker.

Neck and its Annulation

The neck is narrower in its anterior region, broad posteriorly and flat dorsoventrally, and is more or less elliptical in cross sections. It is much narrower than the abdomen, but in young specimens the neck does not differ conspicuously from the abdomen in width.

The number of cervical annuli differs in the various species. *Branchellion lineare* and *B. intybifolium* have 10-12 annuli (Baird 1869) *B. torpedinis* has 12-14, according to Sukatscoff (1912), and 19 according to Leigh-sharpe (1916). *B. orbinensis* and *B. borealis* have 16 (Leigh-sharpe 1933 a). Meyer (1941) figures 22 neck annuli for *B. raveneli*. *B. parkeri* has only 15 (Richardson 1949). Moore (1944) records 16 in a specimen of *Branchellion* collected from the Assumption Island.

In *Branchellion plicobranchus* there are sixteen annuli in the neck. (Fig. 2). Of these the fifteenth and the sixteenth form the inner and the outer walls of the preputial fold, while of the remaining ones, only twelve or thirteen are visible externally (Fig. 3), the posterior most

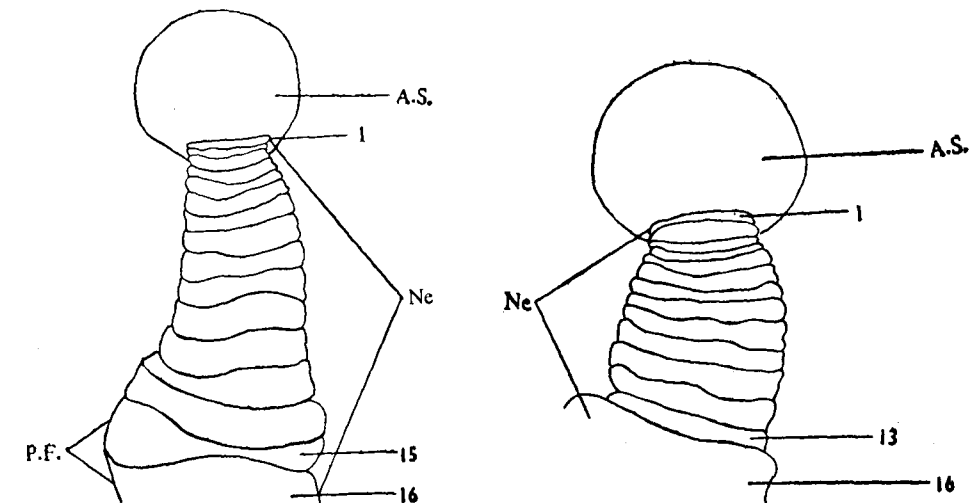


Fig. 2. Neck fully extended-X 14

A.S., Anterior sucker; Ne., Neck; P.F., Preputial fold; 1-16 Neck annuli.

Fig. 3. Neck contracted and drawn into the preputial fold-X 14.

A.S., Anterior sucker; Ne., Neck; 1-16 Neck annuli;

being hidden by the preputial fold. The anterior most annuli are very narrow. The inter-annular grooves between the first three annuli may be indistinct ventrally, but are clear dorsally just over the anterior sucker.

Apathy (1888) pointed out that the preputial fold is formed by the two annuli of the last segment of the neck. In earlier stages, according to him, these two annuli are one behind the other, there being no preputial fold, but later they come to lie one over the other so as to form the fold. Even in the smallest specimen of the present collection, which measures 10 mm. in length, the preputial fold is well formed.

Abdomen and its Annulation

The abdomen is broadest in its middle region and almost flattened. Posteriorly, it is attached to the posterior sucker by the middle of its

dorsal surface, and on its sides it bears the branchiae and the pulsating vesicles. (Fig. 4).

The annulation of the abdomen is distinct on the ventral side, but dorsally the abdominal annuli show biannulation, more especially in older specimens. The segments XIV—XXIV are triannulate; XXV and XXVI are biannulate and the last (XXVII) segment is uniannulate. Thus there are 38 annuli in the whole abdominal region but only 33 rings

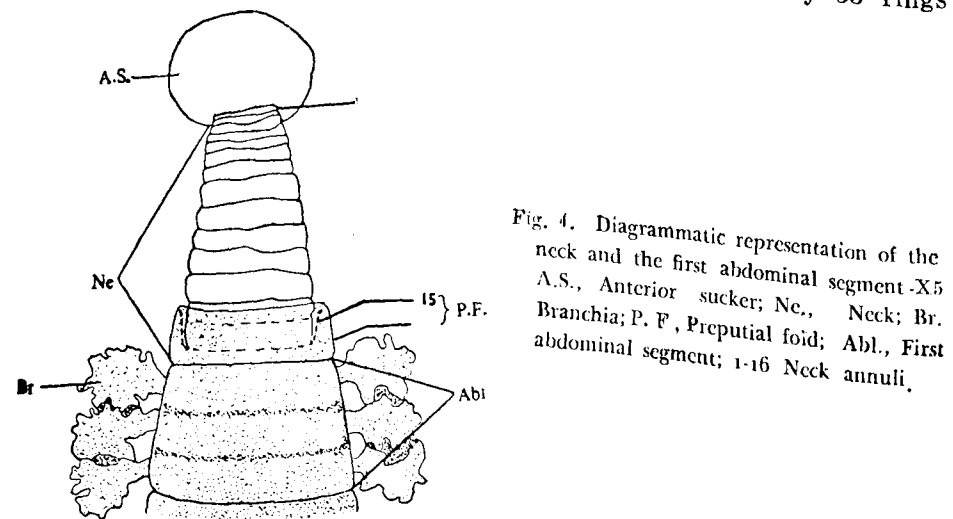


Fig. 4. Diagrammatic representation of the neck and the first abdominal segment-X5. A.S., Anterior sucker; Ne., Neck; Br. Branchia; P.F., Preputial fold; Abl., First abdominal segment; 1-16 Neck annuli.

could be made out on the ventral surface, as the inter-annular furrows for the last five annuli are absent on the ventral side. The biannulation on the dorsal side of the abdomen is one of the unique features observed in the holotype also and is helpful in the identification of the species.

Branchiae

The anterior eleven segments of the abdomen (i.e., the segments XIV-XXIV) bear the thirty three branchiae one pair for each annulus. Although there is no variation in the number of branchiae, there is a great deal of difference in the sizes and complexity of their folds and lobes, as they are simple in small specimens and rather complicated in large ones. The complexity in branchial structure appears to be associated with the growth and age of the individual. In smaller

specimens, such as the one 10 mm. long (Fig. 5), the branchiae are thin plate-like outgrowths, roughly semicircular, blackish in colour, and bearing at their border three or four lobe-like projections which are the beginnings of the complicated lobulation of the adult. The whole branchia is translucent and without the colouration of the adult. In the 19 mm. specimen (Fig. 6), the branchia has 6-7 prominent lobes besides a few less prominent structures which appear as mere projections. At one or two places the latter overlap the ones formed earlier,

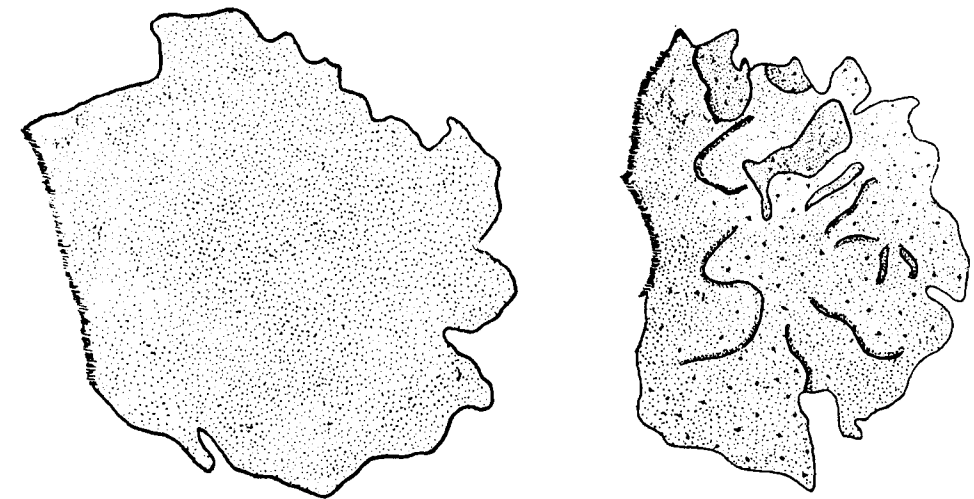


Fig. 5. Branchia of a 10 mm. specimen-X 98.

Fig. 6. Branchia of a 19 mm. specimen-X 42.

but at this stage secondary lobes are lacking. In the 38 mm. specimen (Fig. 7) each branchia is a fairly thick lamina bearing 14 or 15 primary lobes with smaller folded lobes at their border. The primary and secondary lobes arise at different levels from the margin and are directed in different planes, thus overlapping one another and giving an irregularly folded or frilled appearance to the branches. In the type specimen, which is 64 mm. in length, the number of lobes is still greater and the complexity of lobulation still more advanced.

There is no branchial stem or peduncle, but the basal portion of the gill is devoid of lobes. The anterior branchiae are not essentially different from posterior ones, excepting for the greater lobulation of the latter.

Pulsating Vesicles

The eleven pairs of pulsating vesicles are situated, as in the type specimen, in the branchiate segments, one at the base of each branchia of the first primary annulus. Some variations were observed from this typical arrangement. The last pair of pulsating vesicles, for example, are not clearly visible on the thirty first pair of branchiae in these

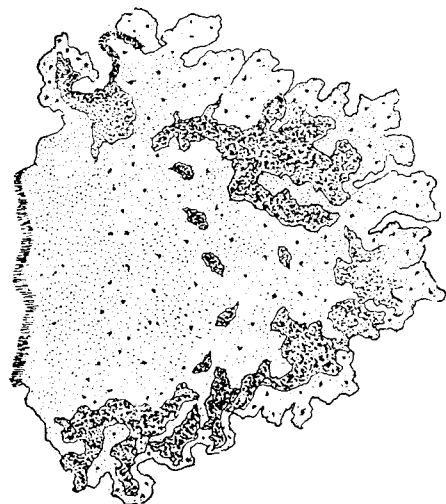


Fig. 7. Branchia of a 38 mm. specimen
-X 18.

specimens. In some the vesicles are fairly large and clearly visible on both sides of the base of the branchia, but in some they are shrunken and on the first branchia especially they are found only on the posterior side of the branchial base. It is difficult to determine whether these variations are natural or artifacts resulting from preservation.

Summary

The external morphology of *Branchellion plicobranchus* Raj, based on specimens collected from the body of the elasmobranch *Dasyatis uarnak* is described. Notes on the live specimens and their colouration are also included.

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Notes on the Anatomy of the Last Instar Nymph of *Bagrada picta* Fabr.

(Hemiptera : Pentatomidae)*

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(Communicated by DR. M. L. ROONWAL)

With 14 Text-Figures

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Introduction

Sufficient morphological and anatomical descriptions are available regarding adult insects, but the information dealing with the nymphal stages is comparatively meagre. The immature stages of Coleoptera, Hymenoptera and Diptera have attracted much attention while the other groups are almost neglected. In these descriptions of the immature stages, however, the sutures and sclerites are generally omitted.

Evans (1939) studied the thorax of *Hemiodoecus fidelis* and has recorded the corresponding sutures and also their significance in the nymphs. Wallace (1953) while describing the biology of *Coranus subapterus* briefly described the nymphs. Hill (1957) described the biology of *Anthocoris nemorum* with short descriptions of the immature stages. In the present work the author has given a detailed account of the last instar nymph of *Bagrada picta* (Hemiptera: Pentatomidae).

* Contribution No. 79 from the School of Entomology St. John's College, Agra.

Technique

Nymphs and adults of *Bagrada picta* were collected from the cabbage fields of Shah-gunj, Agra. Last instar nymphs were also reared in the laboratory. Some nymphs were dechitinized by warming with 1% KOH solution and portions were mounted on slides, which were examined under Panphot and Ortholux, while others were dissected under binocular, using high-power objectives, for the study of the sutures and sclerites.

The Head

(Text-figs. 1-9:) The prognathous head is triangular and measures 1.1 mm. in the males and 1.5 mm. in the females. The sutures of the head are not well marked and it is almost smooth. The bulging eyes are seen at the ends on the base of the head. The occipital region is telescoped within the prothorax. The rostrum is continued with the apex of the head and is directed ventrally backwards. Antenna comes out from near the anterior margin of the eyes.

(a) Sutures of the head. (Text-figs. 2-4.)

The epicranial suture is totally absent. The clypeal folds are deep and prominent, situated on both the sides of the clypeus. The epistomal suture is again absent but the post-occipital suture is well developed which is not seen externally as it is telescoped with the prothorax. The antennal suture is prominent but the ocular suture is faintly marked. On the ventral side the sub-genal sutures are clearly marked and the maxillary folds are prominent.

(b) Sclerites of the head. (Text-figs. 2-4.)

The tentorial-pits are absent. The clypeus extends from the anterior end of the head to the compound eyes. It is convex, elongated dorsally and placed in the anterior mid-dorsal region of the head. Its posterior end is broad and confluent with frons. But in the absence of the sutures some of the sclerites cannot be differentiated. The mandibular plates are well developed and placed on the lateral sides of the clypeus demarcated by deep clypeal folds. The maxillary folds are also prominent and separate the maxillary plates from the mandibular plates which form the antero-lateral part of the head. The gula extends from the post-occiput to the anterior end of the head. Anteriorly it encloses an oval fossa for the attachment of the labium. The gena forms the postero-lateral part of the head capsule. The occiput, frons and the parietals are not differentiated,

(c) Appendages of the head. (Text-figs. 5-9.)

(i) The mouth-parts.

The labium is attached to the anterior end of the head capsule along the oral fossa and forms the rostrum. It has a dorsal labial groove which is deeper distally and roofed proximally by a triangular labrum which is suspended from the anterior end of the clypeus. In between the labrum and labium are lodged a pair of median maxillary and a pair of lateral mandibular stylets.

- (1) The Labium. (Text-fig. 5.) It is four segmented. The first is attached to the oral fossa by a membrane. The second is the largest segment and the two terminal seg-

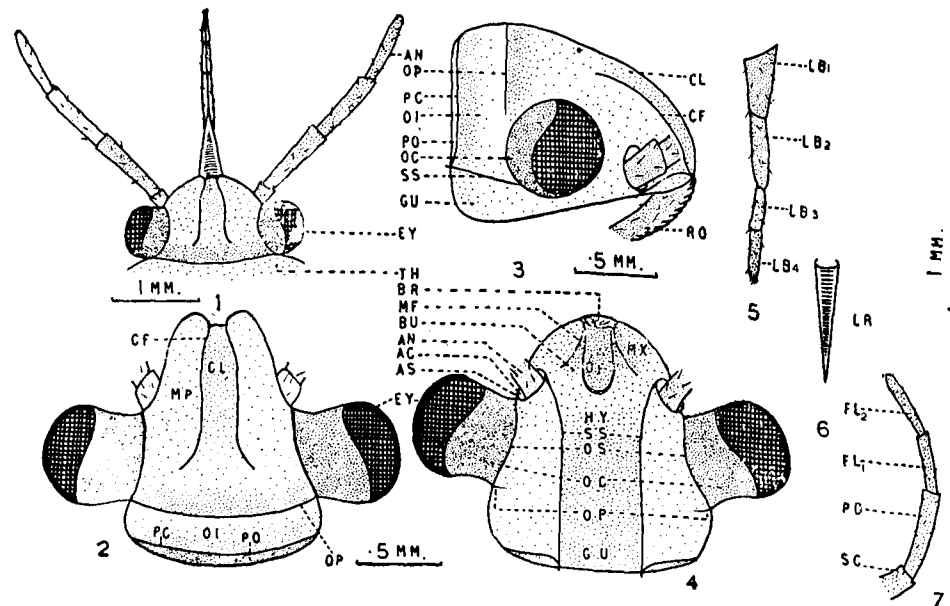


Figure 1 Head with antenna and rostrum. Figure 2 Head in dorsal view. Figure 3 Head in lateral view. Figure 4 Head in ventral view. Figure 5 Labium magnified. Figure 6 Labium magnified. Figure 7 Antenna magnified.

ments are almost equal in length. The tip of the terminal segment is provided with fine hairs which may be sensory. Akbar (1957) also observed the presence of the sensory hair in the last segment of *Leptocoris varicornis*. The labial groove is shallow at the base and deeper at the apex,

while at the extreme tip it becomes almost tubular. The labium is light brown, hairy and measures 2 mm.

