

RECORDS
of the
INDIAN MUSEUM

(A Journal of Indian Zoology)

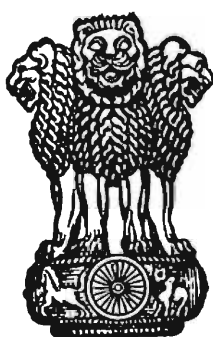
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Note.—*(An asterisk) preceding a name denotes a new variety or subspecies.

†(A dagger) indicates a new species.

‡(A double dagger) indicates a new genus or subgenus.

** (A double asterisk) indicates a new family or subfamily.

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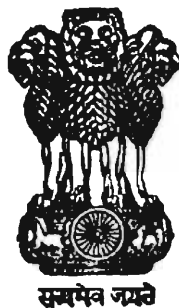
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VARIABILITY IN THE MANDIBLES OF SOLDIERS IN THE TERMITE *ODONTOTERMES OBESUS* (RAMBUR) (ISOPTERA, FAMILY TERMITIDAE)

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(With 7 Text-figures and 10 Tables)

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I—INTRODUCTION

The soldier mandibles in the common mound-building termite of north India, *Odontotermes obesus* (Rambur), are, as in other termites, used in taxonomic differentiation between allied species. The paired mandibles in this species (Text-fig. 1), are long, slender and sabre-shaped, with a pointed, incurved tip. On the inner margin there is a tooth which is minute and rudimentary on the right mandible and relatively large and prominent on the left. The more important mandibular taxonomic characters generally used in the genus *Odontotermes* are the following :—

The length of the mandibles in proportion to that of the head ; the shape, curvature and slenderness of the mandibles ; and the size, angle and position of the mandibular tooth, particularly on the left mandible.

Unfortunately, however, the extent of variability of the various characters in regard to the mandibles within any one of the oriental species of the genus *Odontotermes* is not adequately known at all, the published data being based at the most on a few (half a dozen or so) specimens in each species (*vide* Holmgren, 1913 ; Holmgren and Holmgren, 1917 ; Snyder, 1934). To fill up this gap in our knowledge, it was decided to collect and study the data on mandibular variability in at least one species

to start with, and the common species, *Odontotermes obesus* (Rambur), was selected for this purpose. The results of the measurements and the analysis of several characters in three-different populations, totalling 200 individuals, are presented here.

The three Tables 1, 2 and 3 (not those included in this paper), containing the *original* detailed data on measurements, etc., have been deposited in the library of the Forest Entomology Branch, Forest Research Institute, Dehra Dun.

Acknowledgements.—We are indebted to Dr. K. R. Nayar, the Statistician, Forest Research Institute, Dehra Dun, for his kind assistance in the statistical analysis of the data.

II—MATERIAL AND METHODS

Three population samples of 100, 50 and 50 individual soldiers respectively for each of the three separate populations studied, *viz.*, I, II and III, were obtained from three different mounds in the vicinity of Dehra Dun (in the western sub-Himalayan region of Uttar Pradesh, ca. 600 metres above sea-level) — two from the New Forest Estate and one from the Jhajra Forest, as follows :—

Population I (100 soldiers) : From Champion Block No. 52, in Demonstration Area, chir pine forest, New Forest Estate. 3. iv. 1955.

Population II (50 soldiers) : From Sample Plot No. 75 in Demonstration Area, chir pine forest, New Forest Estate. 24. vii. 1955.

Population III (50 soldiers) : Jhajra Forest (Dehra Dun Forest Division). 2. viii. 1955.

For each individual soldier the following nine measurements and four indices were taken :—

(a) *Measurements*

1. Length of head-capsule.
2. Width of head-capsule.
3. Minimum length of mandible.
4. Inner length of mandible.
5. Maximum mandibular curvature.
6. Mandibular tooth distance.
7. Width of mandible in level of tooth.
8. Length of mandibular tooth.
9. Tooth-angle. (Measured only for the left mandible.)

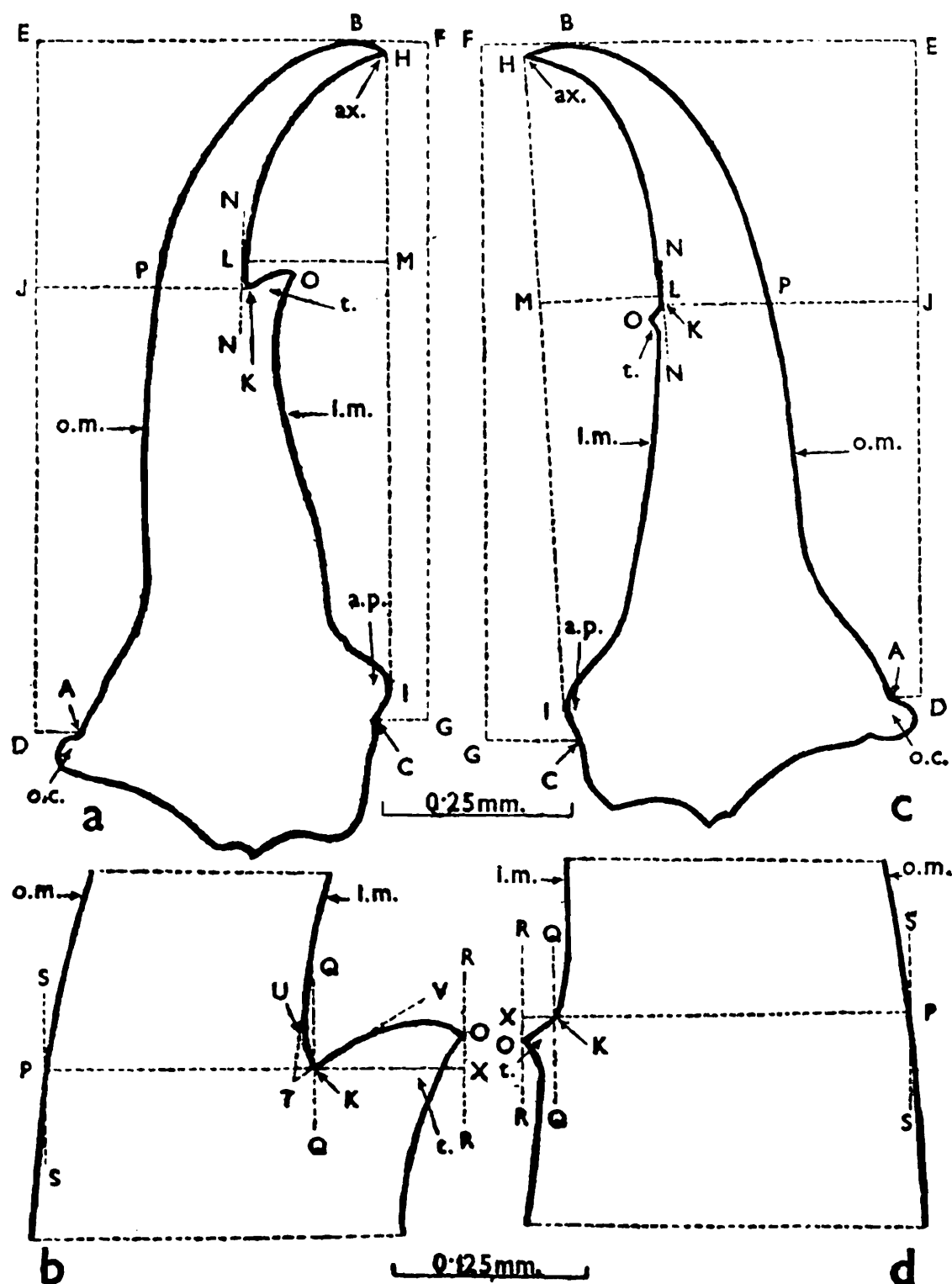
(b) *Indices*

1. Head-Mandible Index (A).
2. Head-Mandible Index (B).
3. Mandibular Tooth Index (A).
4. Mandibular Tooth Index (B).

The measurements were taken under the magnification of a stereobinocular microscope and with the aid of an eye-piece micrometer. For the tooth-angle, which presented considerable difficulty in measuring with accuracy direct from the specimen, an enlarged camera-lucida

sketch of the relevant portion of the mandible was first made for each individual, and the angle measured on the drawing.

The exact definitions of these measurements and indices are given below (also *vide* Text-fig. 1) :—



TEXT-FIG. 1.—Mandibles of *Odontotermes obesus* (Rambur), soldier caste, in dorsal view, to show the method of measuring the various characters in regard to size.

(a). Left mandible. (b). Middle portion of left mandible enlarged to show the tooth. (c). Right mandible. (d). Middle portion of right mandible enlarged to show the tooth.

a.p., anterior mandibular process ; *ax.*, apex of mandible ; *i.m.*, inner mandibular margin ; *o.m.*, outer mandibular margin ; *o.c.*, outer mandibular condyle ; *t.*, tooth. (For other lettering, see text.)

Definitions of measurements and indices of head-capsule of termites, especially Odontotermes obesus (Rambur) (Text-fig. 1).

(a) MEASUREMENTS

1. *Length of head-capsule to lateral base of mandible.*

Definition : Distance between the two parallels marking the hindmost margin of the head-capsule and the external articulations of the mandibles.

2. *Maximum width of head-capsule.*

Definition : Distance between the two parallels marking the outermost lateral margins of the head-capsule (including the compound eyes when present). (Separate measurements to be taken for the right and the left mandibles.)

3. *Maximum length of mandible (Text-figs. 1a, c ; line D-E).*

Definition : Distance DE between the two parallels, AD and BE, marking the notch A at the upper base of the outer mandibular condyle and the most distal point B of mandible.

4. *Inner length of mandible (Text-figs. 1a, c ; line G-F).*

Definition : Distance GF between the two parallels, CG and BF, marking the base (innermost proximal point) C of the anterior molar process and the most distal tip B of the mandible.

5. *Maximum mandibular curvature (Text-figs. 1a, c ; line L-M).*

Definition : Greatest perpendicular distance between the two parallels NN and HI, marking the point L of maximum curvature of the inner edge of the mandible and the most projecting point I of the anterior molar process of mandible to the apex H of the mandible.

6. *Mandibular tooth distance from the distal tip (Text-figs. 1a, c ; line E-J).*

Definition : Distance between the two parallels JK and BE marking the distal point K of the origin of tooth from the inner edge of the mandible and the most distal point B of the mandibular blade.

7. *Width of mandible in level of mandibular tooth (Text-figs. 1a—d ; line K-P).*

Definition : Distance between the two parallels QQ and SS marking the distal point K of the origin of mandibular tooth from the mandibular blade and the farthest edge P of the outer surface of the mandible in that level.

8. *Length of the mandibular tooth (Text-figs. 1b, d ; line K-X).*

Definition : Distance between the two parallels QQ and RR marking the distal point K of the origin of the mandibular tooth from the mandibular blade and the farthest tip O of the tooth.

9. *Tooth-angle (Text-figs. 1b ; angle UTV).*

Definition : Angle in the *left* mandible between the two lines, viz. UT (marking the backward projection from the innermost margin of the mandible just distal to the mandibular tooth) and TV (marking the backward projection from the proximal margin of the tooth). (In the right mandible the tooth is too small for the accurate measurement of the tooth angle).

(b) INDICES

1 *Head-Mandible Index (A).*

Definition : Minimum length of mandible / Length of head-capsule to the lateral base of mandible.

2. *Head-Mandible Index (B).*

Definition : Minimum length of mandible / Maximum width of head-capsule.

3. *Mandibular Tooth Index (A).*

Definition : Mandibular tooth distance from distal tip of mandible / Inner length of mandible.

4. *Mandibular Tooth Index (B).*

Definition : Length of mandibular tooth / Width of mandible in level of mandibular tooth.

III—ANALYSIS OF VARIABILITY

(Text-figs. 2-7 ; and Tables 1-10)

The data for each of the three population samples, Nos. I--III, were analysed, the various statistical constants obtained and their significance tested. The results are given below. It is interesting to note that in almost all the characters studied, the means were significantly different for each population sample.

(a) MEASUREMENTS (Tables 1-3 ; and 6-8)

The measurements were analysed separately for the following three categories :—

(A). Head-capsule. (B). Left mandible. (C). Right mandible.

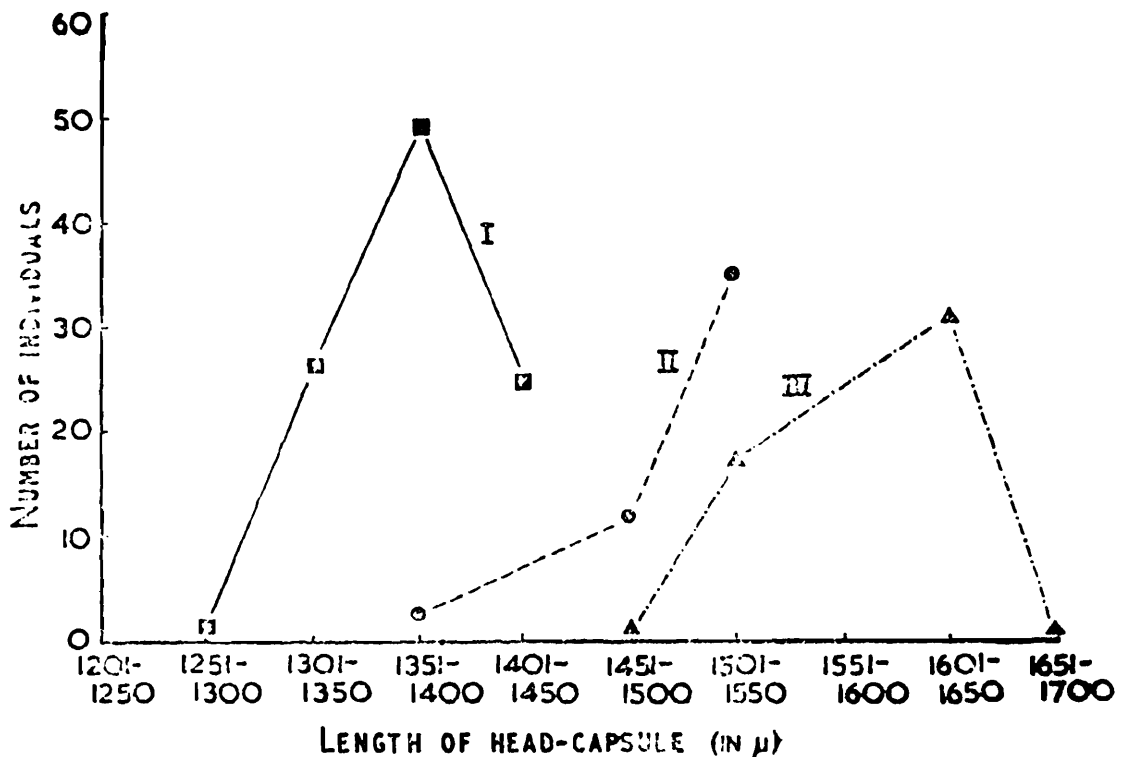
(A). *Head-capsule* (Tables 1 and 6)

1. *Length of head-capsule* (Text-fig. 2).—It varied from 1261-1692 μ . The mean values for each population, viz., 1388.2, 1510.6 and 1587.3 μ , were significantly different from one another at 0.1 per cent level of probability, the order being III>II>I. The standard deviations of the means were not significantly different at 5 per cent level of probability.