- (2) The Labrum. (Text-fig. 6.) This is a long conical flap attached proximally to the clypeus along its broad base. The terminal pointed end exceeds a little beyond the first labial segment. It has alterante transverse grooves and ridges and a longitudinal ventral labial groove.
- (3) The Maxillary stylets. (Text-fig. 8.) These are paired long, narrow structures with sharply pointed tips. The two stylets meet at the proximal one-third to enclose a dorsal food and a ventral salivary canal. At the proximal end each stylet is attached to an almost semicircular maxillary lever.
- (4) The Mandibular stylet. (Text-fig. 9.) The mandibular stylets have a slender body with broad base for the attachment of the muscles. They are lateral to the maxillary stylets and unlike the latter their tips are provided with blunt teeth on the outer margin and fringed with hair on the inner margin.
- (ii) The Antenna. (Text-fig. 7.) It is four-segmented fili form and dark brown. The surface is smooth with evenly distributed short hair. The scape is shortest the pedicle longest and the flagellar segments almost equal.
- (iii) The Compound eyes. (Text-figs. 1-4.) The compound eyes are about 1 mm. apart. They are sessile and situated on either side of the head. They are deep brown, spherical and 0.5 mm. in diameter.

The Thorax

(Text-figs. 10-12.) (a) The thoracic trunk. (Text-figs. 11 and 12.)

This is three segmented, 3.0 mm. in width and prominently differentiated into pro, meso, and metathorax. In the metathorax especially the metatergum is comparatively less developed. The triangular wing-rudiments are clearly visible. Alinotum is distinguishable only in the mesonotum. The fragmanotum of the mesotergum is incompletely developed but the rudiments are visible. The metatergum is almost covered by the mesotergum except a little marginal portion on the posterior side. On the thorax most of the sternal sutures are obliterated, but the pleural sclerites are well marked and all the three pairs of legs well developed. There are two slit-like apertures placed on the latero-posterior coxal margin in the pro- and mesosternum.

- (1) The Prothorax. (Text-figs. 11 and 12.) The protergum is well expanded. Two lines start from its antero-lateral corners. Evans (1939) also observed similar lines in the second nymph of *Hemiodoecus fidelis*. The prosternal sutures are almost obliterated, but the subcoxal parasternite can be differentiated from the eusternite. In the pleural areas the trochantin can be observed. The pleural suture is well developed separating the episternum and epimeron.

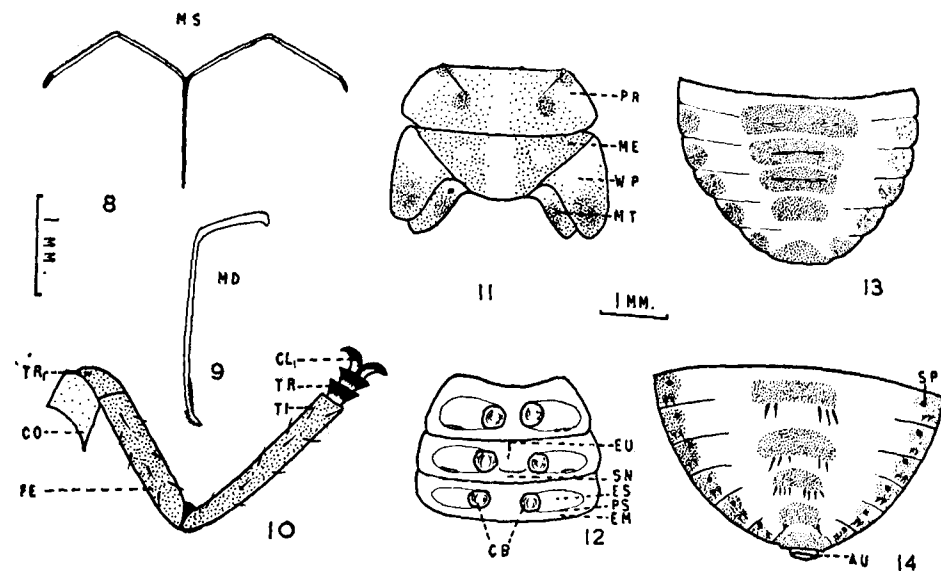


Figure 8 Maxillary stylet. Figure 9 Mandibular stylet. Figure 10 Leg. Figure 11 Thorax dorsal view. Figure 12 Thorax ventral view. Figure 13 Abdomen dorsal view. Figure 14 Abdomen ventral view.

- (2) The Mesothorax. (Text-figs. 11 and 12.) The mesothorax develops a triangular alinotum on either side, which is prolonged posteriorly. The mesothoracic wing rudiments originate from the antero-lateral sides and extend up to the third abdominal segment. The fragmanotum is slightly differentiated from the alinotum along the posterior of the latter. Eusternite and spinasternae are separated by a suture. The pleural suture is better developed than in the prothorax.

- (3) The Metathorax. (Text-figs. 11 and 12.) The metathorax is comparatively less chitinized. Wing-pads develop from

its lateral boundary and are membranous. They extend slightly beyond the mesothoracic wing pads. The sternae are of mesothoracic type except at the spinasterna where it is not differentiated and has probably fused with the first abdominal sternite. The pleural areas are of the mesothoracic type but the pleural suture is less defined, and has comparatively shifted posteriorly resulting in a narrow epimeron.

(b) The thoracic appendages. (Text-figs. 10 and 11.) (i) The Legs. A pair of well developed legs present in each of the thoracic segment. The prothoracic legs are the smallest and the meta-thoracic largest. They are differentiated into a well developed coxa, a small trochanter, a long narrow femur, slender tibia and two tarsi along with the apical claws.

Coxa:—This is well developed. At the base it is concave and is rather flat at the distal end where it articulates with the trochanter. It is small, smooth and light-coloured.

Trochanter:—This is less chitinized, light-coloured, feeble and measures about half of the coxa. It is characteristically curved into a 'J' or 'c'.

Femur:—This is darker than the trochanter, shorter than the tibia, well developed and straight. The distal end has a notch on the inner side, which is covered by a membrane to facilitate the movements of the tibia along this joint. The surface is smooth with few scattered hairs on it.

Tibia:—The tibia is the longest of all the segments of the leg. It is slender but stout enough. Its proximal end is slightly bent to articulate with the femur, and the distal end has a concavity to receive the proximal end of the first tarsal segment. It is well chitinized and the surface is hairy. These short hairs are more prominent towards the distal end.

Tarsi:—There are two tarsal segments in each leg. The first segment is oblique at both the ends and is shorter than the second segment which is more or less spindle-shaped. The pointed end articulates with the tibia; distally it is almost blunt and articulates with the two claws. The claws are curved and sharp, like two hooks directed in the opposite directions, i.e., one inside and the other outside. The surface of both the tarsal segments is provided with evenly distributed fine hair.

(ii) The Wing-pads. (Text-fig. 11). On an average the wing-pads measure 1.7 mm. in length. The basal sclerites of the wings are

not differentiated. The mesothoracic wing-pads are almost directly continuous with the lateral end of the mesosternum. They are almost triangular in shape with the posterior boundary deeply curved. A suture can be marked at the junction of the wing-pad and the mesotergum. The surface is rough and not provided with hair or bristles. The colour is deep brown or almost black. The metathoracic wing-pad is membranous and articulates similarly with the metatergum along a well developed suture. Its posterior boundary is less rounded than the mesothoracic wing-pad but is more or less angular.

The Abdomen

(Text-figs. 13 and 14.) The first abdominal segment is the least developed and almost fused with the metathorax. The second segment is of normal size but is the widest of all the segments, measuring 3.5 mm. in width. The posterior segments are telescoped and the last two segments are indistinctly marked. The posterior sternites of all the segments are curved inwards while anteriorly they are telescoped inside the preceding segment. The median portion and the lateral extremities of the tergites and the sternites are highly sclerotized and deep brown in colour. The ventral region is less chitinized.

In the mid-dorsal region between the fifth and sixth, and sixth and seventh segments there is a characteristic groove-like depression probably formed by the union of two small openings which are seen separated between the fourth and fifth segment. In the rest of the tergites no such openings are present. The pleural sclerites are indistinct. The ventral median sclerotized plates have short spines on their posterior margin directed backwards. The first six abdominal segments have a pair of spiracles placed on the ventral marginal sclerotized plates. They are circular, elongated, microscopical apertures with heavily chitinized margin. On the posterior side near the spiracle in all the spiracle segments are two prominent dark brown setae with a circular base. There is a median longitudinal ridge on the sixth sternite of the female. In the males no such ridge is observed.

Summary

The last instar nymph of *Bagrada picta* has a well developed prognathous head with typical Hemipteran mouth-parts, four-segmented antenna, and prominent sessile compound eyes. Labium, labrum, maxillary styles and mandibular stylets form the piercing and sucking apparatus with the rostrum folded below the body. Most of the sutures and sclerites of the head are obliterated.

The thorax is three segmented, dark brown with a pair of well developed legs in each segment. Wing-pads are developed on the meso-and

metathorax, while on the prothorax only a suture is developed denoting the prothoracic wing-pad on its outer side. The metathorax is the smallest, less chitinized and almost covered by the mesothorax.

The abdomen is oval, dorsally convex and the segmentation is marked by grooves. The mid-dorsal portion and the lateral extremities of all the segments are dark coloured. The spiracles are ventrally placed on the lateral extremities of the first six segments and the sexes could be differentiated.

Acknowledgments

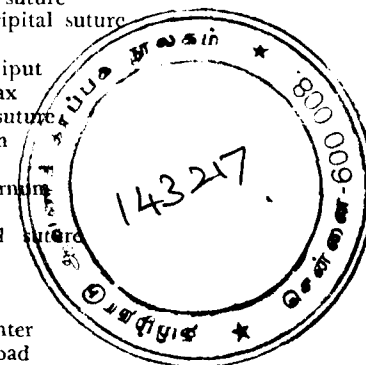
The author wishes to thank Prof. T. Singh, School of Entomology, St. John's College, Agra, under whose guidance the work was undertaken and to whom the author is indebted for helpful suggestions and advice. Thanks are also due to Mr. Y. K. Rathore, Research Scholar, School of Entomology for help in collecting the insects.

Abbreviations

AC	Antennary sclerite	MF	Maxillary fold
AN	Antenna	MP	Mandibular plate
AS	Antennary suture	MS	Maxillary stylet
AU	Anus	MT	Metathorax
BR	Broken rostrum	MX	Maxillary plate
BU	Buccula	OC	Ocular suture
CB	Coxal cavity	OF	Oral fossa
CF	Clypeal fold	OI	Occiput
CL	Clypeus	OP	Occipital suture
CL	Claw	OS	Ocular suture
CO	Coxa	PC	Post occipital suture
EM	Epimeron	PD	Pedicle
ES	Episternum	PO	Post occiput
EU	Eusternite	PR	Prothorax
EY	Eye	PS	Pleural suture
FE	FEMUR	RO	Rostrum
FL	First flagellar segment	SC	Scape
FL	Second flagellar segment	SN	Spinasternum
GU	Gula	SP	Spiracle
HY	Hypostome	SS	Sub-genal suture
LB	First labial segment	TH	Thorax
LB	Second labial segment	TI	Tibia
LB	Third labial segment	TR	Tarsus
LB	Fourth labial segment	TR ₁	Trochanter
LR	Labrum	WP	Wing pad
MD	Mandibular stylet	PO	Post occiput
ME	Mesothorax		

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Heterosaccus ruginosus (Boschma), a Rhizocephalan Parasite on the crab *Neptunus sanguinolentus* (Herbst)

BY A.I. GEORGE, M.A., M.Sc.,

(Communicated by Dr. S. Jones).

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Introduction

Changes brought about in the sexual organization under the influence of parasites are of widespread occurrence in the inverteb.a.a. In no other group are the changes induced by parasitization more conspicuous than in the Crustacea which has provided material for some of the most classical investigations carried out in the past years. An outstanding example of these changes is found in the common crab *Neptunus sanguinolentus* (Herbst) parasitized by *Heterosaccus ruginosus* (Boschma). The present study is a detailed investigation of a species of *Heterosaccus* in its internal stages and of its effect on the host.*

The genus *Heterosaccus* was established by Smith (1906) who gave the following diagnosis of the genus. "Similar to *Sacculina*, save the

* Note:—In the note published in the Proceedings of the 30th Indian Science Congress I described this as a new species of Rhizocephala parasitic on *Neptunus pelagicus*. The species was later on identified as *Heterosaccus ruginosus* Boschma as mentioned by M. J. George (1949) about my unpublished thesis "The Development of the Rhizocephalan parasite *Heterosaccus ruginosus* (Boschma) and effects on parasitic castration on *Neptunus pelagicus*." A subsequent re-examination of the material shows that the host was actually *Neptunus sanguinolentus* Herbst. My idea was to correct this at the time of publication of my full paper but due to preoccupation, the matter was delayed till now. M.J. George (1949) has identified the same parasite as *Sacculina* sp. which has been doubted by Boschma (1957). Boschma is inclined to identify the parasite as a species of *Heterosaccus*. Under the above circumstances the opinion expressed by Boschma that the parasite described by M. J. George could be only a species of *Heterosaccus* is evidently correct.

mesentery is confined to the surface of the visceral mass immediately round the ring of attachment and does not stretch to the mantle opening". To this diagnosis Boschma (1931) added; 'Testes of curved shape. The existence, 'of a wide mantle opening', was not found to hold true for all the species of the genus, a fact noticed by Kruger (1914) and subsequently found to be by no means a peculiarity of the genus.

Boschma (1928) considered the family Sacculinidae to be composed of four genera; *Sacculina*, *Loxothylacus*, *Drepanorchis* and *Heterosaccus*, with the following diagnostic characters.

1. *Sacculina*: mesentery complete, testes straight, visceral mass united with the stalk.
2. *Loxothylacus*: mesentery complete, testes curved, visceral mass united with the stalk.
3. *Drepanorchis*: mesentery incomplete testes curved, visceral mass united with the stalk.
4. *Heterosaccus*: mesentery almost wanting (confined to the immediate vicinity of the stalk.)

Only seven species of *Heterosaccus* have hitherto been described. The present form resembles *H. ruginosus* in all the essential features and has therefore been referred to this species.

I have followed the classification of Boschma (1931). The body is laterally compressed with the mantle opening opposite the stalk. Mesentery is confined to the region immediately near the stalk and does not stretch to the mantle opening. Testes are of a curved shape. Col- leteric glands are found on the central part of the lateral surfaces of the visceral mass, nearer the mantle opening than the peduncle. Outer cuticle is thick and slightly wrinkled in some parts and does not show any clear areas or any special processes. Canals with hyaline chitin are present in certain areas. The presence of a thick outer cuticle and canals with hyaline chitin has not been noted in *H. ruginosus* recorded from *Thalamita prymna* (Boschma, 1931).

Although a good deal of work has been done on the genus *Sacculina*, very little is known about the other genera of the family. Examples of *Heterosaccus* have been recorded from different places and from different hosts, e.g., *H. hians* from Philippine Islands on *Thalamita* sp. (Kossmann, 1874) and from the Red Sea on *Charybdis ornata* (Smith, 1906); *H. sibogae* on *Thalamita admeta* (Van Kampen and Boschma, 1925); *H. occidentalis* from the West Indies on *Microphrys bicornutus* (Boschma, 1931); *H. ruginosus* from Singapore on *Thalamita*

prymna and *Lissocarcinus pulchellus* (Boschma 1931); *H. tasellatus* from Caras Bay, Curaco on *Mithrax ruber* (Boschma 1931); *H. distortus* from Philippine on *Schizophrys* sp. and *H. Californicus* off California on *Pugitta* sp. (Boschma, 1933) and *H. indicus* from India on *Portunus pelagicus* (Boschma, 1957).

Historical

The study of the Rhizocephala may be said to have commenced at Naples in 1787 when Cavolini published his volume "*Sulla generazione dei pesci e dei Granchi*". In 1884 Delage's monograph appeared and it contained a very complete account of the anatomy and life-history of *Sacculina carcini*. It was Giard (1886) who first drew attention to the castration effects caused by these parasites on their hosts. He showed that the males of the crab *Stenorhynchus phalangium* infected by *Sacculina fraissei* began to develop female characters and also believed that the females could be modified towards the male. He explained these phenomena as being due to a retardation of development consequent upon the low rate of metabolism brought about by the parasite. This subject was pursued by Smith (1906) who elucidated certain points in the development of the young parasite and also gave an account of the other members of the Rhizocephalidae. The study of the endoparasitic stages substantially filled the gap in Delage's work and explained the lack of continuity between the structure of the cypris and of the adult *Sacculina*.

Day (1935) in his study of the life history of *Sacculina* gives a brief review of the literature and points out certain anomalies in the accepted account of the life history of *Sacculina*. From the analysis of a year's collection of *Portunus holsatus* infected with *Sacculina carcini* it was concluded that crabs may be infected at any stage. The endoparasitic existence lasts nine months and the first batch of the larvae appear three months later. Two experiments showed that the evagination does not take place as a result of moulting. Both experimental and histological data support the theory that an analogous group of highly modified crabs without external parasites occurs containing living parasitic root systems that are regenerating externae. The effects of *Sacculina* on the secondary sexual characters of the male *Portunus holsatus* show that various degrees of modification are possible, that the percentage of infection increases among large crabs, that the smaller the crab the greater the liability to maximum modification and that the maximum degree of possible modification decreases among larger crabs.

Material and Methods

During the period of a year and a quarter from October 1941 to December 1942, a total of 1431 crabs were examined. The results are

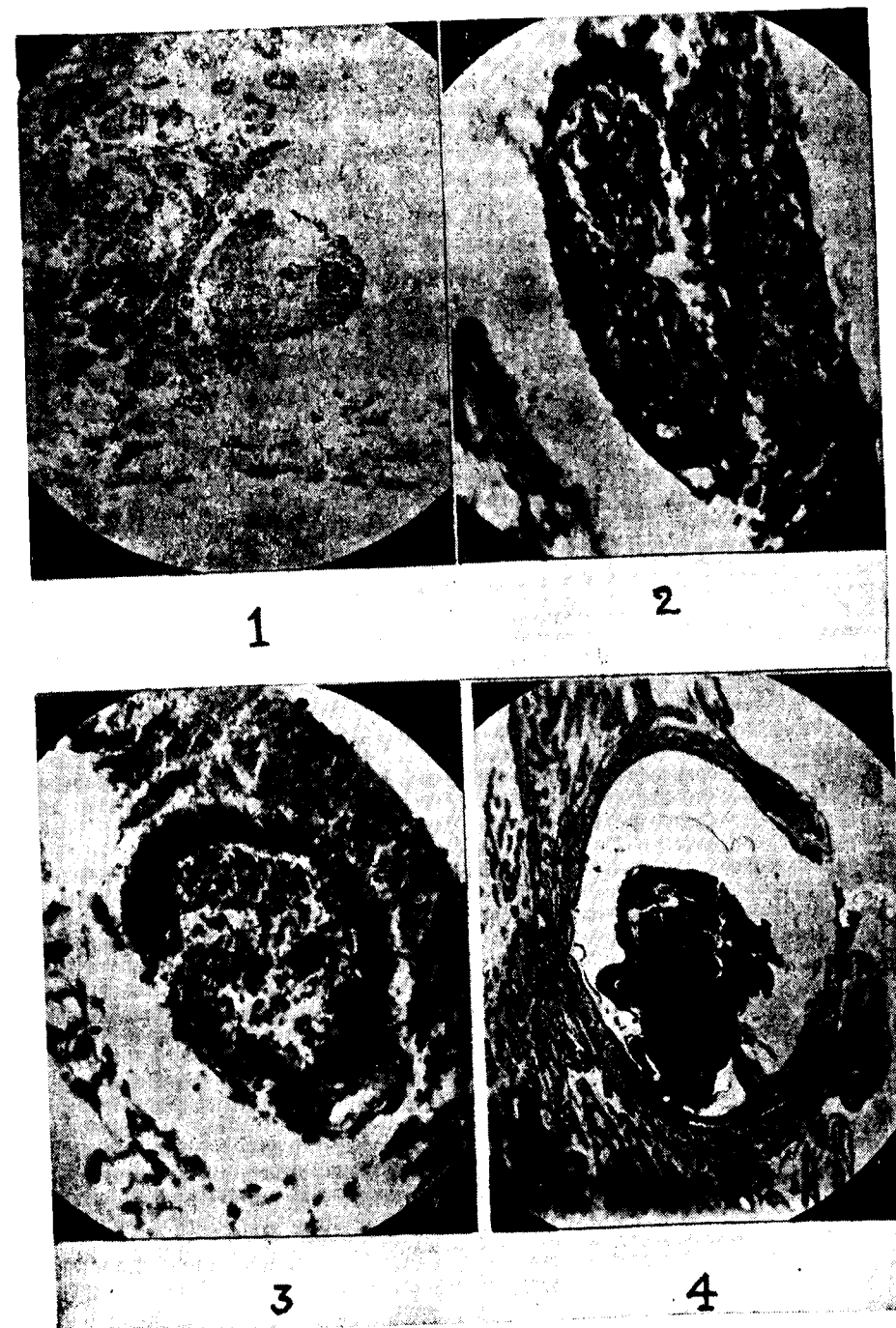
set down in Tables I, II, III and IV. These crabs, which were purchased in the local market at Madras at frequent intervals, were examined, and the various characters, both of the parasite and host, studied. The length and breadth of the carapace, abdomen and chela, the nature of the shell, whether soft or hard and other relevant points were noted. They were then dissected to determine the nature of the gonad and the internae, if present. The method followed was similar to that adopted by Smith (1906). Pieces of the liver were examined and if no roots were found, the whole of the alimentary canal was carefully removed and pieces of the attached liver removed, to find out whether there was any growing interna. When the internae are fairly well developed it is possible to infer their presence even without dissecting the crabs as such crabs show marked atrophy of the abdominal appendages in both the sexes. When internae were present they were removed and fixed in 10% Formol or Bouin's fluid for sectioning and making whole mounts. Sections were cut 8 to 10 μ thick, stained in Heidenhain's iron-haematoxylin, cleared and mounted in canada balsam. For staining internae *in toto* borax carmine was used, cleared in oil of cloves and mounted in balsam. All the drawings were made with the camera lucida. Measurements were taken with a micrometer.

Development

The life-history of *Heterosaccus ruginosus* can be divided into three stages, (i) Embryonic (ii) Endoparasitic and (iii) External.

(1) Embryonic Development and Infection:

The whole of the embryonic development up to the nauplius stage is passed through in the mantle cavity (or the brood pouch). As the ova pass along the colleteric glands, they collect to form egg strings. Fertilization takes place before the secreted chitinous coat hardens. The egg strings as they emerge out of the colleteric glands are grouped together in a definite manner. There is a main stem with a number of branches. At the free ends of the strings the chitinous coating extends a little and this end is attached to the retinacula found on the inner cuticular lining of the mantle wall. The spindles are apposed to the sides of this tubular chitin and with the help of this and the hooks on them the egg strings are firmly held to the inner surface of the mantle wall. How this attachment takes place is not known. Only the free ends of the strings are attached to the mantle wall, the main stem with the attachment of the other ends lies free in the mantle cavity, where it undergoes further development. The eggs at this stage are slightly oval and have a length of 135 μ and a breadth of 108 μ . Eggs which have attained a length of 166 μ are sometimes found free in the mantle cavity. But eggs which have undergone further development are also found in the egg string. The characteristic nauplius shape is attained and the caudal furca is also developed.



1. L. S. of host's abdomen showing the earliest stage of the interna.
2. T. S. of host's abdomen showing the formation of the mantle cavity.
3. T. S. of host's abdomen showing the "Nucleus" (highly magnified) and the formation of the ovaries.
4. L. S. of host's abdomen with interna at the final stage of development.

The backwardly directed frontal horns and rudiments of the three pairs of appendages are seen. Large oil globules are present. The egg membrane still surrounds the embryo and in the next stage, the nauplius frees itself from the egg membrane. The nauplius resembles that of *Galatheascus* more than that of *Sacculina*. This appearance cannot be considered to be of systematic value as Boschma (1927) has found that only the second and later nauplii possess characters of systematic value. The nauplius has a total average length of 200μ . The nauplius eye is a prominent red spot near the anterior margin. Three pairs of appendages are present, the anterior pair being uniramous, the two posterior ones biramous. Three long hairs terminate the anterior pair of appendages, the endopodite and exopodite of the second pair and the exopodite of the third pair whereas the endopodite of this last limb ends in two hairs. The exopodite of the middle pair is three-jointed while that of the last pair is two-jointed. The development in the brood pouch is only upto the nauplius stage. No cypris larvae have been found in the pouch. Water is drawn in and expelled by the contraction and expansion of the highly muscular walls of the mantle. When the nauplii are fully developed they escape along with the expelled water and develop into the cypris stage. The larvae could not be grown in the laboratory tanks. The metamorphosis of the nauplius into the cypris and its infection of the crab were not observed by me, but as in *Sacculina* the cypris probably attaches itself to a hair of the host, drops its appendages and shell, and enters the body of the host in the form of a group of cells and travels to its destination under the intestine.

(2) *Endoparasitic Development:*

The fate of the cells introduced into the host crab is extremely difficult to trace and only when they have reached and established themselves at the definitive position in the vicinity of the unpaired gland, is it possible to study their further development. The present account commences with the internal stage at this definitive position.

The earliest stage obtained is a slightly enlarged tumour lying amongst the liver tubules in the haemocoel of the crab not far beneath the body wall. This tumour (Plate VIII fig. 1) is provided with a few roots and a main root stem. It has a thickness of about 460μ and a diameter of about 680μ . The structure of the tumour is not very different from that of the roots starting from it. The main roots as well as the tumour are hollow structures. Surrounding the tumour is a thin layer of chitin which is continued over the roots also. Below this chitin is a layer of epithelial cells and beneath the epithelial layer is a layer of loosely distributed myoblasts "or spider cells" (Text-fig 1).

The lumen of the main root, trunk and the tumour is filled with a punctated substance. At the side of the tumour, that is nearest the ventral body wall, the cells lining the external wall become definitely epithelial in nature with regularly arranged cells with prominent nuclei. Here, almost in the middle of the tumour, is seen a compact mass of

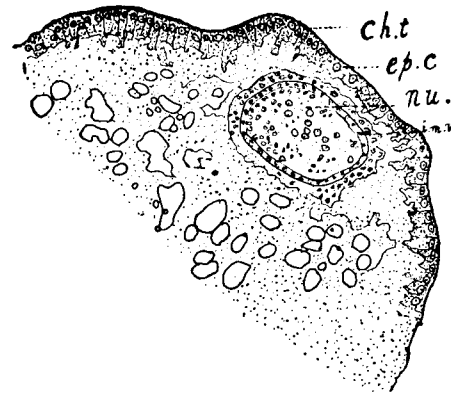
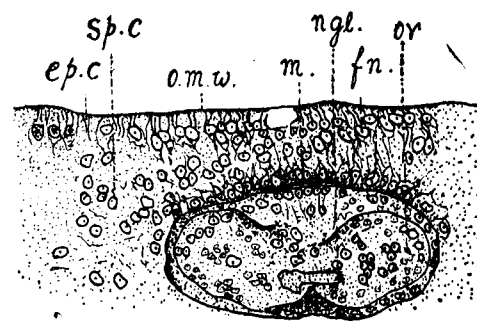


Fig. 1

cells, the "nucleus" or the *anlage* of the future externa, and in a transverse section appears as though the "nucleus" is suspended in the cavity of the central tumour from its epithelial wall. In this "nucleus", the mantle and visceral mass are already differentiated. The formation of the mantle (and thus the mantle cavity) is by a delamination of the ex-



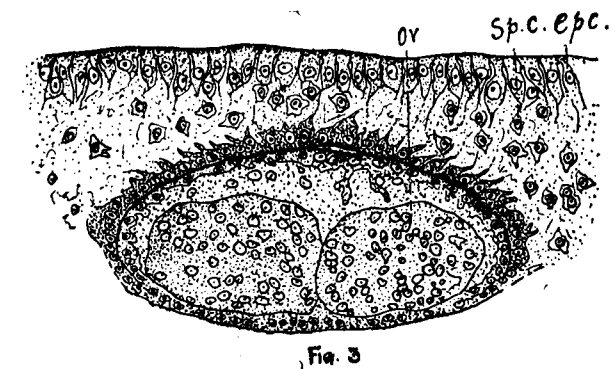
Text-fig 2.

Enlarged view of the "nucleus" × 440.

Fig. 2.

ternal layer of this 'nucleus'. This begins from the middle (Text-fig 2) and then gradually extends to the anterior and lateral sides, but not posteriorly where the two layers are in continuity and at this region the future mesentery (the connection of the visceral mass with the mantle) is formed (Text-fig 3 & plate VIII fig. 2). On the two sides of this arched cleft the cells are regularly arranged and the nuclei are large

with a conspicuous nucleolus in each. The layer of cells thus cut off is destined to form the inner wall of the mantle and the layer that is inside this along with a mass of loosely arranged cells is destined to

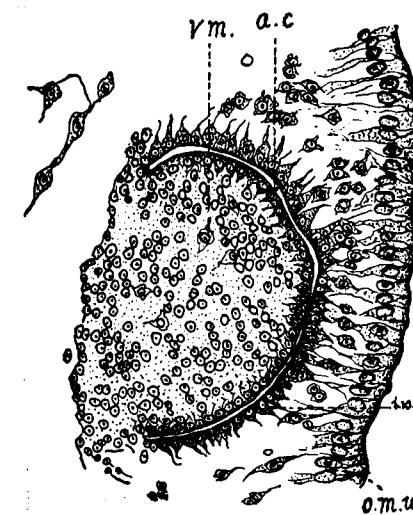


Text-fig 3.

Enlarged view of the "nucleus" showing the place where mesentery is formed × 570.

Fig. 3

give rise to the visceral sac. (Text-fig 4 and plate VIII fig. 3). From this arched cleft originates the future mantle cavity. Between the epithelial layer of the central tumour and the 'nucleus', is seen some of the



Text-fig 4.

Enlarged view of the 'nucleus' showing the arched cleft × 570.

Fig. 4.

spider cells. These cells are destined to form the circular muscles of the adult mantle wall. Excepting for a small space close to the nucleus, the cavity of the tumour has been filled up with "spider cells." These

spider cells are very loosely anastomosing mesenchyme cells. Their nuclei are spherical and smaller than those of the epithelial cells, being about 3.3μ in diameter, and each with a prominent nucleolus. In a later stage the mantle cavity is more differentiated (Text-fig 5) and chitin has been formed on the two opposing sides. The tumour has become very much enlarged but the size of the 'nucleus' remains unaltered. Some of the epithelial cells along the external wall of the tumour are seen to slip out and form muscle cells, the longitudinal muscle fibres of the future mantle. This external layer of epithelial cells

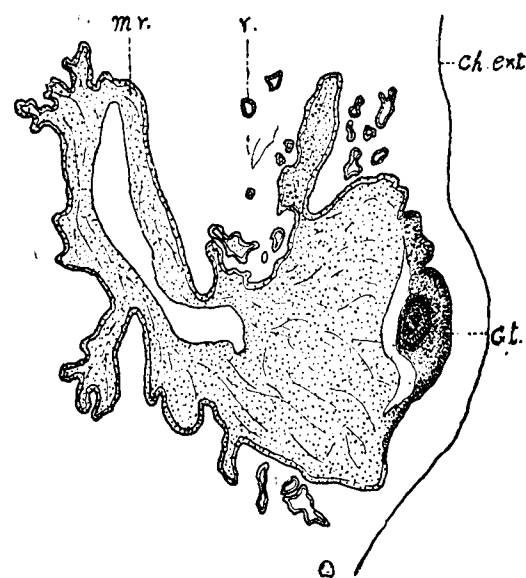


Fig. 5

Text-fig 5.
L. S. of host's abdomen with
interna; $\times 100$.

is destined to form the future outer wall of the mantle and the lining wall of the perisomatic cavity. In the visceral mass, soon after it is formed, an outer layer is differentiated enclosing the loose parenchyma. This outer layer forms the surface epithelium of the visceral sac and secretes the chitin lining on its outer surface. The differentiation of the ovary takes place a little later and it is seen in a transverse section as a bilobed mass (Text-fig 6) surrounded by a membrane. The epithelial cells of the visceral mass opposite the mantle cleft get gradually transformed into the spider cells. It is in this region that the mesentery will be formed. No other organs are visible at this stage. At the end

of this stage the invagination leading to the formation of the perisomatic space has begun. The nucleus has not much altered in size but at the end of the formation of the space, it is conspicuously enlarged. Invagination takes place in a broad area in the epithelial wall nearest

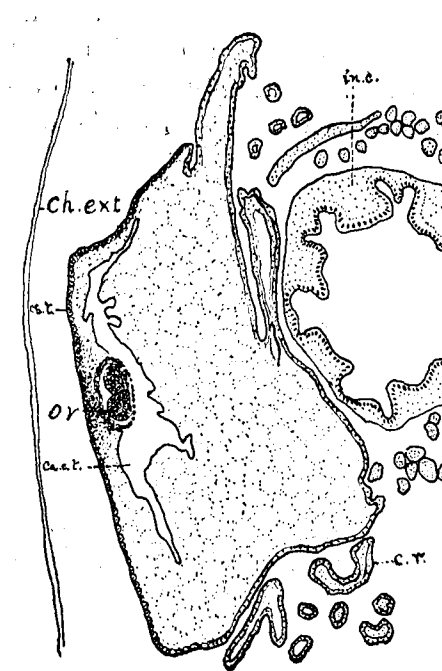


Fig. 6

Text-Fig. 6. T. S. of host abdomen with interna $\times 100$.