2. *Width of head-capsule* (Text-fig. 3).—It varied from 1087-1385 μ . The mean values, 1176.0, 1309.5 and 1328.0 μ , were significantly different at 0.1 per cent level of probability, the order being III>II>I. The standard deviations of the means were not significantly different at 5 per cent level of probability.

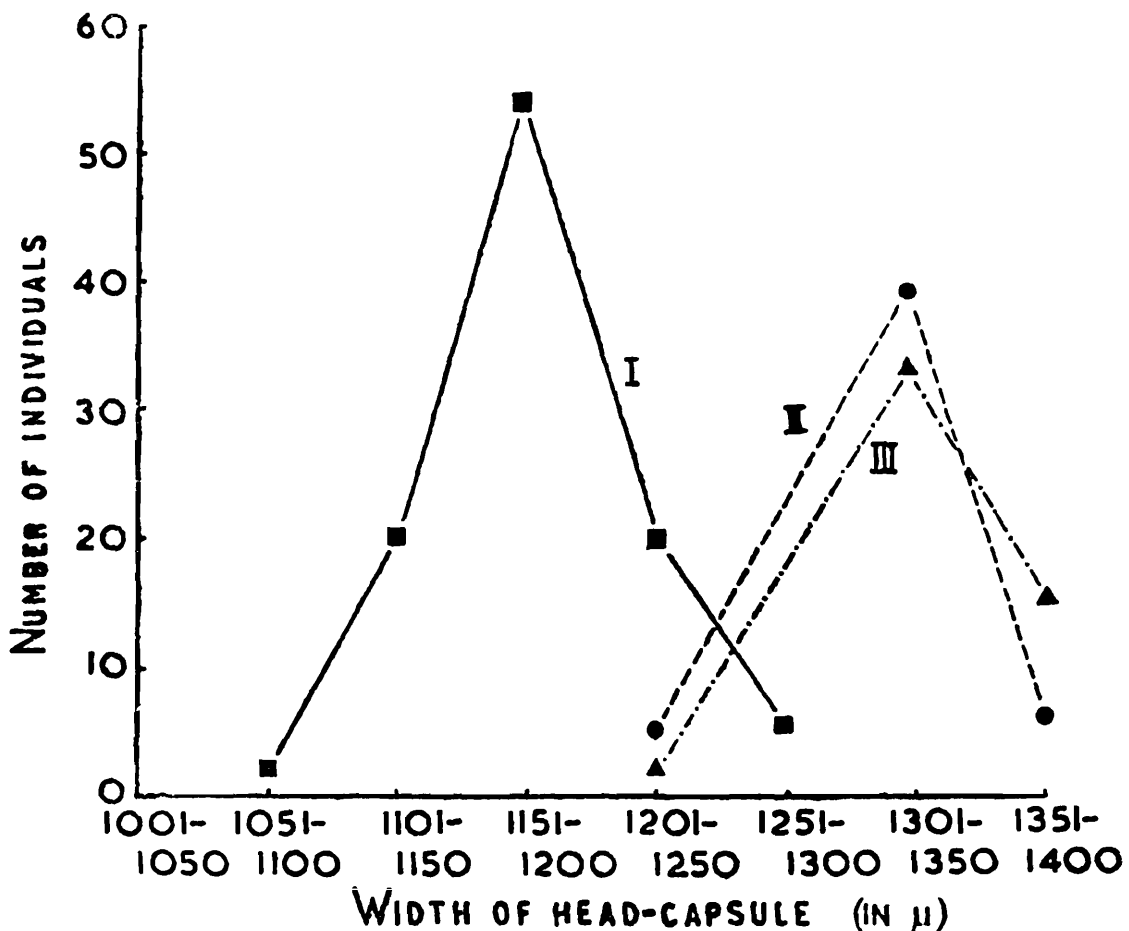
(B). *Left-mandible* (Tables 2 and 7)

1. *Minimum length*.—It varied from 865-1020 μ . The mean values, 912.2, 958.3 and 988.7 μ , were significantly different at 0.1 per cent level of probability, the order being III>II>I. The standard deviations of the means were significantly different at 5 per cent level of probability.

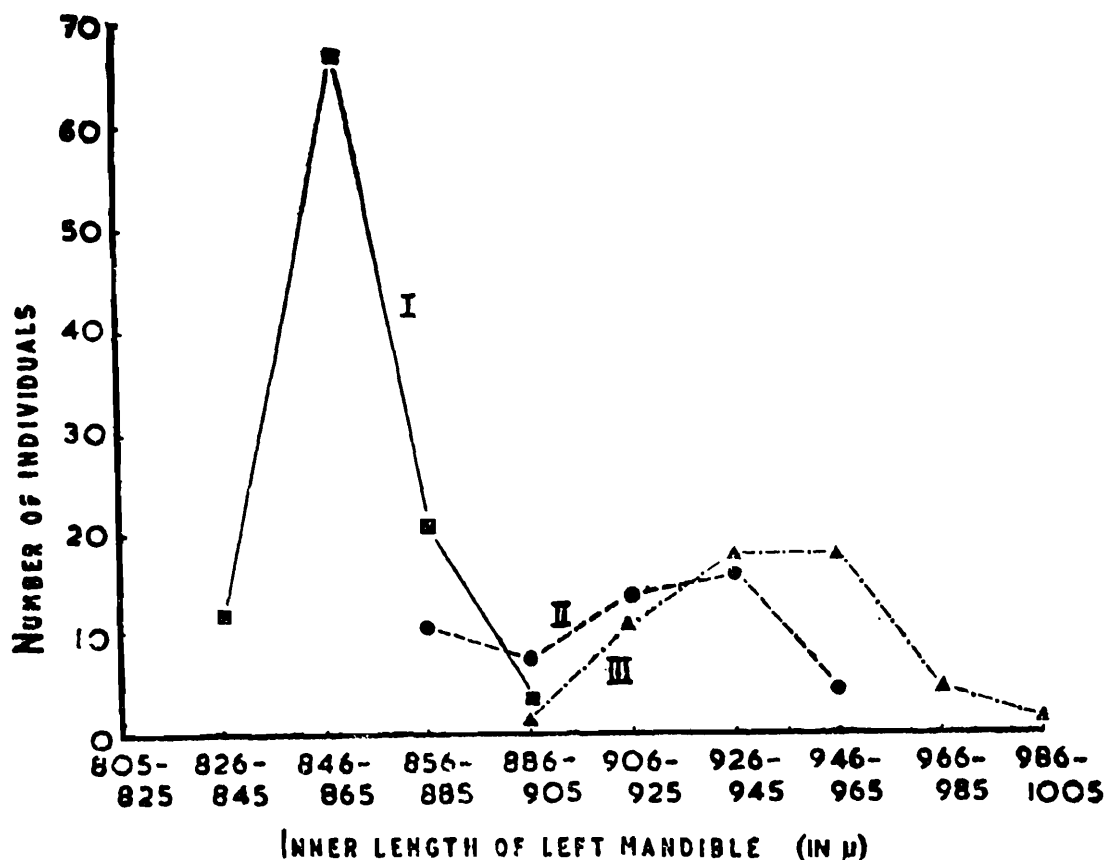


TEXT-FIG. 2.—Graph to show variation in the “length of head-capsule” of soldiers of *Odontotermes obesus* in three population samples, I, II and III, from Dehra Dun.

2. *Inner length* (Text-fig. 4).—It varied from 827-1000 μ . The mean values, 861.1, 915.8 and 944.9 μ , were significantly different at 0.1 per cent level of probability, the order being III > II > I. The standard deviations of the means were significantly different at 5 per cent level of probability.

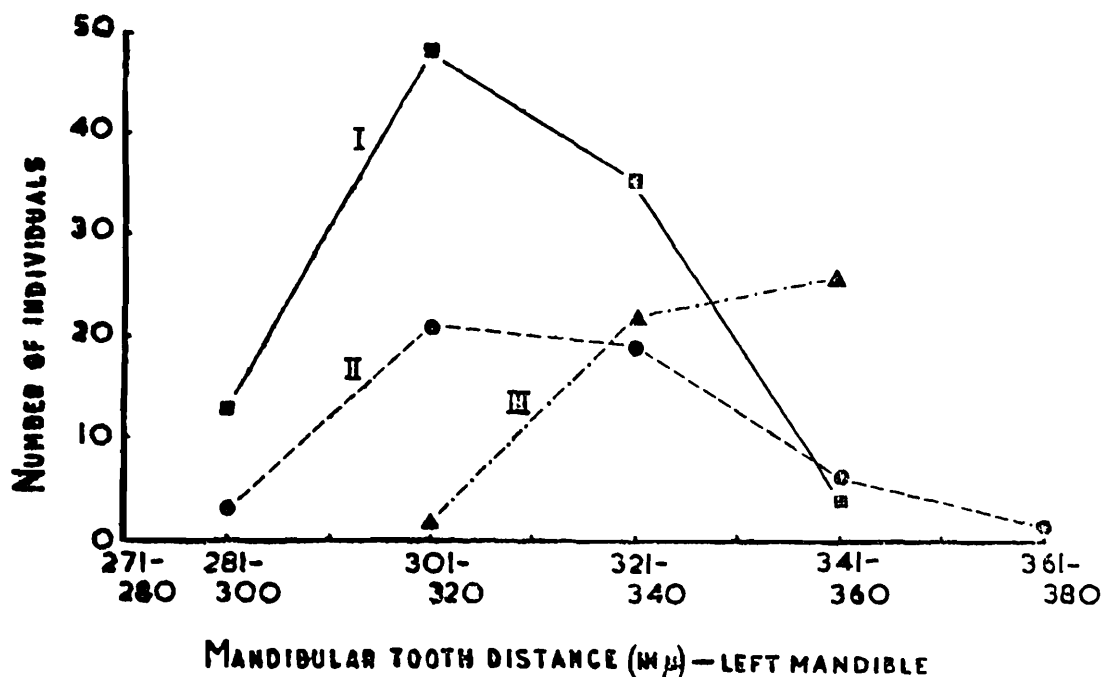


TEXT-FIG. 3.—Graph to show variation in the “width of head-capsule” of soldiers of *Odontotermes obesus* in three population samples, I, II and III, from Dehra Dun.



TEXT-FIG. 4.—Graph to show variation in the “inner length of left mandible” of soldiers of *Odontotermes obesus* in three population samples, I, II and III, from Dehra Dun.

3. *Maximum mandibular curvature*.—It varied from 96-163 μ . The mean for population No. I (129.3 μ) was significantly different from those for population Nos. II and III (139.9 and 142.0 μ respectively) at 0.1 per cent level of probability, but the latter two were not significantly different from each other. The order was $\text{III II} > \text{I}$. The standard deviations of the three means were not significantly different at 5 per cent level of probability.



TEXT-FIG. 5.—Graph to show variation in the “mandibular tooth distance” (distal tip of mandible to base of tooth) in the left mandible of soldiers of *Odontotermes obesus* in three population samples, I, II and III, from Dehra Dun.

4. *Mandibular tooth distance* (Text-fig. 5).—It varied from 286-367 μ . The mean for population No. III (336.1 μ) was significantly different from the means of population Nos. I and II (314.1 and 318.5 μ respectively) at 0.1 per cent level of probability but the latter two were not significantly different from each other. The order was $\text{III} > \text{II} > \text{I}$. The standard deviations were significantly different from one another at 5 per cent level of probability.

5. *Width in level of tooth*.—It varied from 96-163 μ . The mean of population No. I (117.6 μ) was significantly different from the means of population Nos. II and III (137.5 and 133.3 μ respectively) at 0.1 per cent level of probability, but the latter two were not significantly different from each other. The order was $\text{II} > \text{III} > \text{I}$. The standard deviations of the means were significantly different from one another at 5 per cent level of probability.

6. *Length of tooth*.—It varied from 28-61 μ . The mean values, 42.7, 46.2 and 55.6 μ , were significantly different from each other at 0.1 per cent level of probability, the order being $\text{III} > \text{II} > \text{I}$. The standard deviations of the means were not significantly different at 5 per cent level of probability.

7. *Tooth angle*.—It varied from 50°-86°. The mean for population No. I (68.5°) was significantly different from the means of population Nos. II and III (65.2° and 65.3° respectively) at 1.0 per cent level of probability, but the latter two were not significantly different from each other. The order was $\text{I} > \text{III} > \text{II}$. The standard deviations of the means were not significantly different from one another at 5 per cent level of probability.

(C). *Right mandible* (Tables 3 and 8)

1. *Minimum length*.—It varied from 827-1000 μ . The mean values, 888.3, 937.5 and 963.6 μ , were significantly different at 0.1 per cent level of probability, the order being $\text{III} > \text{II} > \text{I}$. The standard deviations of the means were not significantly different at 5 per cent level of probability.

2. *Inner length*.—It varied from 885-1020 μ . The mean values, 930.7, 979.3 and 1003.0 μ , were significantly different at 0.1 per cent level of probability, the order being $\text{III} > \text{II} > \text{I}$. The standard deviations of the means were significantly different at 5 per cent level of probability.