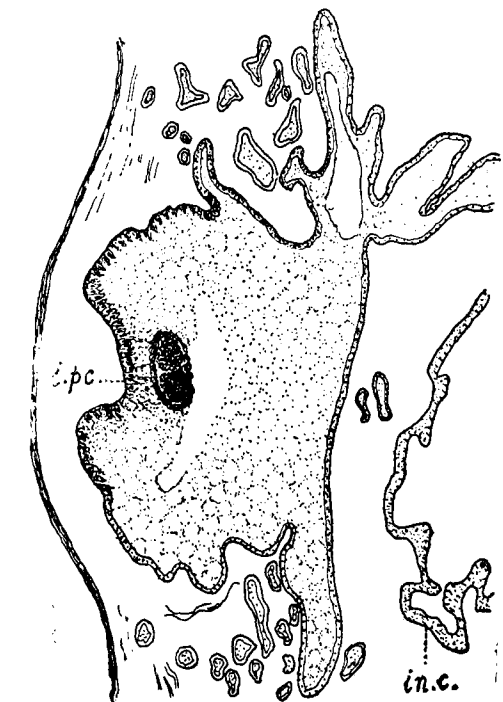


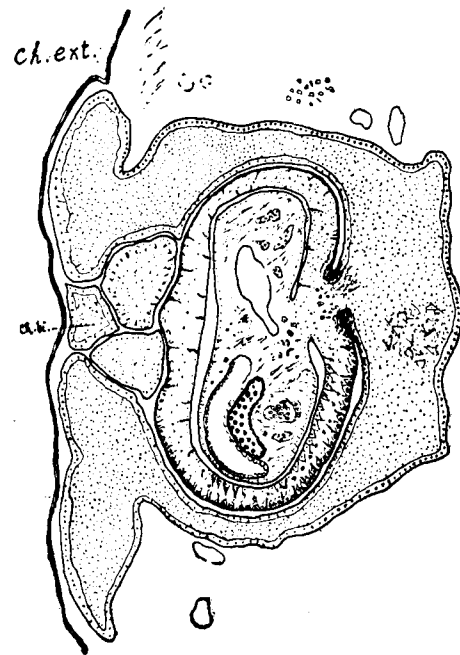
Fig. 7

Text-Fig. 7. T. S. Host's abdomen with interna showing the invagination of the epithelial wall of the central tumour prior to the formation of perisomatic cavity $\times 190$.

the 'nucleus' (Text-fig 7). The epithelium in a broad area gets closely apposed to the 'nucleus' and extends down on all sides leaving a small area at the posterior side. The result of this is that the mantle sac has been completely invested with its outer epithelial lining and the whole future externa has been encased in the cavity so formed.

The invagination of the perisomatic cavity is completed. It is a completely closed space, the invaginating walls having met each other in a narrow space. The cavity itself is negligible as the inner wall of the perisomatic cavity and the outer walls of the mantle are in close

apposition (Text-fig. 8). The chitin that runs over the external epithelium of the mantle is continuous with that of the inner wall of the perisomatic space. While the perisomatic cavity is forming, the rest of the organogeny has been going on. The ovary is highly branched and in sections is seen cut in different parts of the visceral sac. Muscle fibres are formed and occupy the spaces between the ramifications of the ovary. The colleteric glands of the ovary are clearly distinguished by their regular epithelium. The testes are not apparent until further development has taken place. They are formed as two little pockets and



Text-Fig 8.

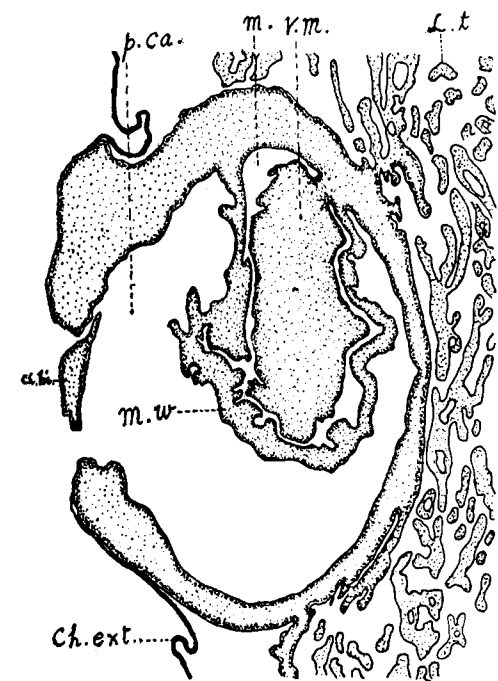
T. S. Host's abdomen with interna; the perisomatic cavity being completely formed $\times 100$.

FIG. 8.

have regular epithelial lining. These form the rudiments of the vasa deferentia and around them a few cells with large nuclei are found grouped together which will form the glandular portion of the testes. The mantle is lined by chitin on the inside and outside. Circular and longitudinal muscle fibres are formed, the former, as stated before, form the spider cells where as the longitudinal muscle fibres are derived from the outer and inner epithelial layers of the mantle. No mantle folds have met, a block of it is being separated by the dissolution of its

cells. The tumour is lying just beneath the very thin body epithelium of the crab.

Text-figure 9, represents the final stage of endoparasitic development when the parasite is ready for emerging to the outside. The fully developed interna lies in the perisomatic cavity attached to its side like a small embryo attached to the uterus of its mother (plate VIII. fig. 4). The narrow perisomatic cavity in the previous stage has enlarged to a very large size. The mantle is made up of a thick outer and a much thinner inner cuticle, the inner and outer subcuticular epithelial layers



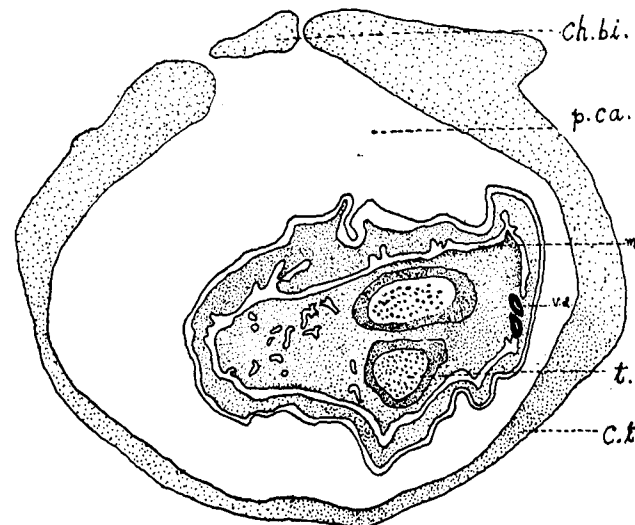
Text-Fig 9.

L. S. Host's abdomen with interna at the final stage of development $\times 38$.

FIG. 9.

and a middle spongy layer of loosely arranged myoblasts. In the mantle wall the opening is formed but as the chitinous block hangs over, a passage is not established. The visceral mass is better organized than in the previous stage. The ovary has become extensively branched even though the ovarian cells are not prominent and these and the reticulum of the connective tissue cells fill the whole visceral mass. The colleteric glands are formed as two protruding masses of cells on the lateral sides of the body. The secretory cells are arranged in parallel rows. In the region of the colleteric glands, almost in the centre of the visceral mass, is seen a lens-shaped structure. This is the nerve

ganglion. The ganglion cells are not stained as deeply as the surrounding cells and have a characteristic yellowish appearance. Nerve fibres could not be traced. Testes are well developed and are seen as two prominent masses at the posterior side of the visceral mass (Text-fig 10). They are seen lying side by side and have an outer layer of proliferating cells. Developing spermatocytes are seen towards the centre of the testes masses. Of the two, the ventral one appears to be larger. The two vasa deferentia with distinct walls are seen in sections. The lumen of the vas deferens is occluded by chitin at this stage and each is seen opening into the mantle cavity on either side of the mesentery.



Text-Fig 10.
L. S. Host's abdomen a few
sections after showing the
testes $\times 60$.

The developing sac has sunk to such an extent that its mesenterial surface nearly touches the opposite wall of the tumour, which itself though enlarged to a great size, has very narrow walls. At this time, there is a circular opening in the outer wall of the tumour, the chitinous block present in the previous stage having been dissolved off probably by some secretions. It is still seen attached to its wall as a small piece. This opening is close to the external skin and the interna may emerge by slipping through this cavity pulling along with it a part of the tumour that will form the peduncle of the externa and the circular opening through which it escapes becomes the chitinous ring seen when it has become external.

In the final stage of development, the longitudinal axis of the parasite is parallel with the longitudinal axis of the host.

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5. L. S. of

6. Dorsal an

(i) Dorsal view of male crab.

(ii)

(iii)

(iv)

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7. Ve

(i)

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(iii)

(v)

(vi)

(vii)

(ix)

(x)

change in

of abdo-

abdomen flexed and externa removed complete; suppression of append.



3. External Development.

The externa (Plate IX fig. 5 and Text fig. 11) may be found on the right or left side of the abdomen of the crab and never in the middle line. Very often it emerges between the 3rd and 4th segments or it may be on the fourth segment. A few cases of double infection showed two externae, one on either side. The mantle opening is still covered over by the chitinous plate which disappears only later. It has been shown by Delage (1884) and Smith (1906) that soon after the appearance of the external *Sacculina* it is surrounded by cypris larvae which attach themselves to the mantle opening. These are the complemental males and Smith found that they have no part in fertilization. No such complemental males have been found in *Heterosaccus*.

The largest externa noted has a length of 19 mm. In the fully developed condition the width of the externa is greater than that of the

Text-Fig 11.
L. S. Abdomen of crab with
small externa $\times 28$.

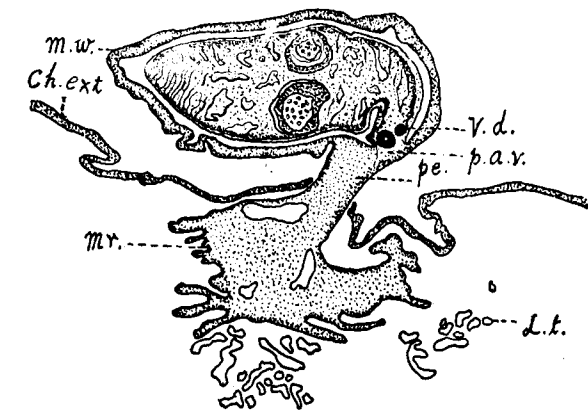
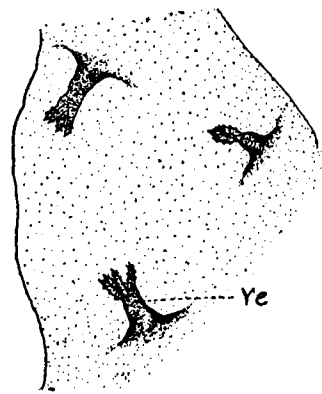


Fig. 11

abdomen of the crab. The body of the parasite is dorsoventrally compressed with the mantle opening at the anterior end, and the peduncle at the posterior end. It is reniform in shape and during the breeding season when the brood-pouch is filled with the growing embryos, it is globular. The peduncle (Text-fig 11) which is in continuation with the internal root system is a short stump of attachment to the host. The surface of the mantle is smooth with the exception of two ridges at the posterior end and a few grooves on the thoracic surface.

The surface pressed against the abdomen of the crab possesses a deep median furrow caused by the projecting posterior gut of the crab. The attachment of the visceral mass to the mantle wall can be seen on the outside as a ridge at the posterior side and is a little dorsal to the attachment of the peduncle to the externa. The mantle opening is a

prominent elongated slit-like or circular opening, the walls of which are thrown into lappets and provided with very strong muscle fibres. The mantle is covered on the outside by a layer of cuticle which is very thick. No excrescences are produced and in sections the outer cuticle shows a slightly wrinkled appearance. In some cases canals filled with hyaline chitin have been noted. The surface of the outer cuticle is not divided into definite areas as seems to be the case for *Sacculina* and certain other species of *Heterosaccus*. The inside of the mantle wall is also lined with a layer of chitin. This layer is much thinner than the outer one and bears on its inner surface numerous retinacula (Text-fig. 12). Each retinaculum has a basal stalk and four to six spindles of 18.2μ length. The spindles are provided with numerous barbs. At the place of insertion of the visceral mass to the mantle, the inner cuticle of mantle on either side is separated.



Text-fig 12.
Inner cuticle of the mantle wall showing
retinacula $\times 440$.

Fig. 12.

The mantle cavity is spacious and encloses the visceral mass. A pair of colletric glands lie at the sides of this visceral mass not far from the middle. Each gland is bilobed and consists of moderately branched tubes.

Testes are fairly large and are contained in the posterior part of the visceral mass on its right side. Both the testes are of the same size but in some, one seems to be slightly larger than the other. They are completely separated and open into the mantle cavity along the highly coiled vas deferens.

Effects of parasitism on host

1. Growth:

An examination of a large number of parasitized and normal crabs leads one to the conclusion that apart from the atrophied appendages, for all outward appearances the general vitality of the host seems to be

unimpaired by parasitism. In all probability the growth of the host crab excepting that of the appendages is not inhibited by the internal *Heterosaccus*. Crabs harbouring small internae grow to a considerable size before the parasite becomes external. Thus it is noted that *Neptunus sanguinolentus* of 14 mm. carapace length with internae could probably grow to 21 mm. carapace length. Orton (1936) found in *Carcinus maenas* of 12-15 mm. carapace width with interna to grow to 25-30 mm. carapace width in the course of 2 or 3 months. There is every reason to think that growth is even more rapid in tropical waters judging from other invertebrate animals (Aiyar 1931 & 1935, Paul 1942, Alikunhi & Aiyar 1943). The influence of the parasite on the growth of the host was found to be negligible by Smith when the parasite was in the internal stage. To quote Smith, "while the parasite is internal it is difficult to calculate what effect it has on the growth of its host but it is probable when the system of roots is well established growth is considerably retarded". He confirmed this by the fact that *Sacculina* interna is present more frequently in crabs which have not moulted for sometime. But later work has proved that there is no retardation of growth even when the parasite is internal. Orton (1936) showed that a crab of 19.5 mm. carapace width, harbouring an interna in a period of 16 months grew to a size of 36 mm. when the *Sacculina* interna became external.

Whether or not the parasite prevents moulting of the host crab has not been ascertained. In *Sacculina* it is believed that moulting is prevented and, in consequence, there is cessation of growth of the host. According to Potts (1909), this is due to mechanical disability, *Sacculina* acting as a rivet and preventing the fleshy part of the abdomen being withdrawn from its chitinous case. *Peltogaster* infecting hermit crabs does not seem to inhibit moulting, and in this case growth appears to be rather favoured by the presence of the parasite (Potts, 1909).

Large externae of *Heterosaccus* have not been observed on soft shelled crabs. Further, two cases of crabs carrying Serpulid tubes and small barnacles were found in the collection. These facts seem to point to the conclusion that in the present species there is a cessation of

moulting apparently when the externa stage has been reached. Individuals with a carapace length of 30 to 40 mm., bearing the externae were present in the collection. The occurrence of these large crabs can be explained only as due to the growth attained by them while the parasite is in the internal stage and not due to growth attained after the parasite has become external. This observation also points to the same conclusion that moulting is prevented once the parasite becomes external.