3. *Maximum mandibular curvature*.—It varied from 96-163 μ . The mean for population No. I (122.5 μ) was significantly different from the means of population Nos. II and III (144.9 and 144.5 respectively) at 0.1 per cent level of probability, but the latter two were not significantly different from each other. The order was $\text{II} > \text{III} > \text{I}$. The standard deviations of the means were not significantly different at 5 per cent level of probability.

4. *Mandibular tooth distance*.—It varied from 346-428 μ . The mean values, 367.0, 389.0 and 407.6 μ , were significantly different at 0.1 per cent level of probability, the order being $\text{III} > \text{II} > \text{I}$. The standard deviations of the means were significantly different at 1 per cent level of probability.

5. *Width in level of tooth*.—It varied from 115-163 μ . The mean for population No. I (134.3 μ) was significantly different from the means for population Nos. II and III (150.4 and 147.4 μ respectively) at 0.1 per cent level of probability, but the latter two were not significantly different from

each other. The order was $II\ III > I$. The standard deviations of the means were not significantly different at 5 per cent level of probability.

6. *Length of tooth*.—It varied from 10-20 μ . The mean values, 18.1, 18.6 and 17.2 μ , were not significantly different at 5 per cent level of probability. The standard deviations of the means were significantly different at 0.1 per cent level of probability.

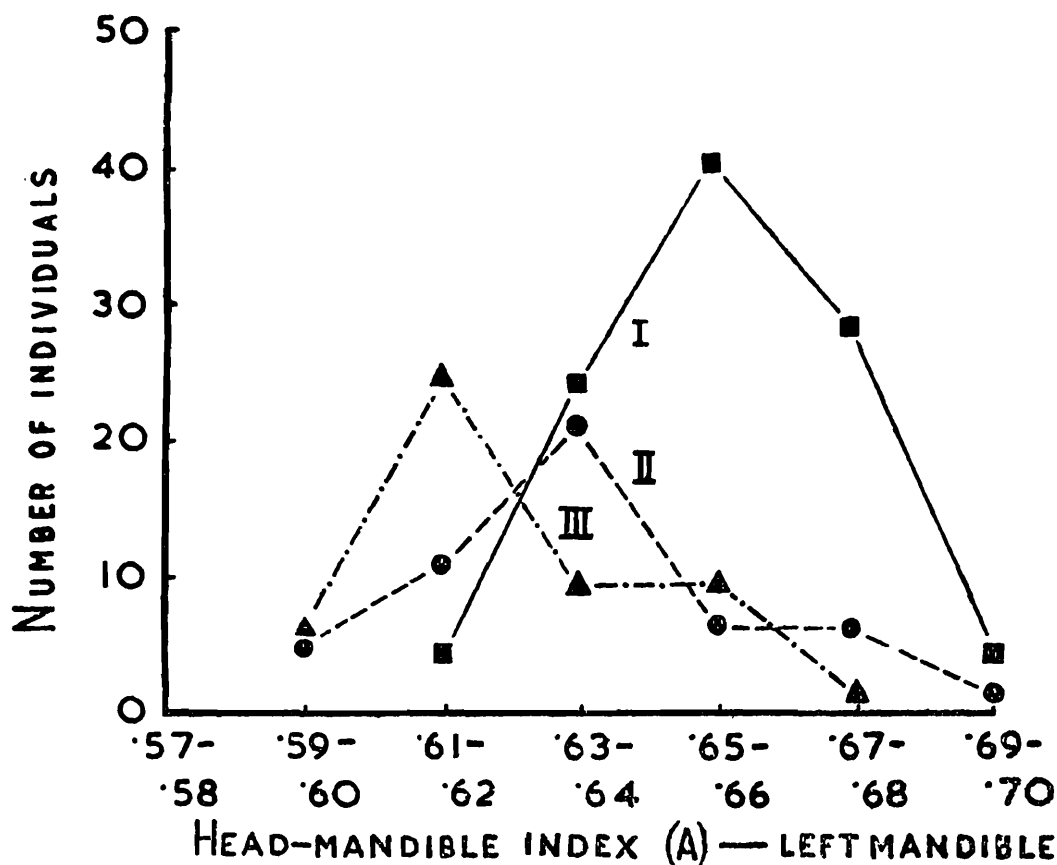
(b) INDICES (Tables 4, 5, 9 and 10)

The indices were calculated and analysed separately for the following two categories :—

(A) Left mandible. (B) Right mandible.

(A). *Left mandible* (Tables 4 and 9)

1. *Head-Mandible Index (A)* (Text-fig. 6).—It varied from 0.59-0.70. The means, 0.657, 0.636 and 0.624, respectively for the three population Nos. I-III, were significantly different from one another at 0.1 per cent level of probability, the order being $I > II > III$. The standard deviations of the means were not significantly different at 5 per cent level of probability.

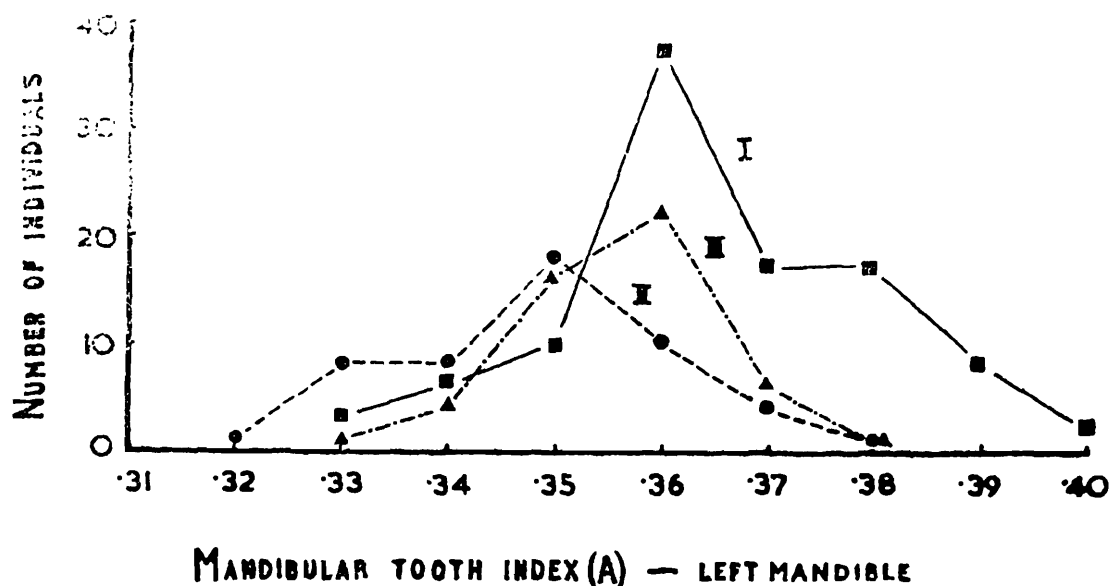


TEXT-FIG. 6.—Graph to show variation in the “Head-Mandible Index (A)” (Minimum length of mandible/Length of head-capsule to lateral base of mandible) in the left mandible of soldiers of *Odontotermes obesus* in three population samples, I, II and III, from Dehra Dun.

2. *Head-Mandible Index (B)*.—It varied from 0.68-0.83. The means, 0.777, 0.733 and 0.744, respectively for the three population Nos. I-III, were significantly different from one another at 0.1 per cent level of

probability, the order being $I > III > II$. The standard deviations of the means were not significantly different at 5 per cent level of probability.

3. *Mandibular Tooth Index (A)* (Text-fig.7).—It varied from 0.32-0.40. The means, 0.365, 0.349 and 0.356, respectively for the three population Nos. I-III, were significantly different from one another at 0.1 per cent level of probability, the order being $I > III > II$. The standard deviations of the means were also significantly different from one another at 1 per cent level of probability.



TEXT-FIG. 7.—Graph to show variation in the “Mandibular Tooth Index (A)” (Mandibular tooth distance from distal tip/Inner length of mandible) in the left mandible of soldiers of *Odontotermes obesus* in three population samples, I, II and III, from Dehra Dun.

4. *Mandibular Tooth Index (B)*.—It varied from 0.25-0.50. The mean values, 0.365, 0.340 and 0.421, for the three population Nos. I—III respectively, were significantly different from one another at 0.1 per cent level of probability, the order being $III > I > II$. The standard deviations of the means were not significantly different at 5 per cent level of probability.

(B). *Right mandible* (Tables 5 and 10)

1. *Head-Mandible Index (A)*.—It varied from 0.58-0.72. The mean values, 0.640, 0.621 and 0.607, for the three population Nos. I—III respectively, were significantly different from one another at 0.1 per cent level of probability, the order being $I > II > III$. The standard deviations of the means were not significantly different at 5 per cent level of probability.

2. *Head-Mandible Index (B)*.—It varied from 0.65-0.83. The mean of population No. I (0.756) was significantly different from the means of population Nos. II and III (0.716 and 0.726 respectively) at 0.1 per cent level of probability, the order being $I > II > III$. The standard deviations of the means were not significantly different at 5 per cent level of probability.

3. *Mandibular Tooth Index (A)*.—It varied from 0.36-0.43. The mean of population No. III (0.408) was significantly different from the means of the population Nos. I and II (0.395 and 0.397 respectively) at 0.1 per cent level of probability, but the latter two were not significantly different from each other ; the order was $III > II > I$. The standard deviations of the means were significantly different at 0.1 per cent level of probability.

4. *Mandibular Tooth Index (B)*.—It varied from 0.06-0.17. The mean value for the population No. I (0.135) was significantly different from the means of population Nos. II and III (0.123 and 0.117 respectively) at 0.1 per cent level of probability but the latter two were not significantly different from each other ; the order was $I > II > III$. The standard deviations of the means were significantly different from each other at 0.1 per cent level of probability.

IV—CONCLUSIONS

It will be seen from the data discussed above that the mean values of the various measurements and indices in the three populations, Nos. I, II and III, were in almost all cases significantly different from one another at 0.1 per cent level of probability. The frequency distribution tables and the graphs (Text-figs. 2-7) further show that the peak values in most of the characters differed in the three samples. Considering that each population sample was from a different mound and presumably represented the progeny of a different queen-mother in each case, the above conclusions are not surprising. The pooled results of the three samples may well be taken as representing the variability occurring in *Odontotermes obesus* (Rambur), at any rate in the form occurring in and around Dehra Dun.

The data given here will, we hope, serve as a standard of comparison for the samples of *Odontotermes obesus* from other areas as well as for other species of the genus where the mandibular character, specially the position, size, etc., of the tooth, has been used to differentiate the various species. For *Odontotermes obesus* the range of some of the significant characters in the Dehra Dun samples are as follows :—

The maximum mandibular curvature of the left mandible is 96-163 μ (means of the three samples 129.3-142.0 μ) ; and for the right mandible 96-163 μ (means of three samples 122.5-144.9 μ).

The mandibular tooth index (A) (which represents the position of the tooth on the mandible) of the left mandible varies from 0.32-0.40 (means of the three samples 0.349-0.365). In other words, the tooth in the left mandible lies at about $\frac{1}{3.1} - \frac{1}{2.5}$ the length of the mandible from the distal end of the latter. In the right mandible the tooth occupies nearly the same position as in the left but tends to shift a little backward (proximally), i.e., towards the middle. Thus, the index varies from 0.36-0.43 (means of the three samples 0.395-0.408). In other words, the tooth in the right mandible lies about $\frac{1}{2.8} - \frac{1}{2.3}$ the length of the mandible from the distal end of the latter.

Regarding the size of the tooth in relation to the mandibular width, the ratio of mandible-width to tooth-width varies in the left mandible from 1 : 0.340 to 1 : 0.421, and in the right mandible (where the tooth is minute) from 1 : 0.0234 to 1 : 0.0326.

In the left mandible the tooth sustains an obtuse angle on the mandible, the angle varying from about 50° - 86° (means of the three populations 65.2° - 68.5°). In the right mandible the tooth is too minute for the angle to be measured with any degree of accuracy.

V—SUMMARY

1. Variability in respect of the size, etc., of the mandibles of the soldier caste in *Odontotermes obesus* from Dehra Dun and vicinity, in three population samples, Nos. I, II and III, each from a different colony (mound), was studied. The number of individuals in a sample varied from 50-100. Nine measurements and four indices were studied as follows :—

(a) *Measurements* : (i) Length of head-capsule. (ii) Width of head-capsule. (iii) Minimum length of mandible. (iv) Inner length of mandible. (v) Maximum mandibular curvature. (vi) Mandibular tooth distance. (vii) Width of mandible in level of tooth. (viii) Length of mandibular tooth. (ix) Tooth angle (in left mandible).

(b) *Indices* : (i) Head-Mandible Index (A). (ii) Head-Mandible Index (B). (iii) Mandibular Tooth Index (A). (iv) Mandibular Tooth Index (B).

2. The precise definitions of these measurements and indices are provided.

3. The data were analysed statistically.

4. The mean values of the various measurements and indices in the three populations were in almost all cases significantly different from one another at the 1 per cent level of probability.

5. The inner length of mandible ranged from 827-1000 μ for the left mandible and 885-1020 μ for the right one.

6. The maximum mandibular curvature ranged from 96-163 μ in the left mandible and the same range applied to the right one.

7. The mandibular tooth distance (the distance between the base of the tooth and the distal tip of the mandible) ranged from 286-367 μ in the left mandible (where the tooth is large) and from 346-428 μ in the right mandible.

8. The "Head-Mandible Index (A)" (Minimum length of mandible / Length of head-capsule to lateral base of mandible) ranged from 0.59-0.70 for the left mandible and 0.58-0.72 for the right one.

9. The "Mandibular Tooth Index (A)" (Mandibular Tooth distance from distal tip of mandible / Inner length of mandible) ranged from 0.32-0.40 in the left mandible and 0.36-0.43 in the right one. In other words,

from the distal tip of the mandible, the tooth lies at $\frac{1}{3.1} - \frac{1}{2.5}$ the length of the mandible in the left one ; and $\frac{1}{2.8} - \frac{1}{2.3}$ in the right one.

10. The ranges of variability provided in the paper may be taken as representing the variability occurring in the species, at least for the form occurring in and around Dehra Dun.

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TABLE 1.—*Summary of measurements (in microns) and their statistical constants of the head-capsule of soldier caste in Odontotermes obesus (Rambur) in three different populations, each from a different mound-colony, collected from Dehra Dun and vicinity.*

Note.—S.E.—Standard Error of Mean. C.V.—Coefficient of Variation.

Population No.	Total number of individuals	Measurements of head-capsule (μ.)							
		Length				Width			
		Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %
I	100	1261—1435	1388.2	3.51	2.5	1087-1261	1176.0	3.64	3.1
II	50	1385—1538	1510.6	6.45	3.0	1231-1385	1309.5	5.16	2.8
III	50	1462—1692	1587.3	6.12	2.7	1231-1385	1328.0	5.74	3.1

TABLE 2.—Summary of measurements (in microns) and their statistical constants of the left mandibles of soldier caste in *Odontotermes obesus* (Rambur) in three different populations, each from a different mound-colony, in Dehra Dun and vicinity.

Note.—S.E.—Standard Error of Mean. C.V.—Coefficient of Variation.

Population No.	Total number of individuals in sample	Measurements, etc., of left mandible											
		Minimum length				Inner length				Maximum mandibular curvature			
		Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %
I	100	865—962	912.2	2.31	2.5	827—904	84.1	1.91	2.2	96—154	129	1.33	10.3
II	50	918—1000	958.3	3.90	2.9	877—959	915.8	3.65	2.8	102—163	139.9	1.95	9.8
III	50	959—1020	988.7	2.69	1.9	898—1000	944.9	2.95	2.2	122—163	142.0	1.85	9.2

Population No.	Total number of individuals in sample	Measurements, etc., of left mandible															
		Mandibular tooth distance				Width in level of tooth				Length of tooth				Tooth angle			
		Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %
I	100	289—346	314.1	1.43	4.5	96—135	117.6	.82	7.0	28—58	42.7	.59	14.0	54—86°	68.5°	0.69	10.0
II	50	286—367	318.5	2.45	5.4	122—163	137.5	1.58	8.1	41—61	46.2	1.00	15.3	53—81°	65.2°	0.92	10.0
III	50	306—347	336.1	1.71	3.6	122—143	133.3	1.49	7.9	41—61	55.6	1.00	12.7	50—79°	65.3°	1.04	11.3

TABLE 3.—*Summary of measurements (in microns) and their statistical constants of the right mandible of soldier caste in *Odontotermes obesus* (Rambur) in three different populations, each from a different mound-colony, collected from Dehra Dun and vicinity. (Tooth angle not measured for right mandible, vide Text.)*

Note.—S.E.—Standard Error of Mean. C.V.—Coefficient of Variation.

Population No.	Total No. of individuals in sample	Measurements, etc., of right mandible											
		Minimum length				Inner length				Maximum mandibular curvature			
		Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %
I	100	827—942	888.3	2.28	2.6	885—962	930.7	2.03	2.2	96—154	122.5	1.11	9.1
II	50	898—979	937.5	3.29	2.5	938—1020	979.3	3.20	2.3	122—163	144.9	1.67	8.2
III	50	938—1000	963.6	2.66	2.0	979—1020	100.3	2.13	1.5	122—163	144.5	1.74	8.5

Population No.	Total No. of individuals in sample	Measurements, etc., of right mandible											
		Mandibular tooth distance				Width in level of tooth				Length of tooth			
		Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %
I	100	346—385	367.0	1.22	3.3	115—154	134.3	0.97	7.2	10—19	18.1	0.27	15.0
II	50	347—408	389.0	2.43	4.4	143—163	150.4	1.36	6.4	10—20	18.6	0.50	18.9
III	50	388—428	407.6	1.56	2.7	122—163	147.4	1.45	6.9	10—20	17.2	0.64	26.4

TABLE 4.—*Summary of indices and their statistical constants, etc., of various measurements of the left mandible of soldier caste in Odontotermes obesus (Rambur) in three different populations, each from a different mound-colony, collected in Dehra Dun and vicinity.*

Note.—S.E.—Standard Error of Mean. C.V.—Coefficient of Variation.

Population No.	Total number of individuals in sample	Indices, etc., of left mandible							
		Head-Mandible Index (A)				Head-Mandible Index (B)			
		Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %
I	100	0.62—0.70	0.657	0.0018	2.8	0.73—0.83	0.777	0.0022	2.9
II	50	0.60—0.69	0.636	0.003	3.7	0.68—0.78	0.733	0.003	3.2
III	50	0.59—0.67	0.624	0.0028	3.2	0.69—0.80	0.744	0.0029	2.8

Population No.	Total number of individuals in sample	Indices, etc., of left mandible							
		Mandibular Tooth Index (A)				Mandibular Tooth Index (B)			
		Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %
I	100	0.33—0.40	0.365	0.0015	4.1	0.26—0.50	0.365	0.0050	13.7
II	50	0.32—0.38	0.349	0.002	3.7	0.25—0.50	0.340	0.008	15.8
III	50	0.33—0.38	0.356	0.0013	2.7	0.29—0.50	0.421	0.0082	13.7

TABLE 5.—Summary of indices and their statistical constants, etc., of various measurements of the right mandible of soldier caste in *Odontotermes obesus* (Rambur) in three different populations, each from a different mound-colony, collected in Dehra Dun and vicinity.

Note.—S.E.—Standard Error of Mean. C.V.—Coefficient of Variation.

Population No.	Total number of individuals in sample	Indices etc., of right mandible							
		Head-Mandible Index (A)				Head-Mandible Index (B)			
		Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %
I	100	0.60—0.72	0.640	0.0020	3.1	0.71—0.83	0.756	0.0023	3.1
II	50	0.58—0.68	0.621	0.0030	3.9	0.65—0.78	0.716	0.0040	3.6
II	50	0.58—0.66	0.607	0.0030	3.5	0.68—0.78	0.726	0.0032	3.1

Population No.	Total number of individuals in sample	Indices etc., of right mandible							
		Mandibular tooth Index (A)				Mandibular tooth Index (B)			
		Range	Mean	S.E.	C.V. %	Range	Mean	S.E.	C.V. %
I	100	0.37—0.42	0.395	0.0012	3.0	0.07—0.17	0.135	0.0025	18.3
II	50	0.36—0.43	0.397	0.0020	4.2	0.07—0.14	0.123	0.0030	19.5
III	50	0.38—0.42	0.408	0.0014	2.4	0.06—0.16	0.117	0.0046	27.9

TABLE 6.—Means, Standard Deviation and statistical significance of body-measurements of the soldier caste in *Odontotermes obesus* (Rambur) in three population samples, collected from three different mounds, in Dehra Dun and vicinity.

Character.—Head-capsule.

Note.—1. S.D.—Standard Deviation.
2. N.S.—Not significant at 5% level of probability.
3. *—Significant at 5% level of probability.
4. **—Significant at 1% level of probability.
5. ***—Significant at 0.1% level of probability.

Population No.	Total number of individuals in sample	Head-capsule (in μ)			
		Length		Width	
		Mean	S.D.	Mean	S.D.
I	100	1388.2	35.12	1176.0	36.44
II	50	1510.6	45.61	1309.5	36.45
III	50	1587.3	43.28	1328.0	40.60
Significance	—	***	N.S.	***	N.S.
Bar diagram at 5% level of probability.	—	III>II>I	—	III>II>I	—

TABLE 7.—Means, Standard Deviations and statistical significance of body-measurements of the soldier caste in *Odontotermes obesus* (Rambur) in three population samples, collected from three different mounds, in Dehra Dun and vicinity.

Character.—Left mandible.

- Note.**—1. S.D.—Standard Deviation.
 2. N.S.—Not Significant at 5 % level of probability.
 3. *—Significant at 5 % level of probability.
 4. **—Significant at 1 % level of probability.
 5. ***—Significant at 0.1 % level of probability.

Population No.	Total number of individuals in sample	Left mandible													
		Minimum length (μ)		Inner length (μ)		Maximum mandibular curvature(μ)		Mandibular tooth distance (μ)		Width in level of tooth (μ)		Length of tooth (μ)		Tooth angle	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
I	100	912.2	23.08	861.1	19.14	129.3	13.32	314.1	14.28	117.6	8.22	42.7	5.95	68.5°	6.86
II	50	958.3	27.55	915.8	25.79	139.9	13.78	318.5	17.35	137.5	11.16	46.2	7.07	65.2°	6.53
III	50	988.7	19.05	944.9	20.86	142.0	13.09	336.1	12.08	133.3	10.57	55.6	7.06	65.3°	7.36
Significance	—	***	*	***	*	***	N.S.	***	*	***	*	***	N.S.	**	N.S.
Bar diagram at 5 per cent level of probability.	—	III> II> I —		III> II> I —		<u>III> II> I</u> —		III> <u>II> I</u> —		<u>II> III> I</u> —		III> II> I —		I> <u>III> II</u> —	

TABLE 8.—*Means, Standard Deviations and statistical significance of body-measurements of the soldier cast in Odontotermes obesus (Rambur) in three population samples, collected from three different mounds, in Dehra Dun and vicinity. (Tooth angle not measured, vide Text.)*

Character.—Right mandible.

Note.—1. S.D.—Standard Deviation.

2. N.S.—Not Significant at 5 % level of probability.

3. *—Significant at 5 % level of probability.

4. **—Significant at 1 % level of probability.

5. ***—Significant at 0.1 % level of probability.

Population No.	Total number of individuals in sample	Right mandible											
		Minimum length (μ)		Inner length (μ)		Maximum mandibular curvature (μ)		Mandibular tooth distance (μ)		Width in level of tooth (μ)		Length of tooth (μ)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
I .	100	888.3	22.75	930.7	20.28	122.5	11.12	367.0	12.23	134.3	9.68	18.1	2.71
II	50	937.5	23.23	979.3	22.65	144.9	11.84	389.0	17.19	150.4	9.65	18.6	3.51
III .	50	963.6	18.81	1003.0	15.09	144.5	12.27	407.6	11.06	147.4	10.23	17.2	4.54
Significance	—	***	N.S.	***	*	***	N.S.	***	**	***	N.S.	N.S.	***
Bar diagram at 5 per cent level of probability.	—	III> II> I	—	III> II> I	—	II> III> I	—	III> II> I	—	II> III> I	—	—	—

TABLE 9.—*Summary of the results of indices of the left mandible of the soldier caste in *Odontotermes obesus* (Rambur) in three population samples, collected from three different mounds, in Dehra Dun and vicinity.*

Note.—1. S.D.—Standard Deviation.
 2. N.S.—Not Significant at 5 % level of probability.
 3. *—Significant at 5 % level of probability.
 4. **—Significant at 1 % level of probability.
 5. ***—Significant at 0.1 % level of probability.

Population No.	Total number of individuals in sample	Indices of Left Mandible							
		Head-Mandible Index (A)		Head-Mandible Index (B)		Mandibular Tooth Index (A)		Mandibular Tooth Index (B)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
I	100	.657	.0181	.777	.0223	.365	.0150	.365	.0500
II	50	.636	.0234	.733	.0237	.349	.0130	.340	.0537
III	50	.624	.0201	.744	.0205	.356	.0095	.421	.0578
Significance	—	***	N.S.	***	N.S.	***	**	***	N.S.
Bar diagram at 5 per cent level of probability	—	I> II> III	—	I> III> II	—	I> III> II	—	III> I> II	—

TABLE 10.—*Summary of the results of indices of the right mandible of the soldier caste in Odontotermes obesus (Rambur)*

in three population samples, collected from three different mounds, in Dehra Dun and vicinity.

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Note.—1. S. D.—Standard Deviation.
 2. N.S.—Not Significant at 5 % level of probability.
 3. * —Significant at 5 % level of probability.
 4. ** —Significant at 1 % level of probability.
 5. *** —Significant at 0·1 % level of probability.

Population No.	Total number of individuals in sample	Indices of right mandible							
		Head-mandible Index (A)		Head-mandible Index (B)		Mandibular Tooth Index (A)		Mandibular Tooth Index (B)	
		Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.
I	100	·640	·0201	·756	·0233	·395	·0117	·135	·0246
II	50	·621	·0242	·716	·0260	·397	·0167	·123	·0234
III	50	·607	·0215	·726	·0226	·408	·0097	·117	·0326
Significance	—	***	N.S.	***	N.S.	***	***	***	***
Bar diagram at 5 per cent level of probability.	—	I > II > III	—	I III II	—	III II I	—	I II III	—

ENTOMOLOGICAL SURVEY OF HIMALAYA*

PART 22.—NOTES ON SOME HYMENOPTERA (INSECTA) COLLECTED BY THE THIRD ENTOMOLOGICAL EXPEDITION TO THE NORTH-WEST HIMALAYAS (1956)**

By

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In an earlier paper I reported on the Hymenoptera collected by the first and second Entomological Expeditions to the North-West Himalayas, organised by Prof. Dr. M. S. Mani of the School of Entomology, St. John's College, Agra. In this paper I deal with a part of the Hymenoptera brought back by the Third Entomological Expedition. 13 species belonging to families Tiphidae, Vespidae, Eumenidae, Sphecidae, Bombidae and Xylocopidae are reported here ; of these, 11 species are being recorded for the first time from the region.

There is a distinct Palaearctic facies in the material, but no European affinity is seen. The majority of the specimens are of a general darker tone of colour than from other areas.

I have also availed myself of the opportunity of examining the material from this region already in the possession of the Zoological Survey of India.

My thanks are due to Dr. M. S. Mani for guidance and encouragement, and to the Director, Zoological Survey of India, for facilities for work.

Superfamily SCOLIOIDEA

Family TIPHIDAE

***Tiphia rufipes* Smith**

1855. *Tiphia rufipes* Smith, *Cat. Hymen. Brit. Mus.*, 3, p. 83.

1897. *Tiphia rufipes*, Bingham, *Fauna Brit. India, Hymen.*, 1, p. 61.

2♀♀, Coll. Nos. 685·1/56 and 685·2/56. Sta. No. 5 : Meadow with a hill to the east of the left bank of River Beas, 1·5 kilometres south of the Manali bridge on the Manali-Hamta mule track, with cultivated farms, Manali (Kulu Valley) ; altitude 2000m., on low vegetation in paddy fields, cloudy day. Coll. V K. Gupta, 25-vi-1956.

The central propodeal carina in specimen No. 685·2/56 does not reach up to the apex of propodeum. Colour of antennae, mandibles and tarsi darker, femora more reddish and wings more infumated than in examples from other areas. Size : 7-13 mm.