2. Abdomen and Abdominal appendages:

(a) Normal females:

The normal uninfected females of *Neptunus sanguinolentus* occur as two distinct forms, the adolescents and adults (Plate IX fig. 6). The adolescent crabs have flat and comparatively small abdomina more or less triangular in shape and lie closely apposed to the thorax. Hairs fringing the margin are very few and small. This form of the abdomen is preserved until the first brood of eggs is produced, that is nearly upto a size of about 33 mm. in carapace length. Four pairs of appendages (Text-fig. 13) are borne on segments 2, 3, 4 and 5. All of them

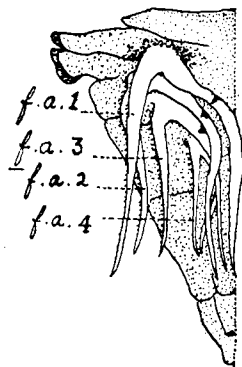


FIG. 13

Text-Fig 13.
Ventral view of the abdomen of adolescent female crab showing the nature and disposition of appendages $\times 6$.

are biramous but lack the development of large hairs characteristic of the adult females. Of the four pairs the first pair is the largest, and the succeeding pairs are increasingly smaller. The endopodite is two-jointed; the exopodite is formed of one piece. Short hairs are developed on both,

The adult females on the other hand have large trough-shaped abdomina (Plate IX fig. 6). The segments 4, 5 and 6 which show considerable mobility are larger in size than those of the adolescent crabs. Fringing the margin there are fairly closely set hairs. Abdominal appendages (Fig. 14) are much better developed, especially the hairs

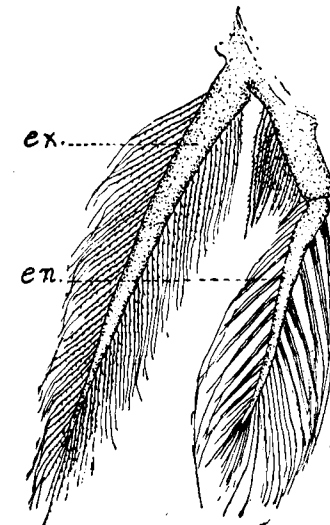


FIG. 14.

Text-Fig 14.

The adult female abdominal appendage. The left one of the last pair $\times 6$.

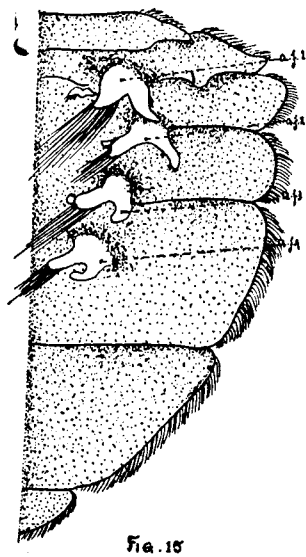
which are particularly prominent on the endopodite. The basal joint bears long feathery hairs only on its outer side. Exopodite bears hairs on both sides which are feathery and moderately long. To the feathery hairs are attached the eggs when they are extruded.

(b) Infected females:

Even when the parasite is in the internal stage, the effects of the parasitism are seen in the atrophy of the abdominal appendages of the host. At first the shape of the abdomen of the infected female (only adolescent crabs are infected) continues to be very much like that of the normal adolescent female. In both cases only very few hairs are present on the margin. A slight tendency in the broadening of the 6th abdominal segment soon reveals itself and so by the time the parasite has become external the abdomen has assumed the shape characteristic of the normal adult female (Plate IX. fig. 7). The typical trough-like appearance has become clear and the hairs along the margin conform to the normal female type,

All the infected crabs whether harbouring the parasite in the internal stage or external stage show profound atrophy of the abdominal appendages. The reduction of these appendages varies from a condition where all the four pairs are present in an extremely atrophied state to total absence of these. The following four stages of reduction of the abdominal appendages have been observed.

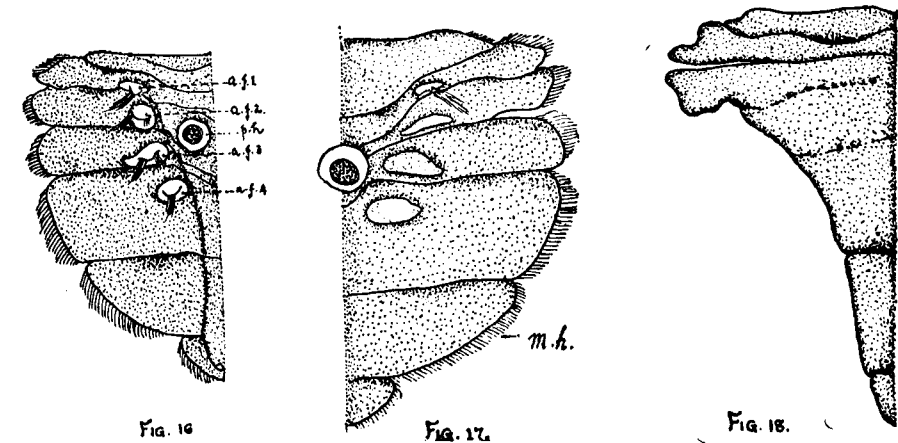
- (1) All the four pairs may be present (Text-fig. 15), though in an extremely rudimentary state, not at all comparable with the condition of the normal females. In the normal females the distal segment of the endopodite of the abdominal appendages is nearly twice as long as the basal joint; the former bearing seven or more bundles of ordi-



Text-Fig. 15.
Ventral view of infected female abdomen showing the highly rudimentary appendages $\times 6$.

nary hairs. But in the infected crab the endopodite is not clearly divided. The distal joint is represented by a small stump in the last three pairs, sometimes bearing at its end a bundle of hairs. In the first pair this stump is better developed than in the others. Basal joint in all the four bears long hairs and is relatively longer than those borne in normal females. Exopodites of the four appendages are present arising as small stumps from the sides of the endopodites.

- (2) In this case all the four pairs are represented in a very much atrophied state. There is no actual differentiation into exo- and endopodites but each one is represented by a bundle of hairs (Text-fig. 16).
- (3) In this, the first and the second pairs of appendages may be present in an extremely reduced state. The tendency is for the complete atrophy of the exopodites but the endopodites may be absent or represented by a few hairs.
- (4) Most of the infected females belong to this type (Text-fig. 17). These have their appendages completely atrophied. Only a few hair like projections are seen in the place where the first pair of appendages would normally



Text-Fig 16. Ventral view of infected female abdomen showing suppression of appendages. Note the non-differentiation into endo and exopodites $\times 6$.

Text-Fig 17. Ventral view of infected female abdomen showing complete suppression of appendages $\times 6$.

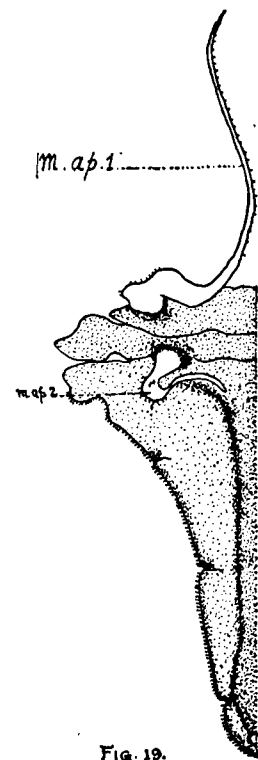
Text-Fig 18. Dorsal view of normal male abdomen $\times 6$.

occur. The places where the other appendages would normally occur are represented by small circular areas from where one or two hairs are seen projecting.

(c) Normal Males.

Male crabs are characterized by a narrow flat abdomen (Plate IX fig. 6) lying closely apposed to the thoracic groove. Segments 3, 4 and 5 are fused together. Fringing the margin are short hairs, shorter and fewer than in the adult female (Text-fig. 18). Two pairs of appendages are borne on the undersurface of segments 1 and 2. The

anterior pair is the longer of the two, and it has a basal swollen part, a middle piece and a long style which has its anterior portion slightly curved. In the apposed condition, the tips of the styles reach the tip of the abdomen. The second pair is much smaller (Text-fig. 19). The style lies in the groove of the anterior pair.



Text-Fig 19.
Ventral view of normal male abdomen showing the copulatory appendages $\times 6$.

(c) *Infected Males.*

The effects of parasitism are more evident in males. The more important changes are the following.

- (1) The re-division of the fused third, fourth and fifth abdominal segments. This re-division appears to be evident while the parasite is in the internal stage and by the time the parasite emerges to the outside this re-division becomes markedly established.
- (2) The broadening and lengthening of the abdomen and elongation of marginal hairs fringing the sides of the abdomen. Parasitism causes a widening of the narrow abdomen in normal male crabs. There is a degree in this modification

and all the infected crabs can be broadly divided into the following three groups:

- (i) In this group are placed all those males with internal infection. At this stage of infection the abdomen shape is like that of a normal adolescent female (Text-fig. 20) and judging such crabs from their external appearance they will be reckoned for normal adolescent females. But a careful examination will show that the abdomen is not firmly apposed to the thorax as in normal adolescent females and also that it is slightly turgid.



Fig. 20.

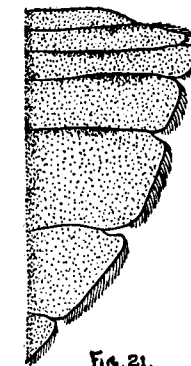


Fig. 21.

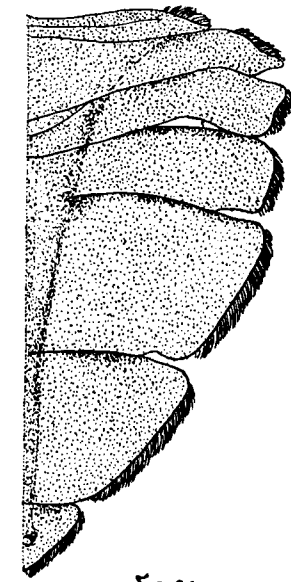


Fig. 22.

Text-Fig 20. Dorsal view of abdomen of infected male crab, with the externa parasite; showing approximation in shape to that of normal adolescent female crab's abdomen $\times 6$.

Text-Fig 21. Dorsal view of abdomen of infected male crab with an externa parasite. Shape in between that of a normal adolescent and a normal adult female crab's abdomen $\times 6$.

Text-Fig 22. Ventral view of abdomen of infected male crab with an externa parasite. Shape that of a normal adult female's abdomen $\times 6$.

- (ii) In this are placed all those males with the external parasite and with an abdomen intermediate in shape between that of a normal adolescent female and a normal adult female. Text fig. 21 shows this type.
- (iii) In the last group are placed all those males with the external parasite and which show the closest approximation in shape to that of an adult normal female (Text-fig. 22).

It was observed that the average width and length of crabs in group (ii) are greater than in group (iii). In group (ii) and (iii) there are large crabs. But in group (iii), in spite of the comparatively smaller size, the modifications are of a more pronounced nature than those found in the group (ii) individuals which have a greater average size. It is therefore more than probable that the degree of modification seen in the host is more in relation with the stage of parasitism reached by the parasite than with actual size of the host. It may also be due to the fact that if the attack of the parasite is in early stages of the host then the modification in the host is more pronounced as has been found in *Portunus* infected by *Sacculina*, Day (1935).

The length of the abdomen is also affected by parasitism. Measurements of infected and normal males show that increase in length of abdomen takes place in parasitized crabs with a carapace length of over 21 mm. Below that the abdominal length tends to be smaller. It is somewhere at this point that the internal parasite is ready to emerge to the outside world. The abdomen increases in length slightly when the parasite becomes external.

The hairs fringing the abdomen in the infected male are longer and more closely arranged, showing approximation to that of an adult normal female.

(3) Abdominal appendages.

Even though the abdomen of the infected male develops like that of the female, in the re-dividing of fused segments, in the broadening of the segments and in the lengthening of the marginal hairs, no tendency towards the development of normal or suppressed female appendages is observed. The male appendages undergo marked atrophy and the degree of atrophy varies from the presence of highly reduced stylets to complete suppression. The following three types are noted.

- (i) Complete suppression of the appendages which is seen in most instances.
- (ii) The two pairs of appendages may be present as mere vestiges, a condition observed only in a few individuals.
- (iii) The two pairs of appendages may be present as mere vestiges or absent altogether. In addition to these, on segments 3, 4 and 5 transparent areas are developed in the place where the 2nd, 3rd and 4th pairs of abdominal appendages would have developed, had the response been the same as in sacculinised males. Excepting for the development of transparent areas there is no formation of any female appendages.

(3) The Chelate leg.

In the normal male and female crabs there is no significant sex difference in size. Neither is there any marked difference in the development of the chelate leg. The left chelate leg is slightly shorter than the right chelate leg in the same sex. Various measurements of chelate legs of normal and infected male and female crabs were recorded. The length was measured from the point of articulation with the thoracic side to the tip of the chela and the breadth was taken at the broadest part of the chela. Parasitism causes the diminution in length of the right chelate leg below to a size that of the left chelate leg of the normal male. While in the left chelate leg, it is below normal till it reaches 27 mm. carapace length and then increases slightly approximating to the condition of the normal right chelate leg. Here the breadth of the left is greater than that of the right. Parasitism causes increase in breadth of the right chela while it is diminished in the left. In the normal female crab the left chelate leg is slightly shorter and thinner than the right. Parasitism causes an increase in length in both the right and left legs upto 28 mm. carapace length. Thereafter it is diminished. In breadth the right is considerably diminished in crabs over 28 mm. carapace length. In the left chelate leg breadth is slightly increased in crabs over 28 mm. carapace length.

(4) Breadth of Carapace.

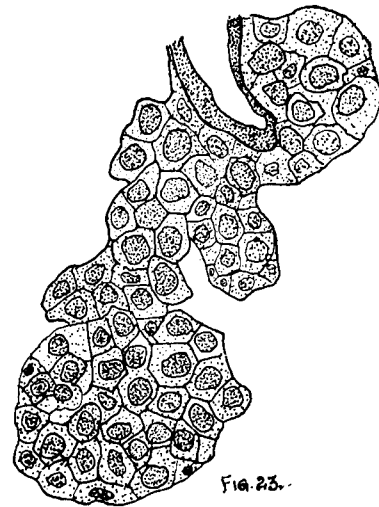
The average carapace breadth of normal and parasitized males and females of the various carapace lengths was determined. The breadth was measured by the distance between the tips of the lateral spines. Parasitism increases the carapace breadth slightly in both sexes above the normal state.

(5) Changes in Internal Organization

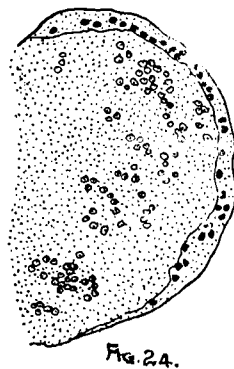
No appreciable reduction of the liver in parasitized individuals has been noticed. Of the internal organs the most important alterations visible are in the gonads.

Male gonads: In the normal male *Neptunus sanguinolentus* testes consist of a pair of sacculated tubes which lie anteriorly in the dorsal region on either side of the stomach extending laterally and connected in front by a transverse bridge across the middle line. They then pass down the sides of the body running along the liver after which they are connected with the highly convoluted vasa deferentia. The terminal part is specialized to form a penis situated on the coxopodite of the 5th thoracic leg (8th thoracic segment) and directed somewhat anteriorly. During the breeding season the vasa deferentia are full of large clumps of spermatozoa which give a milkish white appearance to the whole.

Sections of the testes show various stages of spermatogenesis. Text-fig 23 is a section of testis tubule. The germ cells are seen to form a mass on one side of the tube leaving a clear lumen on the other (Plate X Fig. 8). The tubule is lined by a layer of cells with irregular and more or less oval nuclei.



Text-Fig 23. T. S. Testis tubule showing primary spermatocytes.



Text-Fig 24. L. S. Testis tubule from crab with internal parasite showing degeneration in some parts $\times 440$.

In the parasitized crabs the condition of the testes shows a wide range of variability from one in which it is only very slightly reduced with normal spermatogenesis taking place to one in which no trace of the organ can be detected. This last feature is due to the increased parasitism. In a good number it is impossible to detect any trace of the gonad but in others it may be possible to detect its presence. The semitranslucent appearance of the gonad makes it difficult to trace it. Roots of the parasite have not been found to penetrate the testes. In spite of that, gonads undergo marked reduction in size and appear as mere shreds of epithelium.