* Part 21 of this series was published in *Agra Univ. J. Res.*, 5 (1957).

The Scheme of Research on High Altitude Insect Life of the North-West Himalayas under Dr. M. S. Mani, financed by Council of Scientific and Industrial Research, was formerly at the School of Entomology, Agra.

**All the collections made by the three expeditions are at present in the Zoological Survey of India, Calcutta.

There are 3 examples from Kangra Valley, 1370m. in the Z.S.I. collection.

The species was previously known only from N. India and Burma. This is the first record from the N.-W. Himalayas.

***Tiphia consueta* Smith**

1897. *Tiphia consueta* Smith, In : Bingham, *Fauna Brit. India, Hymen.*, 1, p. 61.

1♀, Coll. No. 899·2/56. Sta. No. 3 : Manali (Kulu Valley), Plantation of Willow and *Alnus nitida* on the right bank of River Beas, 1·6 kilometres south of Manali Post & Telegraph Office on the Manali-Kulu Motor Road. Forest floor with dense growth of stinging nettles and some wild barberry ; altitude 2000m. Coll. R.L. Kotpal, 24-vi-1956.

I have before me 4 examples from Kangra Valley 1370m. in the Z.S.I. collection.

Previously recorded only from Ceylon. The species is being recorded here for the first time from the N.-W. Himalayas.

Superfamily VESPOIDEA

Family VESPIDAE

***Polistes maculipennis* Saussure**

1897. *Polistes maculipennis* Saussure, In : Bingham, *Fauna Brit. India, Hymen.*, 1, p. 396.

1 example, Coll. No. 632·3/56. Sta. No. 50 : Purana Khoksar Village (Lahoul Valley), Kuth field, 1·5 kilometres from P.W.D. Rest House on right bank of River Chandra ; altitude 3200m. In bright sunshine. Coll. V.K. Gupta, 9-vi-1956.

There are 60 examples of this species from : Chitral, 1830m. ; Kangra Valley, 1370m. ; Srinagar, 1830m. ; Chamba Valley ; Simla Hills ; Mussoorie, 2213m. ; Nainital, 1830m. ; Nepal ; Borneo and W. China in the Z.S.I. collection.

Previously recorded only from Sikkim, Assam, Tenasserim and Java. This is the first record from the N.-W. Himalayas.

***Polistes adustus* Bingham**

1897. *Polistes adustus* Bingham, *Fauna Brit. India, Hymen.*, 1, p. 397.

4 examples, Coll. Nos. 678·1/56, 678·60/56, 1043/56 & 891/56. Sta. No. 3 : Manali (Kulu Valley), plantations of Willow and *Alnus nitida* on the right bank of River Beas, 1·5 kilometers south of Manali Post & Telegraph Office on the Manali-Kulu Motor Road. Forest floor with dense growth of stinging nettles and some wild barberry ; altitude 2000m. Coll. V.K. Gupta (2 exs.), S. Singh (1 ex.) and R.L. Kotpal (1 ex.), 24-vi-1956.

The punctation on the mesonotum is rather deep and coarser than described by Bingham (*loc. cit.*).

In the Z.S.I. collection there are 15 examples of this species from Darjeeling, 2134m.-2438m. ; Nepal ; Kumaon, 1370m. ; and Mussoorie.

This species was previously known only from Sikkim, 1830m. The present record extends the range of this species to the N.-W. Himalayas.

Polistes sp.

1 example, Coll. No. 1302/56. Sta. No. 58 : Katrain (Kulu Valley), orchard opposite Circuit Rest House, 1370 metres. Coll. V.K. Gupta, 27-vi-1956.

The specimen comes near *Polistes sulcatus* Smith¹, but differs in (i) the pronotum having striae laterally ; (ii) mesonotum having a black streak in the anterior middle ; and (iii) sides of thorax being not black. In the latter character and in size (2mm.) the specimen approaches close to *P. stach*² Fabr. The material is not adequate for a definite specific identification.

Vespa flaviceps Smith

1897. *Vespa flaviceps* Smith, In : Bingham, *Fauna Brit. India, Hymen.*, 1, p. 406.

1 ♀, Coll. No. 601·35/56. Sta. No. 2 : Willow plantation and Pine Nursery in the compound of the Forest Rest House in Manali (Kulu Valley), near a slow stream at a short distance from the right bank of River Beas ; altitude 2000m. Coll. V.K. Gupta, 20-v-1956.

In the Z.S.I. collection there are 14 examples of this species from Simla, 2133m. ; Mussoorie ; Nainital ; and Nepal.

Previously known only from Kumaon, Sikkim and Tenasserim. This is the first record of the species from the N.-W. Himalayas.

Family EUMENIDAE

Eumenes punctata Saussure

1852. *Eumenes punctata* Saussure, *Mon. Guep. Sol.*, p. 37.

1897. *Eumenes punctata*, Bingham, *Fauna Brit. India, Hymen.*, 1, p. 339.

5 ♂♂, Coll. Nos. 1317·1/56, 1317·3/56, 1349·2/56, 1349·3/56 and 1349·4/56, and 1 ♀, Coll. No. 1349·1/56. Sta. No. 2 : Willow plantation and Pine Nursery in the compound of the Forest Rest House, Manali (Kulu Valley), at a short distance from the right bank of River Beas ; altitude 2000m. Coll. V.K. Gupta, 1-3-vii-1956.

Instead of two yellow spots on the clypeus in female, there is a semi-lunar yellow band on the basal portion and a yellow spot on each side below the tegulae. This spot is absent in the males before me ; the clypeus of males is entirely yellow.

In the Z.S.I. collection there are 4 examples from Kangra Valley, 1370m. Previously recorded only from Kumaon, Sikkim, Burma and Tenasserim. This is the first record from the N.-W. Himalayas.

Superfamily SPHECOIDEA

Family SPHECIDAE

Ammophila punctata Smith

1856. *Ammophila punctata* Smith, *Cat. Hymen. Brit. Mus.*, 4, p. 218.

1897. *Ammophila punctata*, Bingham, *Fauna Brit. India, Hymen.*, 1, p. 233.

4 ♂♂, Coll. Nos. 601·27/56, 601·33/56, 601·34/56 and 601·38/56. Sta. No. 2 : Willow plantation in the compound of Forest Rest House, Manali (Kulu Valley). Coll. V.K. Gupta, 20-v-1956.

¹ Smith, *Trans. ent. Soc. (N.S.)* 2, p. 38 (1852).

² Fabricius, *Spce. Ins.* 1, p. 461.

1 ♂, Coll. No. 643/56. Sta. No. 39 : Chhatru ; extensive alpine meadow on right bank of River Chandra at entrance to Purana Khoksar Nal (Lahoul-Spiti Valley) opposite Sta. 34 and about 15m. above river, with torrents running through, camping ground with P.W.D. Rest House ; altitude 3650m. Coll. V.K. Gupta, 12-vi-1956.

The examples from Manali were caught while entering their burrow in hard ground in bright sunshine. There were three burrows close to each other and the species was hovering near them. The example from Chhatru was caught on low vegetation in bright sunshine.

In the Z.S.I. collection there are 4 examples from Bhimtal (Kumaon), 1370m. ; and Nepal : Nagarkote, Soondrijal and Chitlong.

This species was previously known only from North India, Mussoorie, Sikkim and Burma. This is the first record from the N.-W. Himalayas.

***Ammophila brevipennis* Bingham**

1897. *Ammophila brevipennis* Bingham, *Fauna Brit. India, Hymen.*, 1, p. 232.

1 ♂, Coll. No. 685·1/56. Sta. No. 5 : Manali (Kulu Valley) ; meadow with a hill to the east on the left bank of River Beas, 1·6 kilometres south of the Manali bridge on the Manali-Hamta mule track with cultivated farms ; altitude 2000m. Collected on vegetation in paddy fields ; cloudy day. Coll. V.K. Gupta, 25-vi-1956.

Bingham (*loc. cit.*) has described only the female. The male differs as below :—

Head and thorax more densely pilose ; shallow furrows on each side above tegulae indistinct ; petiole black in basal half.

The species was originally described only from Bombay. This is the first record from the N.-W. Himalayas.

***Ammophila hirticeps* Cameron**

1889. *Ammophila hirticeps* Cameron, *Mem. Manchester lit. phil. Soc.*, (4)2, pp. 94, 99.

1897. *Ammophila hirticeps*, Bingham, *Fauna Brit. India, Hymen.*, 1, p. 234.

2 examples, Coll. Nos. 632·1/56 and 632·2/56. Sta. No. 50 : Purana Khoksar Village (Lahoul Valley), Kuth field, 1·5 kilometres from P.W.D. Rest House on right bank of River Chandra ; altitude 3150m., in bright sunshine. Coll. V.K. Gupta, 9-vi-1956.

The base of the 5th segment is black and reddish only at the sides. Previously recorded only from Gilgit. This is the first record from the N.-W. Himalayas.

Superfamily APOIDEA

Family BOMBIDAE

***Bombus tunicatus* Smith**

1852. *Bombus tunicatus* Smith, *Trans. ent. Soc. (N.S.)*, 2, p. 43, pl. viii, fig. 7.

1922. *Bombus lapidarius tunicatus*, Dover, *Rec. Indian Mus.*, 24, p. 88.

1935. *Bremus tunicatus*, Friess, *Rec. Indian Mus.*, 37, pp. 339, 350.

6 examples (workers), Coll. Nos. 1442·1/56, 1442·2/56, 1442·3/56, 1442·4/56, 1442·5/56 and 1442·6/56. Near Sta. No. 2 : In compound of Forest Rest House, Manali (Kulu Valley) just in front of Rest House on polyhock ; altitude 2000m. Coll. S. Singh, 6-vii-1956.

The examples were collected hovering over Holyhock flowers in sunshine.

This species has a wide range of distribution extending all along the Himalayas from Gilgit to Nepal and Calcutta. In the North-West Himalayas it has been known from Chamba Valley and Dalhousie, 2134m. This is the first record from Manali (Kulu Valley). The vertical distribution of the species from the plains of Calcutta to an altitude of 3050m. in Gilgit is also interesting.

***Bombus rufofasciatus* Smith**

1852. *Bombus rufofasciatus* Smith, *Trans. ent. Soc. (N.S.)*, 2, p. 48.

1955. *Bombus rufofasciatus*, Gupta, *Agra Univ. J. Res. (Sci.)* 4, p. 756.

1 ♀, Coll. No. 973/56. Sta. No. 18 : Marhi, Alpine meadow at the point of bifurcation of the mule track to Rohtang and the foot path to the frozen lake. Facing south, altitude 3600m. Coll. S. Singh, 29-v-1956.

1 example, Coll. No. 639·1/56. Sta. No. 5 : Manali, meadow to the east on the left bank of River Beas, 1·6 kilometres south of Manali bridge and on the Manali-Hamta mule track with cultivated farms ; altitude 2000m.

The example bearing Coll. No. 685·6/56 differs from the female collected at Marhi in the following respects : (i) smaller size, and (ii) in having the first abdominal tergite with yellow pubescence laterally in addition to white pubescence all over the first tergite.

This species has been recorded previously from Chhatru, 3460m. in the Lahoul-Spiti Valley north of Pir Panjal Range.

Family XYLOCOPIDAE

***Xylocopa auripennis* Lepel.**

1897. *Xylocopa auripennis* Lepel., In : Bingham, *Fauna Brit. India, Hymen.*, 1, p. 558.

1922. *Xylocopa auripennis*, Dover, *Rec. Indian Mus.*, 24, p. 86.

1 example, Coll. No. 601·30/56. Sta. No. 2 : Pine Nursery in compound of Forest Rest House, Manali (Kulu Valley) ; altitude 2000m. Coll. V.K. Gupta, 19-v-1956.

This example differs from the published description in the following respects :—Mesonotum rather sparsely and shallowly punctured and shiny (not smooth) ; apical margin of fore-wing without any greenish tinge.

Recorded previously from Barrackpore, Calcutta, Darjeeling, Nepal, Sikkim, Naga Hills, Sibsagar (Assam), S. India, Burma and China. This is the first record of the typical oriental species from the low elevations of the N.-W Himalayas.

ECOLOGY OF OVIPOSITION AND THE STRUCTURE OF EGG-PODS AND EGGS IN SOME INDIAN ACRIDIDAE

By

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(With 19 Text-figures)

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I—INTRODUCTION

Little work has been done on the ecology of oviposition and egg-pods, etc., of Indian short-horned grasshoppers (Orthoptera, family Acrididae), except in the case of Desert Locust, *Schistocerca gregaria* Forskal and one or two other species. Considerable work, however, has been done by Zimin (1935 ; 1938) on the Russian species, by Waloff (1950) on those of Great Britain and by Morales Agacino (1951) on the Spanish species.

In the present account the author has described the mode of oviposition in 14 northern Indian species occurring in Dehra Dun and Saharanpur Districts of Uttar Pradesh, the ecological relationship to soil in 20 species, the structure of the egg-pods in 14 species and of the egg-chorion in 10 species, all from the same area as mentioned above.

The author wishes to thank Dr. M. L. Roonwal, F.N.I., Chief Research Officer (Forest Entomologist), Forest Research Institute, Dehra Dun (now Director, Zoological Survey of India, Calcutta), under whose guidance this work was carried out, for his stimulating advice and encouragement during the progress of this work.

II—MODE OF OVIPOSITION

(a) General

Künckel d' Herculais (1893-1905) first observed the process of oviposition in *Schistocerca gregaria*. Fedorov (1927) studied the details of oviposition, by means of a special cage, in the Egyptian grasshopper,

Anacridium aegyptium. Uvarov (1928) described oviposition in general in the Acrididae. Agarwala (1951) gave a detailed account of oviposition in *Locusta migratoria migratorioides*. Katiyar (1955, 1956a) briefly described oviposition in two Indian species, namely, *Aularches punctatus* and *Parahieroglyphus bilineatus*.

The present account deals with oviposition in the following 14 species as observed in the insectary as well as in the field under natural conditions :—

Subfamily (i) *ACRIDINAE*

1. *Ceracris deflorata* Brunner
2. *Phlaeoba panteli* Bolivar

Subfamily (ii) *CATANTOPINAE*

3. *Choroedocus insignis* Thunberg
4. *Choroedocus* sp.
5. *Eyprepocnemis roseus* Uvarov
6. *Hieroglyphus banian* Fabricius
7. *Hieroglyphus nigrorepletus* Bolivar
8. *Parahieroglyphus bilineatus* Bolivar
9. *Schistocerca gregaria* Forskal
10. *Spathosternum prasiniferum* Walker
11. *Xenocatantops humilis humilis* Serville

Subfamily (iii) *OEDIPODINAE*

12. *Locusta migratoria migratorioides* Reich & Frm.

Subfamily (iv) *PYRGOMORPHINAE*

13. *Aularches punctatus* Drury
14. *Chrotogonus concavus* Kirby

(b) *Observations and discussion*

In all the 14 species studied, the abdomen of the female, during oviposition, is extended out gradually to almost double its normal length. The mechanism of the extension is obscure. Künckel d' Herculaïs (1893-1905) maintained that the primary cause of extension is blood pressure. The deposition of eggs and their orientation in the egg-pod is fundamentally similar in all these species but there are important differences in detail which are described below.

After depositing the frothy material, the female extrudes the eggs one by one after a little pause between two successive eggs. Each egg passes out between the tips of the dorsal valvulae of the ovipositor. The micropylar end of the egg always comes out first and points downwards during oviposition and, thus, that end always points downwards in the egg-pod. When all the eggs have been laid, the female plugs the egg-pod in one of the two following ways, the exact method differing with the species, thus :—

i In the cases of *Aularches punctatus*, *Ceracris deflorata*, *Choroedocus insignis*, *Choroedocus* sp., *Chrotogonus concavus*, *Eyprepocnemis roseus*, *Phlaeoba panteli*, *Spathosternum prasiniferum*, and *Xenocatantops humilis humilis*, the female makes a fragile, frothy cap above the eggs. In the cases of *Hieroglyphus banian*, *H. nigrorepletus* and *Parahieroglyphus bilineatus*, the female plugs the egg-pod with some secretion which forms a hard cap above the eggs. A little hardened secreted material is also deposited above the cap. When the female withdraws the abdomen from

the oviposition hole, it scraps the surface of the soil around the hole with its hind-legs and throws it on the top of the hole to cover it completely. In a few cases, the soil is so nicely levelled that no trace of the hole can be detected from the outside.

During oviposition the various species make different angles varying from about 10° to 65° with the body above the surface of the soil and from about 80° to 140° below the soil with the abdomen. The angles are measured from the ventral aspect of the female. An accurate measurement of the angles is rather difficult due to the small size of the females in two species, namely, *Spathosternum prasiniferum* and *Chrotogonus concavus*. This varying range of angle during oviposition has been studied by me under 3 categories. The angle so made seems to be correlated with the mode of copulation of which I have recognised three types as follows :—

Mode I—Male rides on the back of the female head to head during copulation.

Mode II—Male comes to be on the side of the female during copulation.

Mode III—Male neither rides on back of the female nor lies at her side, but hangs passively attached to the abdomen of the female during copulation (Katiyar, 1952 & 1956).

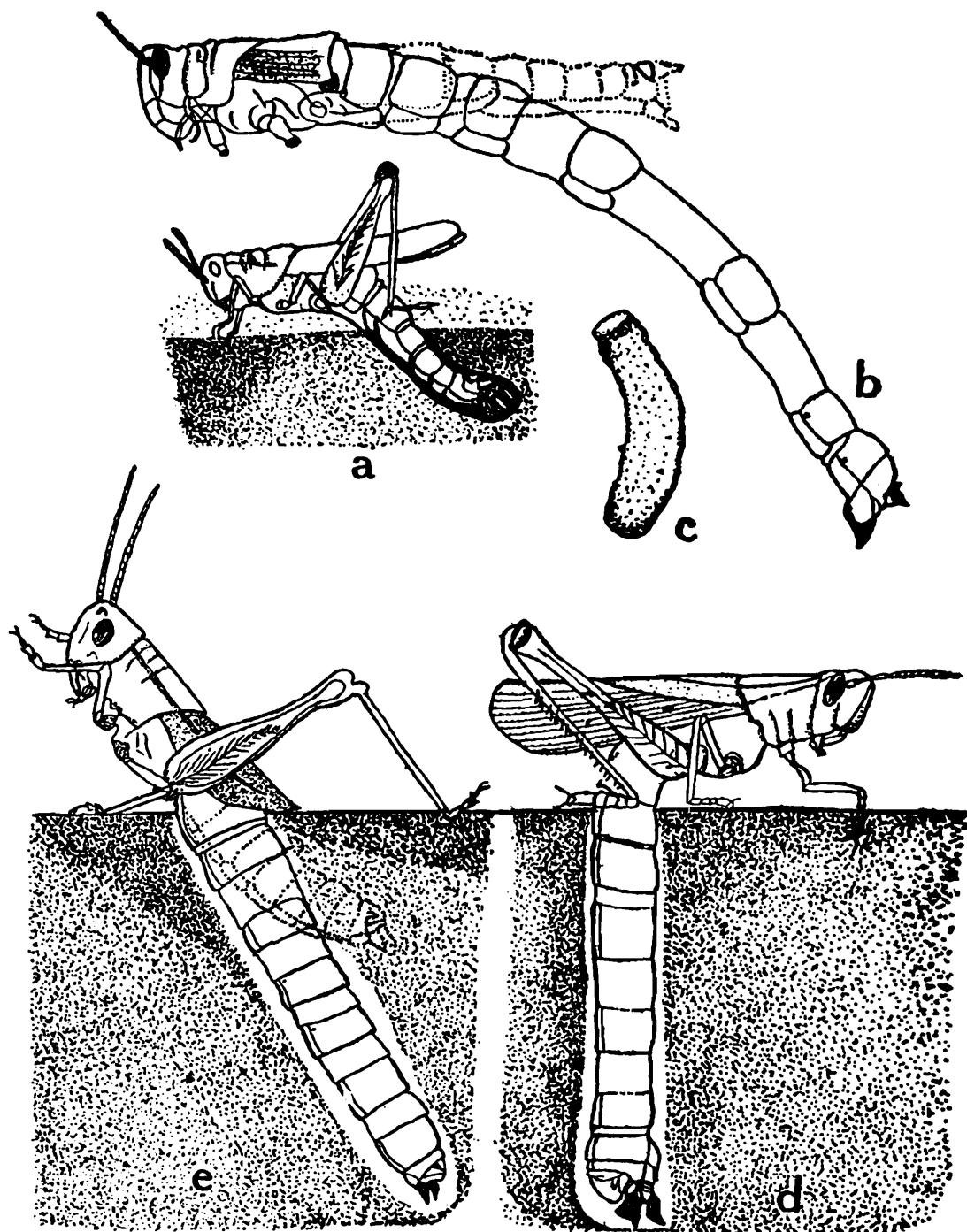
The three types of ovipositions are described below :

(i) *The First Category*.—The female as usual searches for a suitable place for oviposition. It then makes a slanting hole (Text-fig. 1a) with an angle of 10° — 25° above the soil with the body and of 120° — 140° below the soil with the abdomen. This type of posture was observed in all the 10 species which copulate by Mode I, and in *Phlaeoba panteli* which copulates “dorso-laterally”, i.e., intermediate between Modes I and II. The species are :—

- | | |
|--------------------------------------|--|
| 1. <i>Aularches punctatus</i> | 7. <i>Locusta migratoria migratorioides</i> |
| 2. <i>Ceracris deflorata</i> | 8. <i>Phlaeoba panteli</i> (Mode of copulation between Modes I and II) |
| 3. <i>Chrotogonus concavus</i> | 9. <i>Schistocerca gregaria</i> |
| 4. <i>Eyprepocnemis roseus</i> | 10. <i>Spathosternum prasiniferum</i> |
| 5. <i>Hieroglyphus banian</i> | 11. <i>Xenocatantops humilis humilis</i> |
| 6. <i>Hieroglyphus nigrorepletus</i> | |

(ii) *The Second Category*.—The female first starts digging the hole in a slightly slanting position as in Category I. A little lower down, the angle of the hole is changed to a right angle with the surface. The female thus makes an angle of 15° — 35° above the soil and of 80° — 90° below the soil (Text-fig. 1d). Two species, viz., *Choroedocus insignis* and *Choroedocus* sp., fall in this category and both copulate by Mode II.

(iii) *The Third Category*.—The female makes an angle of 45° — 65° above and of 110° — 120° below the soil. The entire body of the female remains virtually in a straight line during oviposition. The only species falling under this category is *Parahieroglyphus bilineatus*; it copulates by Mode III (Katiyar, 1952). Unlike other categories, the female here buries itself in the ground up to the hind tibia (sometimes up to the hind tarsi and even claws) and the head is lifted up. Thus, during oviposition, the body-parts above the soil form a straight line with the abdomen below the soil (Text-fig. 1e).



TEXT-FIG. 1.—Oviposition in the Desert Locust, and in *Choroedocus insignis* Thunberg and *Parahieroglyphus bilineatus* Bolivar.

(a) Female grasshopper, Desert Locust, during oviposition (after Gibson). (b) Extension of abdomen of female Desert Locust during oviposition; dotted outline shows the normal size of the abdomen (after Vosseler). (c) Egg-pod of Desert Locust. (d) Extension of abdomen of female *Choroedocus insignis* Thunberg during oviposition. (e) Extension of abdomen of female *Parahieroglyphus bilineatus* Bolivar during oviposition.

III—ECOLOGY OF OVIPOSITION IN SOME INDIAN ACRIDIDAE

Some general ecological observations on 20 species of Acrididae studied around Dehra Dun in relation to egg-pod deposits are recorded here.

All the species of Acrididae studied around Dehra Dun deposit their eggs under the soil-surface in egg-pods. For this study several hundred females, of different species have been watched in different localities in fields as well as in different cages in the insectary, trying in

two or three places and then finally selecting a suitable place for oviposition. I have noticed that the place for oviposition is always selected by the female with the following two considerations in view :—

1. That the eggs should be deposited under the xerophilic soil (dry soil), mesophilic soil (soil without abundance of moisture although top layer being moist), or hygrophilic soil (soil with abundant moisture), as the case may be, but usually at places where the egg-pods may not be destroyed or detected easily.

2. That the eggs should be laid at places where green vegetation as food may easily be available for the newly hatched hoppers.

As regards the first point, egg-pods have been dug out from (or the females have been watched ovipositing the eggs in) various situations, such as near or along the margins of trodden paths, field margins, near the roots of bushes and hedges, sometimes under the shaded trees and occasionally in high grass-lands, but never in the middle of the fields, gardens and nurseries, etc. The above noted places of oviposition are favourable for the newly hatched hoppers too, as they get enough food there when it is not available in the middle of the fields.

The preferences of the various species for soil conditions are given below :—

(a) Species preferring dry or xerophilic soils for oviposition :—*Hieroglyphodes assamensis*, *Hieroglyphus concolor*, *H. banian*, *H. nigrorepletus*, *Parahieroglyphus bilineatus*, *Schistocerca gregaria*, *Locusta migratoria* and *Chrotogonus concavus*.

(b) Species preferring mesophilic soils :—*Xenocatantops humilis humilis*, *Catanotops splendens*, *Choroedocus insignis*, *Choroedocus* sp., *Eyprepocnemis roseus*, *Oedaleus abruptus*, *Gastrimargus transversus* and *Spathosternum prasiniiferum*.

(c) Species preferring hygrophilic soil :—*Aularches punctatus* and *Poecilocerus pictus*.

(d) Species ovipositing in all types of soils :—*Ceracris deflorata* and *Phlaeoba panteli*.

The preference for the preferred soils is so great that in many cases the females were observed feeling quite miserable on unfavourable soils due to heavy weight in their ovaries. Under such conditions they either drop their eggs on the soil-surface, grass-leaves, etc., or stop taking food and ultimately die* without oviposition.

It was observed that egg-pods of species which prefer xerophilic soil are easily distinguishable morphologically from those of meso- and hygrophilic soils. The xerophilic egg-pods are simple and short, while there is a great variation in the length and shape of the meso- and hygrophilic pods. In the xerophilic pods the outer wall consists of very rough, tough, hard and cemented secreted material ; there is a hard, smooth and concave cap just above the layers of the eggs or at the apex of the pod ; in some cases above the cap, the top-section is filled with secreted material which is hard, compact and easily detachable. In the mesophilic pods the outer wall of the egg-pod is not cemented, but is rough, slightly hard and consists of a few layers of dense, laminated, secreted material, with or without a cap at the top ; the cap is usually soft and membranous when present. In the hygrophilic pods, the outer wall is usually smooth or rough, spongy or frothy, usually fragile ; it is without any cap at the top but the top-section is filled with coarsely-meshed, spongy secreted material, with septa- or hexagonal empty spaces or cells.

* Such females were dissected and it was noticed that their ovaries were laden with the matured eggs, but the alimentary canal was quite empty.

It was also observed that variation in the length of the egg-pods depends on the nature of the soil in which they are laid. Such variation was noticed in the egg-pods of the same species ovipositing in different soils, as in *Ceracris deflorata* and *Eyprepocnemis roseus*. The pods laid in different soils varied greatly in length. The females of average length of *Ceracris deflorata* were bred in the insectary in 3 different cages provided with sandy-loam, clayey soil and stony soil. The length of egg-pods was found to be 9—16 mm., 8—13 mm., and 4—7 mm., respectively.

It was further observed that soil moisture also plays some part in determining length of the egg-pod laid by a female. The pods of a few common species, namely, *Spathosternum prasiniferum*, *Phlaeoba panteli* and *Choroedocus insignis* found in the New Forest Estate, near Dehra Dun, were longer and thicker than those of the some species obtained from comparatively damper places in the Bibiwala forests near Hardwar (about 40 miles away from Dehra Dun). An experiment in the insectary also confirmed the above fact as follows :—

Three different flower-pots, with a long chimney covered with muslin cloth, were provided with 8—10 cms. thick layer of sandy-loam. Twenty average sized females of *Spathosternum prasiniferum* were kept in each pot for egg-laying. The soil of the first pot was kept without any added moisture ; of the second with a little added moisture ; and of the third very wet. The egg-pods from the first lot (without moisture) were the longest and those from the third lot (very wet soil) were the shortest, the size-range in the 3 lots being as follows :—

Dry soil : 10—17 mm. long.