Text-fig. 24 is a section through a testes from a crab with an internal parasite. Sperm production is still going on. There is a general breaking down of the cells constituting the tubules (Plate X Fig. 9). The follicle layer is very indistinct and only a few nuclei are seen distributed near the walls of the tubules. Apparently there is no fresh formation and development of germ cells. When the parasite emerges

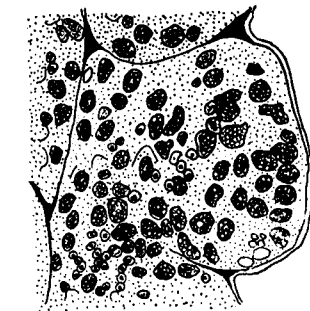
to the outside, further development of the germ cells is prevented. There is loss of compactness in the arrangement of cells. In Text-fig. 25 extensive degenerative changes are seen (Plate X fig. 10) and there is the complete degeneration in some of the tubules.

Abnormal proliferation of the follicle cells without the formation of the germ cells has occasionally been noted. In extreme cases of parasitization the follicle cells are also broken down and undergo degeneration. Oocytes have never been observed to be produced in the testes. The penis is very much reduced, but the external opening is not obliterated as is found in other cases of parasitization.

Female gonads: The ovaries are similar in shape and position to those of the testes. The oviducts are large, short and wide. When the ova are ripe they give a characteristic pink colour to the ovaries which occupy a large part of the body cavity and the oviduct may be found



Text-Fig 25. T. S. Testis tubule of crab with external parasite showing extensive degeneration $\times 440$.



Text-Fig 26. L. S. Ovary of normal crab showing developing eggs $\times 60$.

distended with eggs almost down to the external opening. The ducts are short and thin walled and when not distended with eggs it is difficult to make them out by dissection. Each oviductal aperture is a conspicuous, translucent, oval area with an oblique slit sharply defined from the surrounding opaque white chitin and situated on the sternite of the 6th thoracic segment, very near the point where the tip of the abdomen would lie in the apposed condition. Text-fig. 26 shows the structure of normal uninfected ovary (Plate X fig. 11 & XI 12).

In general, the effect of the parasite on the female gonad is more drastic than in the male. This is only to be expected since the yolk that is required for the production of ova is just the material which is absorbed by the parasite. In a large number of parasitized females no

trace of the gonad could be recognized on dissection but in a few specimens a reduced but complete ovary could be dissected out. Such ovaries are in a state of reduced activity but otherwise normal. Well yolked eggs were present but probably none of them reached the fully mature condition while other eggs were seen degenerating (Plate XI figs. 13 & 14).

No correlation exists between the degree of degeneration of gonads and of secondary sexual characters. Even though the atrophy of the gonads continues even after *Heterosaccus* becomes external the secondary sexual characters do not change after this point.

General Conclusions

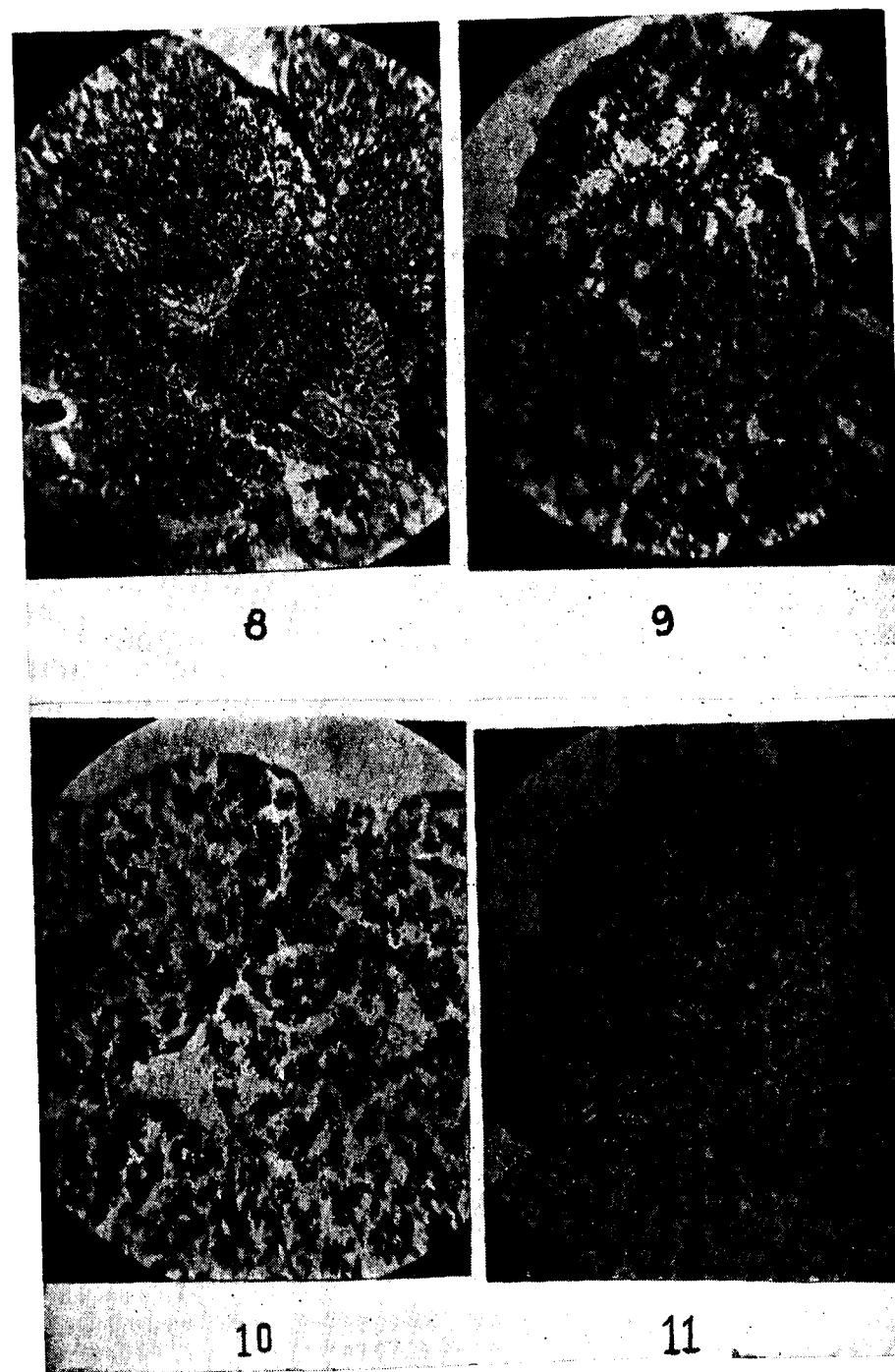
1. The period of attack by the parasite.

Delage (1884) considered this event in the life history to be correlated with the seasons. Day (1935) found that the life-history of the parasite had close correlation with that of the host and that crabs of all sizes were attacked. According to Delage, infection occurs when the crab is very young. He states that, in general, the internae are found in *Carcinus* of 5 to 12 mm., large internae in crabs of 20 to 25 mm. and externae on crabs of 30 to 40 mm. But Day finds that the internae may be present in *Portunus* of all sizes and finds no correlation between the size of the crab and the state of development of the parasite.

In *Neptunus sanguinolentus* internae of *Heterosaccus* were found only in crabs under 24 mm. carapace length. I am fully convinced that the almost invariable infestation by the parasite takes place while the crab is still very young, and the host and parasite develop simultaneously. This observation on distribution of the developmental stages of *Heterosaccus* in crabs of various sizes confirms this. The "internae" refers to the stage when the parasite reaches its definite position on the alimentary canal of the crab near the unpaired diverticulum. Small externae are those under 10 mm. length and large externae are those of 10 mm. and above. This division is arbitrary but convenient. Internal infection is seen in crabs of 14 to 28 mm. carapace length, while externae begin to appear only in crabs above 20 mm. carapace length. Internae in crabs over 22 mm. carapace length are very rare and it may be assumed that infection takes place in crabs under 14 mm. carapace length. No sexually mature *Neptunus* was found to bear a parasite. It may be argued that if larger individuals are also attacked the reduction of the abdominal appendages could not be so very drastic. Here the abdominal appendages of both males and females are reduced to a very great extent as described before. It is only natural to think that if

George :

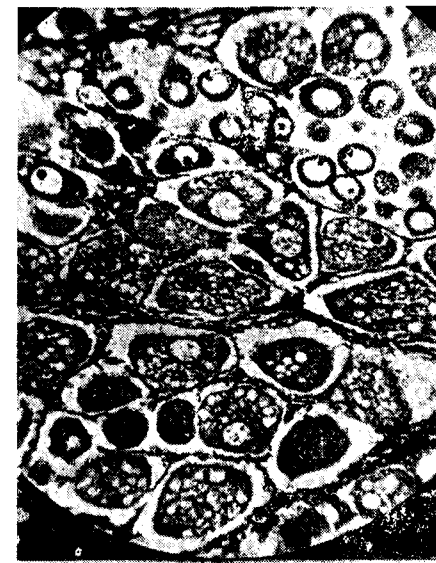
Plate 10



8. L. S. of testis of a normal male crab.
9. L. S. of testis of a parasitized crab, with an externa.
10. L. S. of testis of a parasitized crab with a large externa.
11. L. S. Ovary of normal female crab.

George :

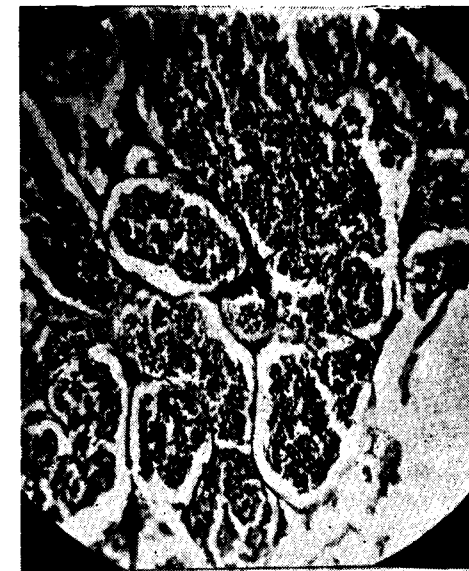
Plate 11



12



13



14

12. L. S. of ovary, highly magnified.
13. L. S. ovary of a parasitized crab with interna.
14. L. S. of a parasitized crab with large externa.

large crabs were attacked the atrophy brought about would be proportionately smaller. But actually even fairly large crabs show no such indication of recent attack.

The available evidence seems to indicate that the initial attack usually takes place when the host is under 14 mm. carapace length.

In one or two crabs of 22 mm. carapace length and harbouring internae, thin abdominal appendages were present but were very much reduced. Here the infection must have been comparatively late in the life of the crab. It is probable that earlier the infection the greater is the arrest of development of the abdominal appendages. Many of the crabs with large externae do not reveal the presence of any abdominal appendages, others showing varying degrees of reduction. The conclusion that may be drawn from these facts is that infestation rarely takes place when the crab is over 14 mm. carapace length but usually when below this size.

Heterosaccus is found to differ from *Sacculina* and *Peltogaster* in that infection takes place apparently only (or with few exceptions) during a short period in the very early life of the host. Consequently unlike crabs parasitized by *Sacculina* where a considerable number about a quarter to a third of the total) are externally unmodified, having apparently been attacked too late in life, such a condition is unknown amongst any of the *Neptunus* parasitized by *Heterosaccus*. Here the crab grows up under the parasite's influence and so it is convenient to study the effects of parasitism without the complicating factors introduced by parasitization at widely different ages. Reference has been made to the degree of modification probably caused by infection occurring at different times during this comparatively short period. But this variability cannot all be attributed to the time of parasitization but must also be due to constitutional differences of hosts. The same conclusion is insisted upon by Potts (1906) with reference to *Eupagurus* and *Peltogaster*; vide also Smith (1910) with whom it is a major contention.

2. Endoparasitic Development.

In *Sacculina* there is an 'interna migrans' stage. The developing embryonic cells of the Kentrogon larva, entering the haemocoel, get applied to the intestine and begin to grow down the intestine developing more and more roots. In this migrans, the anlage of the visceral mass and mantle is formed. In *Peltogaster*, Reinhard (1942) found that, at the definitive position, a globular mass of cells, containing the anlage of visceral mass and mantle are formed before the formation of any roots. In *Heterosaccus* also the growth of the root trunk is from the definitive position. This is evident as older roots are found nearer the tumour and younger roots farther and farther away.

In *Sacculina*, Delage (1884) found the mantle sac to be formed by delamination from the inner wall of the original investing sac, the cavity of the latter forming the cavity of the perisomatic space. But Smith (1906) proved this to be wrong and that the original investing sac remains unaltered as the mantle cavity or brood pouch while the perisomatic cavity is formed by separate invagination of the wall of the central tumour. In *Heterosaccus*, at the very early stage observed, the mantle cavity has been formed prior to any other organ. The mode of formation of the perisomatic cavity is different from that of *Sacculina*. Invagination starts at a point opposite the visceral mass and the intestine of the crab, and at the posterior part of the central tumour. In *Heterosaccus* the perisomatic cavity is closed and the opening is only formed later. In *Sacculina* it is an open space from the very beginning and the cavity is formed before the *Sacculiana migrans* has reached the definitive position while it is formed only much later in *Heterosaccus*, a feature noticed in *Pellogaster* as well (Reinhard, 1942). The development of the other organs are in essential agreement with that of *Sacculina*.

3. The Evagination of the Parasite.

In the last stage of endoparasitic development described above it was shown that the membrane separating the tumour from the outside world was a very thin chitinous lining of the abdomen of the crabs. But I have not observed the actual emergence of the parasite. Smith surmised that the evagination of the parasite happens with a moult of the host crab in the case of *Sacculina*. Day has recently disproved it. In *Heterosaccus* it has not been definitely observed how the emergence of the parasite occurs. Small externae were always found on crabs with soft abdominal shells. In all probability just before the emergence of the parasite there may be a moult of the host crab. The difference in the shape of the abdomen having mature interna and externa is highly suggestive that it has taken place at a moult. When the parasite is in the internal stage the abdomen is narrow and triangular but the abdomen becomes much broader and in the male crabs the segmentation of the fused segments completely established. While Day (1935) has proved that a moult is not necessary for emergence in the case of *Sacculina*, all evidence shows that in *Heterosaccus* the emergence of the parasite takes place at a moult.

4. The Breeding period of the Parasite.

Foxon (1940) found that in *Sacculina* the breeding period was much influenced by its host and that, in particular, the breeding periods of the host and parasite resemble in their duration, as has also been noticed by Orton (1936). *Neptunus sanguinolentus* with fully developed externae were numerous in October, December January and February.

In January 10% of the female crabs were with berry. An analysis of the collection of the female crabs suggests that the female crabs are mature in July, August and September. From October to January crabs which carry the brood of eggs are constantly met with. So, along with the nauplii of the uninfected females of the population or a little earlier the nauplii of the parasite are also liberated so that infection takes place when the crabs are very young. A definite correlation in the breeding seasons of the host and parasite is thus observed.

5. Fate of the Parasite

In *Sacculina carcini* infecting *Portunus holsatus*, Day (1935) found that after one breeding season of the parasite it drops off, and the host thus liberated will moult and may regenerate an externa. Crabs from which the parasites drop off, he called scarred crabs, the scar being due to the blackened stump of attachment of the former *Sacculina externa*. As no crabs with scars have been obtained during this study it is concluded that there is no general dropping off of the parasite at the end of a breeding season, and that the length of parasite's life is co-extensive with that of the host. There was a single instance of a crab with evidence of having been freed from the parasite. But it was impossible to say whether the parasite was separated off by accident or otherwise.

6. The Fate of the Host.

Smith (1906) found that infected crabs may recover but he found the process to be slow and exceedingly few recovered crabs were obtained in nature. Day (1935) suggested that an anomalous group of highly modified male crabs without externae but containing living parasitic roots are 'scarred' crabs that have moulted. Such modified crabs or recovered crabs were not in the collection of crabs examined in this case and the absence of such is highly indicative of the fact that there is not the general dropping off of the parasite.

7. Some data on the numbers of host & parasite.

During the period of this study 1431 crabs were examined. Nearly 10% of these were parasitized. The number of infected crabs varied considerably in the different months. It reached the maximum of 40% in October 1941, dropped to 20% in December of the same year and reached a minimum of 6% in January 1942, rising again to 20% in February. In July it was 5%, and 12% in August reaching a minimum of 30% in December 1942. But in the absence of detailed statistical data, no conclusions may be reached from these figures.

8. *Effect of Sexual Characters.*

The time when this transformation of the secondary sexual characters occurs was found by Smith to be at the ecdysis of the host. In a few cases he observed this moult failing to bring the *Sacculina* to the exterior, so that the phenomenon was observed of the effects of the parasitic castration, being apparently brought about by *Sacculina interna* but such cases could easily be distinguished. *Neptunus sanguinolentus* transformation of the secondary sexual characters is not as described by Smith (1906) in *Inachus scorpio*. Even when the parasite is in the interna stage there is a profound modification of the secondary sexual characters in the male as well as the female.