Medium soil : 8—12 mm.

Very wet soil : 5—8 mm. (9 mm. in one case).

Again, the egg-pods from the light soils are larger than those from the heavy or hard clayey soils. The dimensions of egg-pod also depend to a certain extent on the carrying capacity of the female. Furthermore, egg-pods of the first oviposition are always larger and have more eggs than those of the successive layings, as noticed in *Aularches punctatus* by Katiyar (1955).

The egg-pods in the species studied were laid 5.0—12.5 cms. below the soil-surface. The depth varies from species to species, mainly depending on the length of the abdomen of the female and to some extent on the nature of the soil as well as moisture present in it.

IV.—STRUCTURE AND KEY TO THE IDENTIFICATION OF EGG-PODS OF SOME INDIAN ACRIDIDAE

Vorontsovsky (1926) classified the egg-pods of the Russian Acrididae into the following types : bag, pot, pill, capsule, etc. Zimin (1935) also working on the Russian Acrididae, classified egg-pods according to the following characters :—(i) Sculpture peculiarities of the egg-chorion. (ii) Character (physical structure) of the coagulated secretional liquids in the egg-pod and their consistency and colour. (iii) Structure and structural material of the egg-pod. (iv) Form, colour and distribution of eggs in the pod. (v) Degree of complexity of the structure of the egg-pod. (vi) Manner of closure of the exit-aperture. (vii) Number of eggs in the pod. (viii) Distance from the top of the egg-pod to the top-level of the eggs.

I have followed Zimin's classification as far as possible. In the measurements of size, the *length* is measured along the outer curvature of the egg-pod, and *width* across the maximum diameter.

The egg-pods of the following 14 species were studied :—

Subfamily (i) *ACRIDINAE*

1. *Acrida gigantea* Herbst
2. *Ceracris deflorata* Brunner
3. *Phlaeoba panteli* Bolivar

Subfamily (ii) *CATANTOPINAE*

4. *Choroedocus insignis* Thunberg
5. *Eyprepocnemis roseus* Uvarov
6. *Hieroglyphus concolor* Herbst
7. *Hieroglyphus nigrореpletus* Bolivar
8. *Hieroglyphodes assamensis* Uvarov
9. *Parahieroglyphus bilineatus* Bolivar
10. *Spathosternum prasiniferum* Walker
11. *Xenocatantops humilis humilis* Serville

Subfamily (iii) *OEDIPODINAE*

12. *Gastrimargus transversus* Thunberg
13. *Oedaleus abruptus* Thunberg

Subfamily (iv) *PYRGOMORPHINAE*

14. *Aularches punctatus* Drury

(a) *Description of egg-pods and eggs.*—The characters of the egg-pods and eggs of each of the species listed above are given below briefly :—

Subfamily (i) *ACRIDINAE*

1. *Acrida gigantea* Herbst

(Text-fig. 8 g-i)

General : Three pods examined. Pods rough and fragile ; long, cylindrical, straight ; base round or conical ; apex flat, provided with a concave cap. Length of pod 2.8-4.4 cms., width 0.55-0.56 cm. Outer wall dirty brownish white ; internally, the frothy mass above and around eggs light brown. Outer wall consisting of compressed layers of frothy secretion, thin near the top, thick at the base ; rough, due to the adherence of fine sand particles and bits of stones. Internally, top section filled with very finely meshed froth ; lower or egg-section surrounded by a similar thin layer of froth. A few thin layers of secreted material also lying in between eggs, with a thick frothy pad at the base of pod.

With 52-65 eggs in a pod. Eggs arranged obliquely, one above the other and sloping towards the pod-wall.

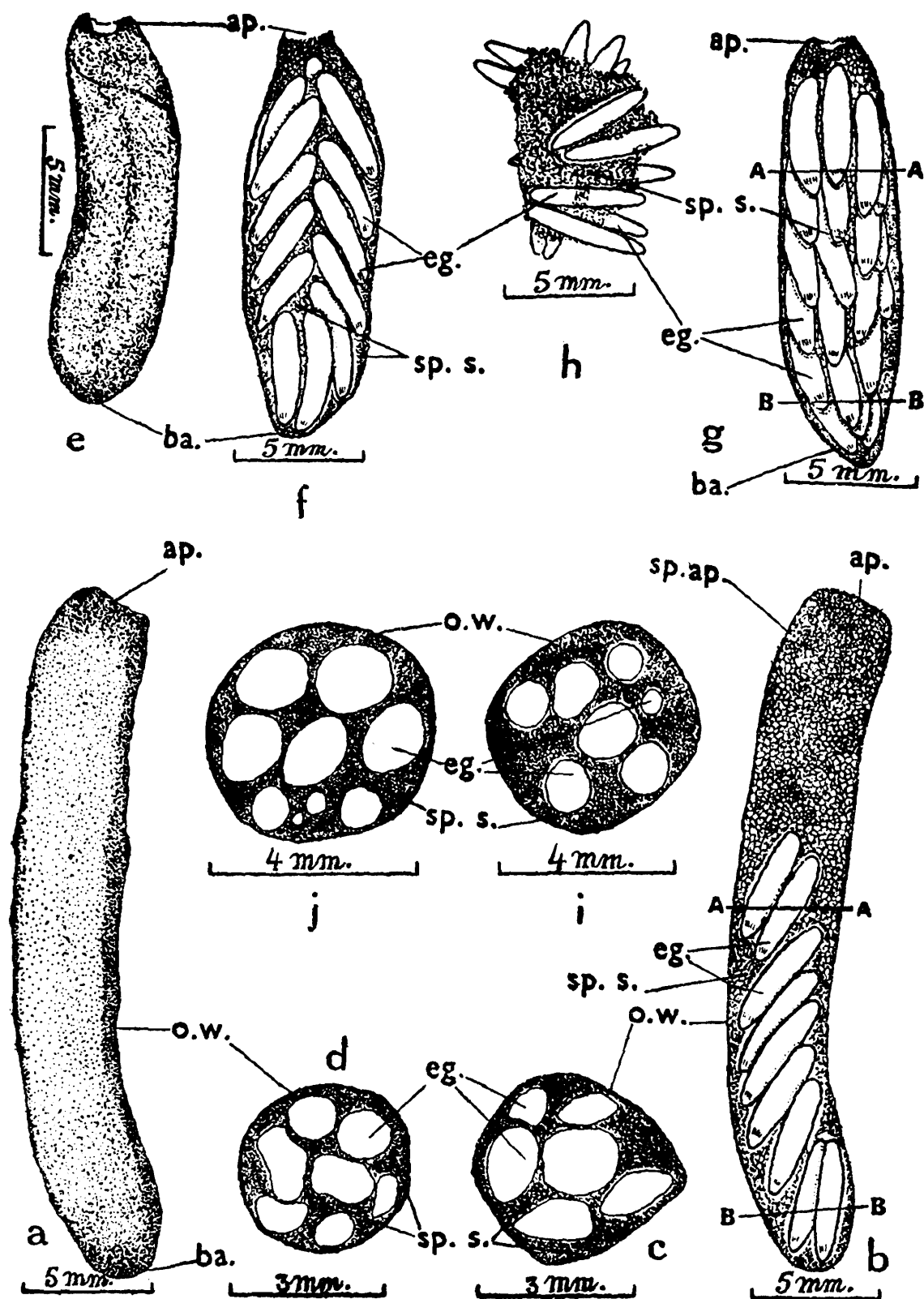
Eggs : Length, 4.5-5.25 mm. ; width, 0.5-0.75 mm. Thin, slender ; rounded at the anterior pole, subconical at the posterior.

Egg-laying : In insectary eggs laid in sandy-loam, eggs laid 5.2-8.8 cms. below soil-surface. Egg-laying observed in 3 cases only ; occurs in Dehra Dun in 3rd and 4th weeks of August.

2. *Ceracris deflorata* Brunner

(Text-fig. 2 e-j)

General : Eighteen egg-pods examined. Pods rough and hard ; small, cylindrical, straight or curved ; base round or semiround ; apex



TEXT-FIG. 2.—Eggs and egg-pods of *Phlaeoba panteli* Bolivar and *Ceracris deflorata* Brunner.

(a) Egg-pod of *Phlaeoba panteli*. (b) Same, with the wall partly removed from lateral side to show arrangement of eggs. (c) Same, transverse section across upper line (A-A) in Fig. b. (d) Same, across lower line (B-B). (e) Egg-pod of *Ceracris deflorata*. (f) Same, with the wall partly removed from the concave side to show arrangement of eggs. (g) Same, with the wall of the convex side removed to show arrangement of eggs. (h) Eggs of *Ceracris deflorata* embedded in frothy material laid abnormally on a leaf surface. (i) Transverse section of egg-pod of *Ceracris deflorata* across upper line (A-A) in Fig. g. (j) Same, across lower line (B-B) in Fig. g.

ap., apex of egg-pod ; ba., base of egg-pod ; ca., cap of egg-pod ; eg., egg ; o.w., outer wall of egg-pod ; sp. ap., spongy secretion at apex of egg-pod ; sp. s., spongy secretion in between eggs.

flat, cap usually wanting but in some cases present as a thin, membranous, concave covering caused by contraction of froth when dried. Length of pod 1.45-1.85 cms., width 0.45-0.6 cms. Outer wall dirty salmon to dirty orange-pink ; internally almost all frothy mass above and around eggs orange-pink. Outer wall thin, membranous and rough, due to adherence of soil particles and bits of stones and sometimes bits of leaves and grass also. Internally, one-third of top-section filled with finely-meshed orange-pink froth ; two-thirds of the remaining lower or egg-section surrounded by coarse-meshed layers of orange-pink froth ; lining of secreted material in between eggs seen only here and there ; but a thin frothy pad at base of pod always present.

With 14-22 eggs in a pod (or about 14-16 in a mass, when laid on leaves or grass). Eggs arranged in two different styles : On concave side of pod, the posterior end of eggs tending to slope towards pod-wall and anterior end of eggs meeting in middle when viewed from hollow side of pod ; on convex side of pod, eggs arranged irregularly one above the other, *i.e.*, at base a few rows of eggs arranged vertically at right angles to base ; above these the anterior end of eggs tending to slope towards pod-wall, and at top, a few eggs again lying vertically at right angles to base. (When laid on leaves and grasses, no definite arrangement of eggs seen.)

Eggs : Length, 4.5-5.25 mm. ; width, 1.0-1.45 mm. Thin, subcylindrical, straight, with both anterior and posterior ends subconical ; pale yellow to pale brown.

Egg-laying : In insectary, eggs laid in sandy-loam ; in fields in hard soil ; eggs laid 1.5-4.0 cms. below soil-surface. At times eggs deposited at random on leaves, stones or blades of grass instead below the soil ; froth whitish after oviposition, changes to orange-pink. Egg-laying occurring in Dehra Dun from 2nd week June to 3rd week August ; maximum in last week of July.

3. *Phlaeoba panteli* Bolivar

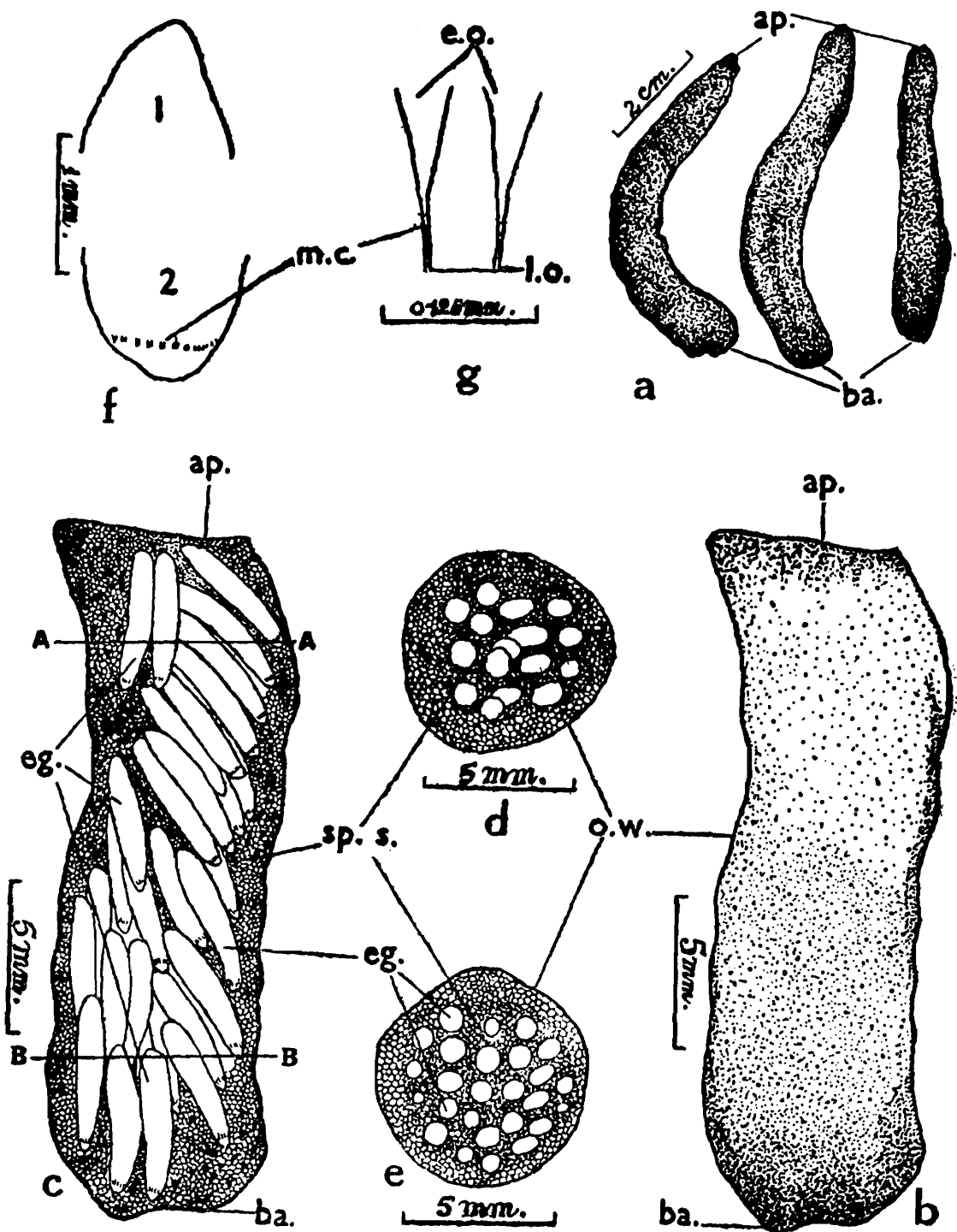
(Text-fig. 2 *a-d*)

General : Twenty-five egg-pods examined. Pods rough and hard ; elongated, straight or bent near base, sometimes near one-third the length from the top ; base round ; apex somewhat round, with no definite cap at top but only a frothy mass above eggs. Length of pod 1.9-2.85 cms. ; width, 0.4-0.7 cms. Outer wall dirty brown or pink ; internally, the frothy mass above eggs pale clay yellow, below and around the eggs pinkish brown. Outer wall consisting of a compressed, thick layer of frothy secretion ; wall rough due to adherence of sand particles and bits of small stones. Internally, one-third of top section filled with thick-meshed froth with hexagonal spaces or cells ; two-thirds of the remaining lower or egg-section surrounded by coarsely-meshed thick layer of pink-froth. A thin frothy layer of secreted material lying in between eggs, with coarse-meshed froth at micropylar end of each egg. No thick frothy pad at base of pod.