The next question that should be considered is the nature of castration brought about by *Heterosaccus*. The term parasitic castration was introduced by Giard (1887) and has since been extensively used. Objection has often been raised as to the validity of the term on the ground that the changes do not necessarily mean a destruction of the gonad. Wheeler (1910) employs the word "Castration" in Zoology in a broad sense to mean, "any process that interferes with, or inhibits the production of ripe ova or ripe spermatozoa in the gonads of an organism and not merely in the concise original meaning as the sudden and complete extirpation of the gonads."

In crabs there are five instances of parasitic castration brought about by Rhizocephalans namely that by *Sacculina*, *Peltogaster*, *Lerna-eodiscus*, *Triangulus* and the present instance of *Heterosaccus*. When a comparison is made between *Heterosaccus* and other forms, the first thing that strikes is the great modification of appendages in both sexes of *Heterosaccus*. With *Sacculina* on *Portunus carcinus* only about 70% of the parasitized crabs show obvious modification of the secondary sexual characters; in the case of *Peltogaster* on *Eupagurus* about 75% are modified. In *Neptunus* parasitized by *Heterosaccus* we find striking modification of the abdominal appendages ranging from total absence to highly vestigial appendages in both male and female crabs. This is presumably due to the early infection of these crabs. In the male crabs there is no development of female appendages but it may be suggested that the transparent areas on segments 3, 4 and 5 of the infected male abdomen indicate changes in that direction as also are the broadening of the abdomen, the lengthening of the hairs fringing the sides and the re-established segmentation in infected males.

It has been pointed out that in female crabs where the suppression of abdominal appendages is far reaching, only the transparent areas are seen on segments 2, 3, 4 and 5. The reduction of the appendages is gradual and the tendency is for the gradual suppression of the exopodites. In other instances of castration cited above, it is the endopodite of the female appendage that is most affected.

Giard (1887-b) described typical feminization of male crabs but considered that there was no essential difference in the reactions of the male and the female and that the changes are reciprocal. Smith (1910) proved however that the sexual modifications induced by the parasites were solely in the direction of male to female but never from female to male. The changes such as the accelerated assumption of certain adult characters in young females and minor degenerative or regressive changes in the appendages noted were assigned to malnutrition.

It has been proved that the primary sexual characters have no control over the development of secondary sexual characters. Brinkman (1936) experimentally investigated and found the presence of sex hormones in Crustacea and the changes brought about by these parasites and attributes these changes to the following three factors:

- (i) The castration of the host which is brought about by substances which are produced by the parasite and transferred into the blood of the host;
- (ii) The consequences of the low metabolism of the crab; and
- (iii) The absence of sex hormones of the host as a consequence of castration.

Reverberi (1943) feels that the observations made by him invalidate attempts to explain the phenomena of parasitic castration by sex hormones, alimentary subtraction and regression to juvenile state. He interprets data collected by him as evidence of sex transformation brought about by the action of the parasite on the essentially intersexual nature of crustacea.

Reinhard (1944) adversely criticizes the theory of Smith from the standpoint of comparative physiology. He bases his observations on the theory of elaboration of toxins by the parasites.

Summary

1. The life history of *Heterosaccus ruginosus* (Boschma) infecting the crab *Neptunus sanguinolentus* (Herbst) is described.
2. A total of 1431 crabs collected between October 1941 and December 1942 forms the material of which 10% of the crabs was found to be parasitized.
3. Fixation of the parasite probably takes place when the host is under 14 mm. carapace length.
4. The endoparasitic development follows essentially the same lines as those of *Sacculina* and *Peltogaster*. The mantle cavity is

formed by delamination and the perisomatic cavity by an invagination of the epithelial layer of the central tumour.

5. The life of the parasite is probably co-extensive with that of the host.

6. The effect of the parasite on the general vitality and viability of the host is apparently negligible. The available evidence suggests that moulting is prevented.

7. On account of early parasitization *Neptuns sanguinolentus* undergoes greater modification than other parasitized crabs. This is in contrast to other Rhizocephalan parasites in which a considerable percentage of the hosts are unmodified, due probably to late parasitization.

8. The effect of parasitism in the female is to alter the shape of the abdomen of the adolescent crab causing it to assume the shape of the abdomen of the adult prematurely. Suppression of all the abdominal appendages occurs.

9. Parasitized males develop certain female characters like the shape and redivision of the abdomen and lengthening of marginal hairs. Copulatory styles are suppressed. Female abdominal appendages are not developed. Development of testes is markedly retarded and in some cases completely checked but no ova are developed.

10. Modification of the external sex characters is only from male to female but not in the reverse direction.

Acknowledgements

This study was undertaken at the suggestion of Prof. R. Gopala Aiyer, Director, University Zoological Research Laboratory, Madras. My thanks are due to him for the valuable help and suggestive criticism throughout the course of this study, and to the University of Madras for granting me a research scholarship.

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NOTE:—References marked with an asterisk have not been referred to in the original.

Key to Lettering

a.c.	arched cleft formation
a.f. 1—a.f. 4	atrophied female appendages 1 to 4
ca.c.t.	cavity of central tumour
c.r.	chitin over roots
c.t.	central tumour
ch.bi.	chitin block
ch.ext.	external chitin of thorax of crab
ch.t.	chitin of central tumour
en.	endopodite
ep.c.	epithelial cells of central tumour
ex.	exopodite
f.a. 1—4	female appendages 1—4.
fn.	folicle nuclei
i.m.v.	cells forming the visceral mass
in.c.	intestine of host crab
i.p.c.	invagination to form the perisomatic cavity
i.w.m.	analage of the inner wall of mantle.
l.t.	Liver tubules of host crab
m.	mantle cavity
pm.a. 1—2	male appendages 1 and 2
mr.	main root trunk
m.w.	mantle wall
ma.h.	marginal hairs
n.gl.	nerve ganglion
nu.	'nucleus'
o.m.w.	Outer mantle wall
ov.	ovary
p.a.v.	place of attachment of visceral mass
p.c.	perisomatic cavity
p.h.	place of attachment of externa
pe.	peduncle
re.	retinaculum
r.	roots of Heterosaccus
sp.c	spider cells
v.m.	visceral mass
v.d.	vas deferens
t.	testes

Address of the President

To the Annual General Meeting of the Zoological Society of India held at Delhi on the 22nd January, 1959.

BY M. L. ROONWAL,
President, Zoological Society of India.

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Part 1

THE PROGRESS OF THE SOCIETY DURING 1958.

I. General

This is the second year of my service to the Society as its President, and I am grateful to all the office-bearers and members for their

valued co-operation during this period. May I also wish all the Members of the Society a Happy and Prosperous New Year.

I welcome the three new members of the Executive Council, namely,

1. Prof. P. K. Menon, our new Manager of Publications. (Elected January 1958).
2. Dr. S. M. H. Khatib, our new Foreign Secretary. (Elected July 1958).
3. Dr. B. S. Bhimachar, our new Editor of Publications (Elected July 1958.)

I also heartily welcome the new Members of the Society as well as the new Ordinary Fellows, Corresponding Fellows and Honorary Fellows.

II. Honorary Patronship of the Society

Members will be glad to learn that last month (December, 1958), the Prime Minister, Shri Jawaharlal Nehru, was pleased to agree to be the Honorary Patron of the Society. This association will, I am sure, be a source of great inspiration to all Members and Fellows. To record the occasion, a Scroll, which is exhibited here, will be presented to the Honorary Patron. (*Vide Year-Book Zool. Soc. India 1958-59*, pp.3).

III. Membership

(i) *New Addition*:—The total number of Members on our rolls is 540 but the effective membership, i.e., those who are in good standing and not in arrears of subscription, is 194 as against 146 last year—an increase of 48. The total number of Ordinary Fellows on the rolls is 59, of which 48 are in good standing. The number of new Members who joined the Society this year is 61 as against 26 last year. While we are glad that the membership-strength has increased, the rise is not as much as we could wish for and we should continue our membership drive to which I referred in my Address last year.

(ii) *Deaths*.—We regret to record the death of our distinguished Corresponding Fellow in the Soviet Union, Professor Boris S. Vinogradov, the Head of the Department of Vertebrates and the Curator of Mammals in the Zoological Institute of the U.S.S.R. Academy of Sciences in Leningrad. He was elected a Corresponding Fellow in 1952 and died on the 10th of July, 1958, after a long illness.

IV. Finances

A detailed account of the condition of the finances of our Society has already been given by the Treasurer in his report. The total permanent reserve of the Society stands to-day at Rs. 36,989 as against

Rs. 33,946 last year, i.e., there is an increase of Rs. 3,043. The book value of the stock of our publications, e.g., the *Journal*, the *Bulletin*, etc., stands at Rs. 35,570.

The following donations have been received during the year and are acknowledged gratefully:—

(i) From the National Institute of Sciences of India ...	Rs. 2,000
(ii) From the Annamalai University, Annamalai Nagar ...	Rs. 50
(iii) From the Burma Shell Oil Storage and Distributing Co. of India Ltd., Calcutta ...	Rs. 100
Total ...	Rs. 2,150

V. Publications

(a) *The Journal*.—The progress in the publication of the *Journal of the Zoological Society of India* has been satisfactory. The No. 2 issue of Volume 8 (for 1956), which was being edited by the previous Editor, Dr. M. L. Bhatia, was, after long delays, at last published during the year 1958.

As mentioned in my last year's Address, our present Editor, Professor R. V. Seshaiya, assisted by our new Manager of Publications, Professor P. K. Menon, has been making great efforts to clear up the arrears left over in the past. A new press was chosen as an experimental measure, and Vol. 9 (No. 1) for 1957 was published in October 1958. The press had again to be changed and this entailed some further delay in bringing out the other issues. But I am glad to say that No. 2 of Vol. 9 is also now out and I hope members have by now received copies of both the issues of Volume 9 (Nos. 1 and 2). The Editor expects that No. 1 issue of Vol. 10 will be out in February and No. 2 issue in April, 1959. The No. 1 issue of Vol. 11 is expected to be published at the scheduled time, i.e., June 1959, and with the timely appearance of that issue the arrears will have been cleared.

(b) *The Year-Book for 1957-58*.—Members will recall that the first *Year-Book* of the Society was brought out last year and covered the period 1956-57 (1st April 1956 to 31st March 1957). The second one, the *Year-Book for 1957-58*, is in print and I hope that Members will receive their copies shortly.

(c) *The Indian Zoological Memoirs*.—As mentioned in my Address last year, the Society has now shouldered the responsibility of publishing the *Indian Zoological Memoirs* (initiated by the late Professor K. N. Bahl). The progress in their publication is briefly as follows:—

Revised editions of two of the old *Memoirs* were published during 1958, and a third is still under revision. The manuscript of a new memoir is under scrutiny, while another manuscript is expected soon. The details are given below:—

- (i) The fourth edition of Memoir No. 2 (on the Shark of the Indian Seas, *Scoliodon*), by Dr. Miss E. M. Thillayampalam, was reprinted.
- (ii) A second edition of Memoir No. 6 (on The Indian River-Prawn, *Palaemon*), by Dr. S. S. Patwardhan, was published.
- (iii) Memoir No. 7 (on the Indian Sea-urchin, *Salmacis*), by Prof. R. Gopala Aiyar, is under revision since over a year by Dr. P. N. Ganapati, and it is hoped that the revision will be carried out soon.
- (iv) A memoir on the fish *Ophiocephalus punctatus* (Bloch), has been assigned to Dr. Har Swarup of the Saugar University, Sagar.
- (v) The manuscript of a new memoir (on the Desert Locust, *Schistocerca gregaria*) was received and is under scrutiny.
- (vi) A new memoir on the centipede *Scolopendra*, by Dr. B. S. Jungi of the Science College, Nagpur, has been promised very soon.

Tentative rules to regulate the relationships between authors and the Society in respect of such matters as copyright, profits, etc., have been framed.

In agreement with Messrs Lucknow Publishing House, Lucknow, and with the consent of the authors, the entire available stock of the Indian Zoological Memoirs (*viz.*, those on *Ostrea* and *Salmacis*) present with that firm has been taken over by the Society for sale.

(d) *The 'Who's Who' of the Society*.—To finalise the *Who's Who*, the Treasurer had issued circular letters to Members and Fellows and, as a result, biographical and scientific particulars and photographs were received from a large number of Members and Fellows. The manuscript of the *Who's Who* is now nearly ready to go to the press. I hope that it will be published in the next few months, and that Members will find it a useful work of reference.

(e) *The National Register of Zoologists in India*.—The Treasurer, Dr. B. S. Chauhan, had sent a circular post-card to several hundred zoologists in India, both members of the Society and non-members, and the replies received were sent several months ago to the Secretary-General for compilation, and it is hoped that the compilation will be speeded up.

VI. The First All-India Congress of Zoology

You will recall that at the Annual General Meeting held at Madras in January, 1958, it was decided to organise the First All-India Congress of Zoology under the auspices of the Society, and with this aim in view a Steering Committee was formed. The Local Secretary sent out circulars, etc. to about 2,000 zoologists. The Steering Committee met several times in Calcutta but, for certain unavoidable reasons, arrangements could not be finalised. The Committee was dissolved in September, 1958. Subsequently, we have received invitations from two universities. The matter is now before you.

VII. Symposia on Zoological Topics

The publication of the Proceedings of the Symposium on "Application of Zoological Knowledge to National Advancement," held at Calcutta in January 1957, was delayed owing to the late receipt of the full papers. The Proceedings have now been published as No. 2 *Bulletin of the Zoological Society of India*, and copies are now before you.

The second symposium, *viz.*, on "Modern Trends in Zoological Research in India," was held the day before yesterday (20th January).

VIII. The Society's Awards

The Tata Medal.—The Sir Dorabji Tata Gold Medal (third award), for the most outstanding contributions to zoological researches published in India during the three-year period 1955-57, has been awarded to Professor A. P. Mathew, Retired Professor of Zoology at the University College, Trivandrum, for his work on the embryology and biology of scorpions.

The Bhalerao Medal.—The Bhalerao Memorial Medal (second award), for the most meritorious contributions to Helminthology during the three year-period 1955-57 is under consideration.

IX. Representation of the Society on Outside Bodies

Indian Board for Wild Life.—Dr. H. Srinivasa Rao, our Vice-President, continues to be our representative on the Indian Board for Wild Life of the Government of India. He has, however, recently expressed a wish to be relieved of these duties and the Society has now to choose a substitute.

X. The Appointment of Non-Zoologists in Posts Requiring Primarily Zoological Qualifications

From time to time instances come to light when, owing perhaps to misconception of duties, local influence or some other factors, non-zoologists are appointed to posts requiring primarily zoological qualifications. As the premier all-India society of zoologists in India, it is our

duty to protect the legitimate interests of the zoologists and to bring the undesirability of perpetuating such incongruities to the notice of the employers who, if rightly approached, will, I am sure, respond suitably.

I would particularly request that Members should bring such cases, along with full facts, to the notice of the Society to enable the latter to take up the matter with the appropriate authorities.

XI. Prof. K. N. Bahl Memorial Fund

Members will recall that as a result of appeals for the Memorial Fund of the late Professor K. N. Bahl of Lucknow, we had collected a few hundred rupees, and this sum now stands at Rs. 741/-. To this fund Mrs. K. N. Bahl, the wife of the late Professor Bahl, has recently donated a sum of Rs. 800/- which we have gratefully accepted. It is proposed to institute a Bahl Memorial Medal at the Lucknow University. Negotiations with the University on this matter are continuing.

XII. Registers of Signatures, the Scrolls, etc.

As decided last year, the following action has been taken in this matter:—

- (i) *Register of signatures of members.*—A Register made of special hand-made paper is being made ready and Members will be requested to record their signatures in it.
- (ii) *Album of photographs.*—Photographs have been received from a large number of Members and Fellows. They will shortly be arranged in an album.
- (iii) *Scrolls to Members and Fellows.*—There was some delay in the selection of paper for the Scrolls and getting them printed. It is, however, hoped that the Scrolls will be ready soon for distribution.
- (iv) *Group photograph of members.*—Last year a beginning was made and a group photograph of the Members was taken soon after the Annual Meeting at Madras in January, 1958—the photograph is being reproduced in the *Year-Book for 1957-58*.

XIII. The Society's Library

The Society's Library, which is maintained at Calcutta, received, during 1958, an addition of 335 volumes including books, periodicals and reprints, and the total number now stands at 1751 volumes. We are grateful to the donors for their generosity. Among the more valuable additions this year are seven volumes (volumes 4-10) of the well-known

work on the insects of Brazil, *Insectos do Brasil*, presented by its author, Professor Costa Lima of Rio de Janeiro, who has further promised to send the remaining volumes of this book.

XIV. A Permanent Building for the Society

For a long time the Society has felt the need for a permanent building of its own where it could house its growing library and also start a laboratory. I would recommend that we should start forthwith a special Permanent Building Fund for the purpose. With some efforts it should, I believe, not be difficult to collect an adequate sum of money for erecting at least a modest building to start with.

Part 2

TERMITE RESEARCH IN INDIA

(a) *Introduction.*—My excuse for selecting this topic is that for the last many years I have been rather intimately connected with termite research. Furthermore, termites provide good material for investigating certain fascinating biological problems in many fields which are still unresolved, and if my Address will induce even one or two zoologists to take up the study of these insects, I should feel amply rewarded. Termites have a caste system, and there occur soldiers, workers and reproductives (kings and queens), each caste being morphologically easily distinguishable and performing well-marked separate functions. How do the castes arise? There are various theories but little exact knowledge. The taxonomy of termites is complicated by the fact that an ideal account of each species must contain descriptions of at least three castes—the soldiers, the workers and the alates (reproductives)—and sometimes even more, as there are, in several species, different kinds of workers (major and minor) and sometimes as many as four different kinds of soldiers. In practice, soldiers and workers are the forms most commonly available while collecting in the field. The alates or reproductives are formed in the colony generally only a few times in a year, and soon after the full development of wings they fly away to start fresh colonies. Unless, therefore, all the castes of a species are collected from the same nest, it is not always easy to correlate them to one another, and this difficulty has been the source of much confusion in the literature.

Out of about 2,000 species of termites so far described in the world, about 170 are known from the Indian region (*i.e.*, India, Burma, Ceylon, Nepal and East and West Pakistan), but many more remain to be discovered. Every major Indian collection that I have examined during the last few years has produced at least one or two new species, and it may be surmised as a rough guess that the total number of species occurring in Indian region is about 225 to 250.

Termites are well known as serious pests of agriculture, of stored products (books, timber, ordnance stores, etc.) and of buildings, and there have been recent examples of towns being ruined by termites about which I will tell you a little later.

Probably the earliest recorded scientific observations on Indian termites in modern times are those of Koenig (1779), a Danish naturalist and medical man who lived and worked in southern India; he recorded some interesting biological observations. In the latter part of the nineteenth century and the early part of the twentieth, Wasmann, a Jesuit priest from Holland, made extensive researches on the taxonomy of termites and termitophilic insects of the Indian region. Fletcher (1912), who was the Agricultural Entomologist in the Madras Presidency and later on the Imperial Entomologist at Delhi, made valuable observations on the biology of Indian termites. Holmgren (1913), the Swedish zoologist working in Stockholm, wrote a fine monograph on the taxonomy of the oriental termites. In 1951 when I was in Stockholm, I was able to examine his valuable collection now preserved in the Zoology Department of the Hogskola (Stockholm University), Stockholm.

(b) *Recent Work*.—In spite of some valuable work done in the past by such authorities as Wasmann, Holmgren, Silvestri, Snyder, etc., much more remains to be done. The Indian Council of Agricultural Research has, for the last few years, sponsored three major schemes of research on termites—one on taxonomy under myself at the Zoological Survey of India, Calcutta, and two on biology and control at the Indian Agricultural Institute, Anand (Bombay State).

A brief review of recent work in India (1947-57) was published by me (Roonwal, 1958) a few months ago.

In the field of taxonomy several new species have been discovered in the last few years. A comprehensive monograph by Roonwal & Sen-Sarma on several genera, namely *Kaloterms*, *Neoterms* and *Eremoterms*, is expected to be out in the next few months, and is being published by the Indian Council of Agricultural Research. Special mention may be made here of the discovery of a new family, Indotermitidae R. & S., from Burma.

In the field of morphology, Professor K. S. Kushwaha has recently worked out in great detail the external morphology of our common mound-building termite of northern India, *Odontotermes obesus* (Ram-bur). In that same species Dr. Vishnoi (1956) has studied the musculature and the mechanism of working of the mouth-parts and the feeding apparatus.

Several interesting facts have been discovered in biology and ecology, and a few examples will be mentioned. Professor S. D. Gupta

(1953a) found that the total population of a mound-colony of *Odontotermes obesus* varies from about 4,548 to 90,961 individuals of all castes depending upon the size of the mound, the soldiers being no more than about 7-18% of the total population (soldiers, workers and nymphs). In the same species, Gupta (1953b) showed that, contrary to the views held by some workers, neither the queen nor the royal chamber have any favoured directional orientation which according to some other authors is North-South. Observations on biology and ecology have also been made by Roonwal (1954-58) and Roonwal and Sen-Sarma (1955-56). Especial mention may be made of the occurrence of the death of plantation teak in 1952 in the Gorakhpur Forest Division of Uttar Pradesh as a result of excessive eating of the bark by the termite *Odontotermes parvidens* Holmgren (Roonwal, 1954b).

An even more striking example of termite damage is, as I reported a few years ago (Roonwal, 1955) the virtual ruin of the medieval town of Sri Hargobindpur, in the Gurdaspur District of the Punjab, due to the persistent attack of wood work of houses by the termite *Heterotermes indicola* (Wasm.). Stray damage was first noticed about the year 1940, and from 1945 onward the attack became general. New wood work, e.g., beams, lentils, doors, window frames, etc., does not last for more than a year. One after another, houses have collapsed, and the town to-day presents the appearance of a bombed place. Many inhabitants have left for good, never to return.

(c) *Conclusions*.—With the exception of the Himalayan species, *Archotermopsis wroughtoni* (Desn.), whose biology was studied long ago by Imms (1919), the biology and ecology of none of the Indian species is adequately known, and here is a fascinating and virgin field of research which I can recommend to any one to take up. For the study of life-histories, I would suggest the rearing of artificial colonies in small, flat, portable cages of glass or plastic.

Termite Protozoa.—Several species of termites harbour Flagellate Protozoa in their gut. A few species of Indian termites have been studied in this respect, but many other species still await examination. The results of these studies are expected to be of great interest both from the point of view of the Protozoa as well as of the host termites.

I have said enough to show that there is a great field for termite research in India in several directions such as, systematics, morphology, biology, physiology, etc., and I hope that more and more zoologists will take up these problems.

Ladies and gentlemen: I thank you very much for listening to this Address patiently.

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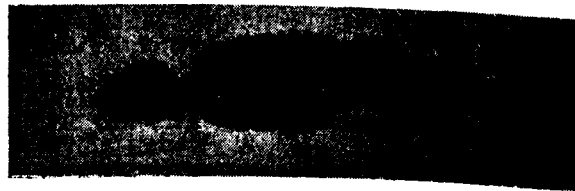
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A New Gobiid Fish from Porto Novo

BY J. JACOB AND K. RANGARAJAN,
(Annamalai University Marine Biological Station,
Porto Novo, Madras State.)

With 2 Text-figures.

During one of our periodical field trips in February 1959, a few specimens of a Gobiid fish (Fig. 1) were collected from burrows (1—2 feet deep) in the muds of a creek which runs into the Vellar estuary near Station B. (Vellar estuary and location of the estuarine stations, vide, Jacob and Rangarajan, 1959). The muds in question are exposed during low tides and are submerged under high salinity waters during



Text Fig. 1. Photograph of a new Gobiid from Porto Novo.

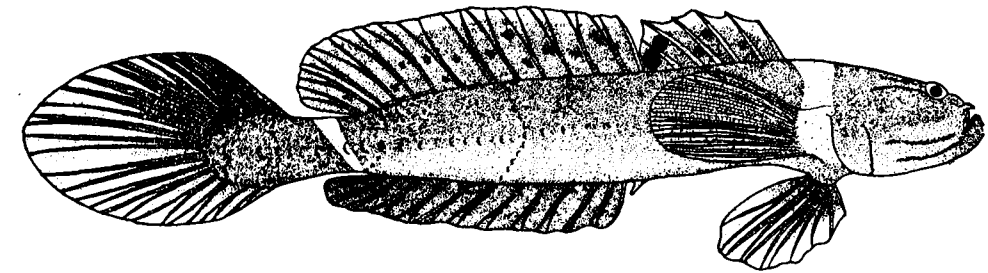
high tides. Adult specimens of both sexes have been obtained, the largest so far collected measured 62 mm. and incidentally it may be mentioned that in specimens measuring 50—58 mm. collected in October 1959, the ovaries were in fully ripe condition. Specimens have so far been obtained only from the region of the estuary stated above.

A study of the characters of this fish, especially the completely united ventral fins, indicates that this belongs to the family Gobiidae, but from a survey of the available literature (Day 1878, Herre 1941, Koumans 1948, Munroe 1955) it would appear that this Goby has not so far been reported in India or Ceylon and is probably new to science. A preliminary account is therefore given below to draw attention to these facts, pending a detailed study of a larger number of specimens and their bionomics.

Body is elongate, sub-cylindrical anteriorly and laterally compressed posteriorly and head is rather pointed. Length of head $5 \frac{1}{3}$, of caudal $4 \frac{2}{5}$, height of body $9 \frac{1}{3}$ in total length. The eyes are small, (diameter about $\frac{1}{8}$ in length of head) placed close together (1 diameter apart) much anteriorly ($1 \frac{1}{2}$ diameters from

end of snout) and are sub-cutaneous. Fine pores are present around the orbit.

The lower jaw is much longer and the mouth nearly vertical. The nostrils are very close to one another and the anterior tabular ones overhang the upper jaw. The head and the sides of the jaw bear many ridges of microscopic papillae. These features have been represented in Fig. 2.



Text Fig. 2. Sketch of a new Gobiid from Porto Novo.

Teeth in the upper jaw are small and pointed and are present in a band which is broad in the middle and narrow posteriorly. The outer ones are enlarged. The lower jaw contains 4—5 rows of larger pointed teeth and a pair of conspicuously large canine teeth are present, one on each side near the symphysis.

Tongue is rounded, free and not notched in the middle. Scales embedded in slimy skin and sparsely distributed except in the posterior regions and in the row along the median line of the caudal half as shown in Fig. 2. Anteriorly small cycloid scales are present, but they increase in size posteriorly, where both cycloid and ctenoid scales occur. Head, cheek and nape with minute scales. About 32 rows of scales between the axil and hypural joint and about 12 rows between the second dorsal and anal.

D 1. VI; D 2. I/12-13; A. I/11-12; P. 17; V. I/5;
C. 16-17.

First dorsal low and originates over the anterior half of the pectoral. The undivided rays increase in length from first to fifth, and the tips of the fifth and sixth when adpressed extend beyond the origin of the second dorsal. Second dorsal higher and the rays increase in length to the penultimate which reaches the base of the caudal when adpressed. Anal situated opposite to and though smaller in height is similar in form to the second dorsal. Pectorals large and rounded and

their origin is vertical with that of the ventrals. They extend beyond the ventral, but do not reach the anal. Ventral fins completely united and their basal spines are connected by a rather well developed membrane. Caudal is oblong to rounded.

The body is deep brown in colour especially the dorsal half which is almost black. The basal half of the first dorsal fin is deep brown; but the anterior end and outer margin deep yellow. Second dorsal also is deep brown with yellow margins. Splashes of red present on both the dorsals. Prominent patches of peacock blue on the membrane between 5th and 6th spines and the body. Pectorals yellow with many minute black spots and its deep yellow base rather fleshy. Caudal transparent yellow with dark base. Anal black and ventral almost colourless, excepting base which is dark.

The most striking feature of colouration in this fish, however, is the occurrence of a broad and deep yellow band across the shoulder extending to the base of the pectorals and another slanting yellow band on the caudal peduncle almost continuous all round (Fig. 2). An yellow patch, more or less conical, is present on the mid-dorsal region of the head beginning from the anterior margins of the orbit and tapering to the end of the upper jaw.

The characters of this fish, like the shape of the body, number, and distribution of scales, ridges on the head and sides of the jaw, the position of the eye in relation to each other and the snout, the anterior tubular nostrils and fin counts largely agree with the genus *Callogobius* Bleeker. However, in the presence of a pair of canines in the lower jaw and the rather well developed basal membrane of the ventral fin, it differs from this genus. Further, the characteristic colour of this Goby, especially the deep yellow bands on the body and the patch on the head (which are retained even in preserved specimens), and the smaller size of the eye and the higher number of fin rays in the second dorsal and the anal, show that this differs from *Callogobius hasseltii* (Bleeker) described from India (Koumans, 1941) and the other two species, *Callogobius sclateri* Steindachner and *Callogobius centrolepis* Weber described from elsewhere (McCulloch and Ogilby 1919 and Max weber 1913).

Acknowledgments

We wish to thank Prof. R. V. Seshaiya, Director, Marine Biological Station, Porto Novo, for his interest and encouragement and Dr. P. Vijayaraghavan for help.

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I, Sri R. V. Seshaiya, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Date, 31-3-60,

R. V. SESHAIYA,
Editor.

FORTHCOMING PAPERS

It is hoped to publish the following papers in the next issue of the
JOURNAL OF THE ZOOLOGICAL SOCIETY OF INDIA

1. Racial analysis of *Rita chrysea* Day inhabiting the Mahanadi River. By K. C. Jayaraman.
2. On the Development of the Eel-like Fish *Symbranchus bengalensis* (McCelland) By K. Rangarajan and J. Jacob.
3. On the Embryonic Nutrition of *Lychas tricarinatus* Fimon By A. P. Mathew.
4. Further Studies on the Cyto'ogy of Pulmonates (Mollusca: Gastropoda) By R. Natarajan.
5. On the Breeding Habits and Early Developmental Stages of *Pteroscirtes bipunctatus* Day. By S. Dutt and V. Visweswara Rao.
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LIST OF ERRATA TO Vol. 11, No. 1

Page 66, para 2, lines 4 and 5: delete "The pre-zoea sheds its abdomen by which it swims" and read the next sentence as "The pre-zoea sheds its thin pre-zoeal membrane....."

Page 69, at the end of last but one para add "(Fig. 32)."

Page 78, line 15; for "All the cheek teeth are of "pli-caballin" read "All the cheek teeth are devoid of "pli-caballin".

Page 80, line 4; for "vusvature" read "curvature".

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The First All-India Congress of Zoology, sponsored and organised by the Zoological Society of India and originally scheduled to be held in 1958 had, for certain reasons, to be postponed, and was actually held from October 24-28, 1959, at Jabalpur at the invitation of the Jabalpur University, and under the Presidentship of Dr. M. L. Roonwal, Director, Zoological Survey of India.

The inauguration and the scientific meetings were held in the splendid buildings of the Mahakoshal Mahavidyalaya. Both the Government of India and the Government of Madhya Pradesh gave their valuable patronage. The President of India sent a gracious message. The Minister for Scientific Research and Cultural Affairs, Professor Humayun Kabir, inaugurated the Congress on the 24th October, and the Deputy Minister for Scientific Research, Dr. Mono Mohan Das was also present. Dr. S. D. Sharma, the Education Minister in the Government of Madhya Pradesh, opened the Exhibition.

In his Inaugural Address, Professor Kabir laid stress on the popularisation of zoology. Dr. M. L. Roonwal, in his Presidential Address, emphasised the need for work on field ecology and taxonomy and the importance of the protection of wild life.

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(B) Marine zoology and fisheries in the Indian Ocean	Dr. B. Sundara Raj	Dr. H. Swarup
(C) Recent evolutionary studies in India	Dr. M. A. Moghe	Dr. B. K. Behura

A little over 100 members and delegates attended the Congress, and several Universities, Government Departments and Institutions had sent delegations.

The First Plenary Session of the Congress was held on the 24th October. The Final Plenary Session, was held on the 27th October, and passed a number of resolutions dealing with a variety of subjects. It was also decided to hold the Congress every three years, the next Congress to be held in 1962.

The Proceedings of the Congress, which will include the official reports, the full papers together with illustrations, and the full contributions made to the symposia, are under active preparation and are expected to be issued in the next few months.

During the Congress, a Zoological Exhibition was also organised in which several institutions and private enterprises took part. The Exhibition consisted of three principal items, namely; (i) an exhibition of new discoveries; (ii) a general exhibition on zoological matters; and (iii) an exhibition of recent zoological publications.



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