With 22-32 eggs in a pod. Eggs arranged in 2-3 rows, sloping towards the pod-wall. 8-9 eggs visible in one plane one above the other on either the concave (hollow) side or the convex (bulging) side of pod.

Eggs : Length, 4.2-5.25 mm. ; width, 0.8-1.2 mm. Straight or slightly curved anteriorly ; rounded at the anterior and conical at the posterior pole ; pale to clay yellow.

Egg-laying : In insectary, eggs laid in sandy-loam ; in the field also laid in sandy-loam near roots of thorny bushes and herbs ; eggs laid 2.5-4.8 cms. below soil-surface. Eggs sometimes laid abnormally on leaves and grass. Egg-laying occurring in Dehra Dun from 2nd week May to 3rd week July.



TEXT-FIG. 3.—Eggs and egg-pods of *Choroedocus insignis* Thunberg.

(a) Three complete egg-pods to show variation in shape ; upper frothy portion and lower pod-portion. (b) Egg-pod without the upperfrothy portion. (c) Same, with the wall partly removed to show arrangement of eggs. (d) Transverse section of egg-pod across upper line (A-A) in Fig. c. (e) Same, across lower line (B-B) in Fig. c. (f) (1) and (2) Anterior and posterior poles of egg respectively. (g) Two micropylar canals enlarged from posterior pole of egg shown in Fig. f.

ap., apex of egg-pods ; ba., base of egg-pod ; ca., cap of egg-pod ; eg., egg ; o.w., outer wall of egg-pod ; sp. s., spongy secretion in between egg.

Subfamily (ii) *CATANTOPINAE*4. *Choroedocus insignis* Thunberg

(Text-fig. 3 a-g)

General : Twenty-five egg-pods examined. Pods smooth to slightly hard ; long, subcylindrical, straight, sometimes bent in middle ; base round ; apex subconical, without any cap. Length of pod, 4.8-7.4 cms. ; width, 1.1-1.35 cms. Outer wall dirty clayey due to adhering soil ; internally, apical frothy mass yellowish white, lower part (surrounding eggs) dirty yellow to light brown. Outer wall consisting of thin layer of frothy secretion ; internally, half of top section filled with coarse-meshed froth with hexa- or septagonal empty spaces or cells ; half of the remaining lower, or egg-section, surrounded by fine-meshed frothy pad ; lining of secreted material in between eggs scanty ; a thick frothy pad at base of pod always present.

With 64-95 eggs in a pod. Eggs near bottom arranged vertically at right angles to the base, with the micropylar end pointing straight down to base, above these, eggs tending to slope towards pod-wall ; and at the top, a few layers of eggs again lying vertically at right angles to base ; number both of rows and of eggs in a row variable.

Eggs : Length, 5.2-5.6 mm. ; width, 0.9-1.0 mm. Thick, subcylindrical ; straight, sometimes bent slightly ; with both anterior and posterior ends rounded ; Yellow to light brown.

Egg-laying : In insectary, eggs laid in sandy-loam ; in field also in sandy-loam near the roots of the high bushes or grasses ; eggs laid 6.4-10.0 cms. below soil-surface. Egg-laying occurring from 1st week August to 2nd or 3rd week October around Rishikesh (Saharanpur District) and in Dehra Dun from 1st week August to 4th week September.

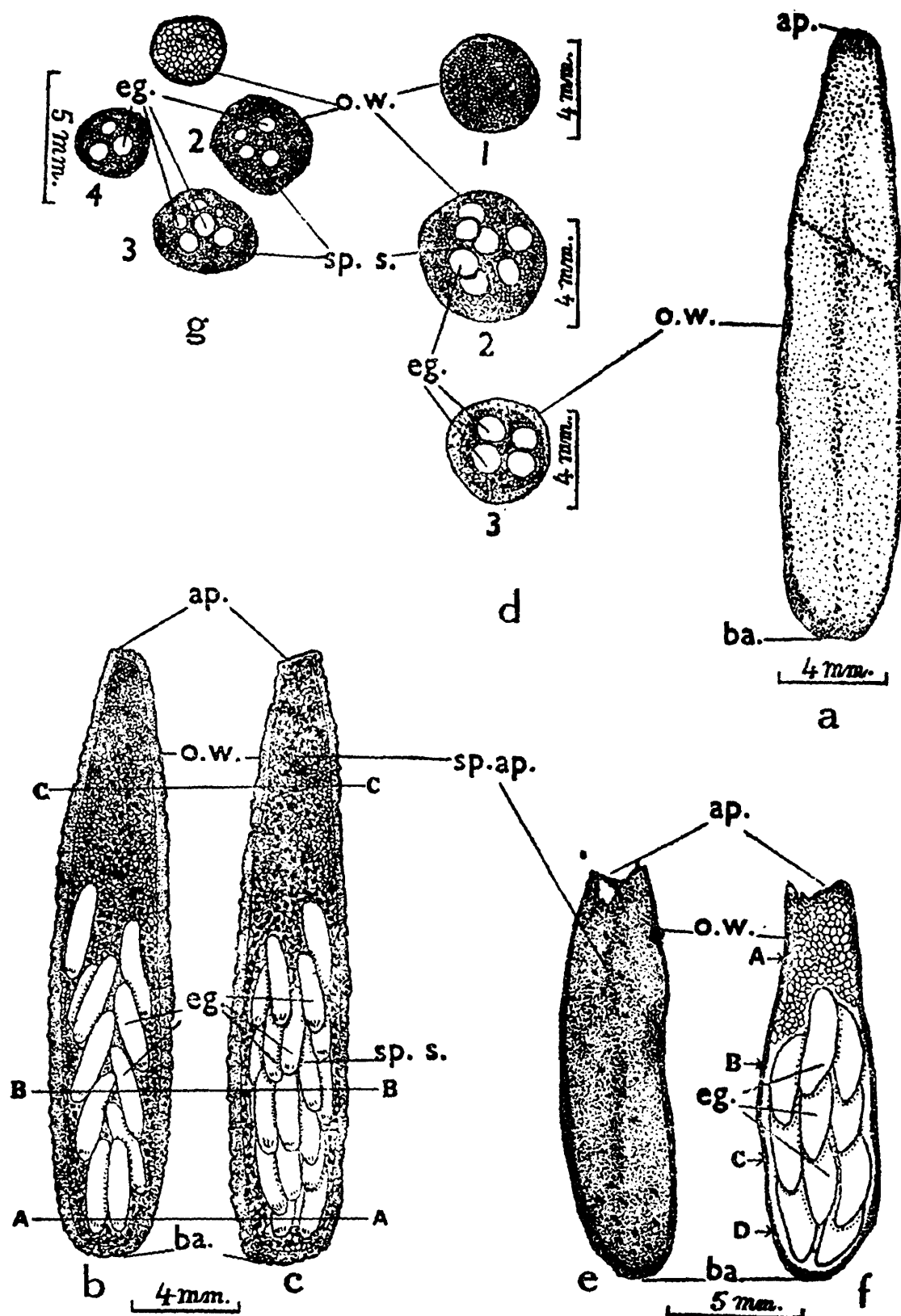
5. *Eyprepocnemis roseus* Uvarov

(Text-fig. 4 a-d)

General : Forty-one egg-pods examined. Pods rough and fragile near apex ; rough, hard near base, surface sometimes appears cork-like ; long, narrow, subcylindrical, straight or curved ; base round ; apex usually flat or subconical, without any cap. Length of pod, 2.7-3.8 cms. ; width, 0.35-0.5 cms. Outer wall dirty brown or pinkish brown ; internally, frothy mass above the eggs pinkish, and below and around eggs pinkish brown. Outer wall consisting of compressed layers of frothy secretion, thin near the top, thick at the base ; rough, due to adherence of sand particles, bits of stones and sometimes bits of leaves. Internally, one-third of top section filled with fine-meshed froth ; two-thirds of remaining lower, or egg-section, surrounded by coarse-meshed frothy mass. A very thin layer of secreted material also lying in between eggs, with a thick frothy pad at base of basal eggs of pod.

With 10-18 eggs in a pod. Usually, with four basal eggs, a pair on each side ; towards the concave (hollow) side of pod, eggs arranged in groups of twos, each egg lying in a slanting position ; towards convex (outer) side, eggs arranged vertically in groups of threes in irregular rows (Text-fig. 4 c, d.)

Eggs : Length, 4.8-5.5 mm. ; width, 1.0-1.5 mm ; subcylindrical ; straight, rarely curved ; with both anterior and posterior ends subconical ; creamy white to dirty brown.

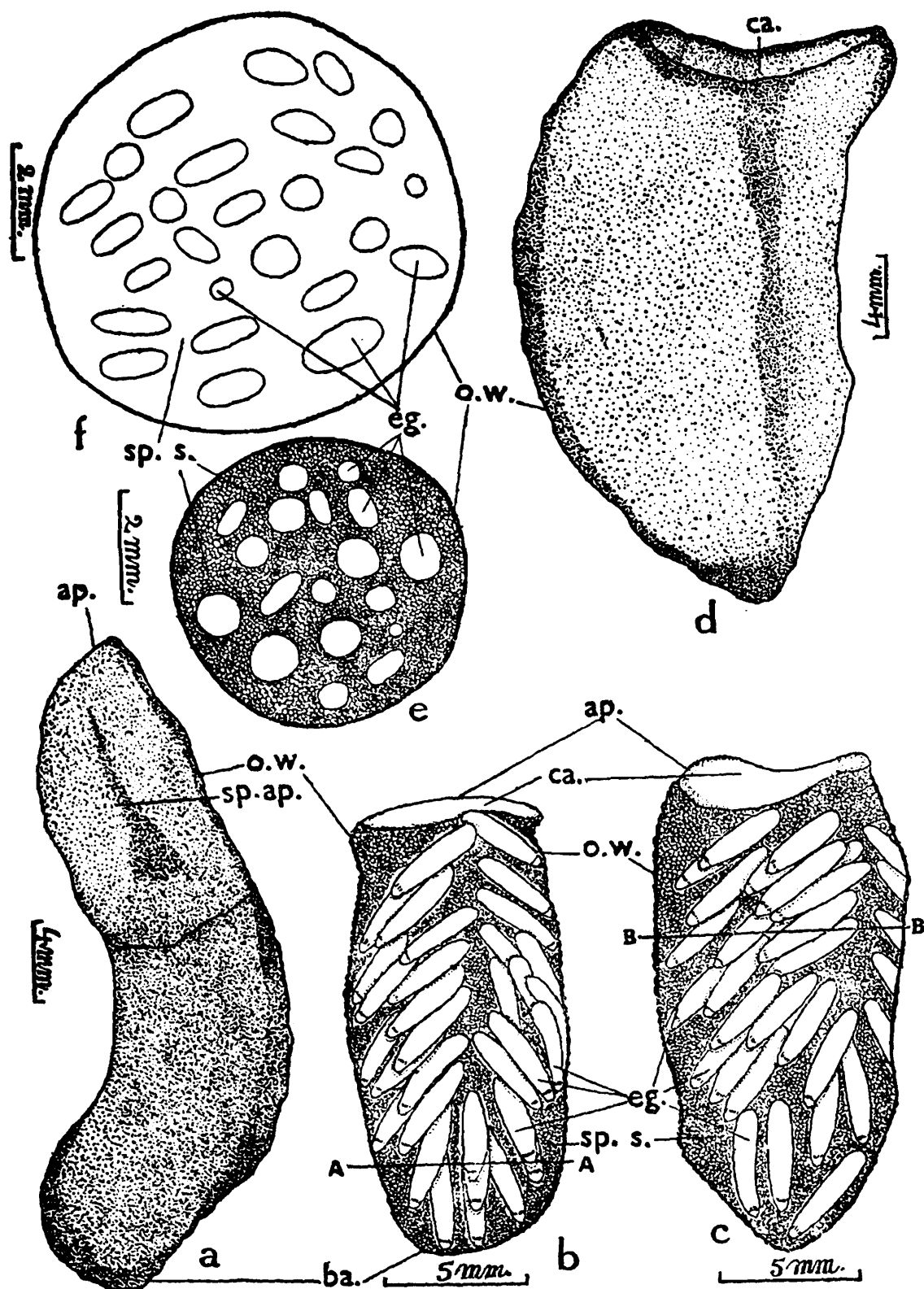


TEXT-FIG. 4.—Eggs and egg-pods of *Eyprepocnemis roseus* Uvarov and *Spathosternum prasiniferum* Walker.

(a) Entire egg-pod of *Eyprepocnemis roseus*. (b) Same, with the wall partly removed from concave side to show arrangement of eggs (cf. c). (c) Same, with the wall of the convex side removed to show arrangement of eggs (cf. d). (d). Transverse sections of egg-pod of *Eyprepocnemis roseus*: (1) Across upper line (C-C) in Figs. b and c; (2) Across middle line (B-B) in Figs. b and c; (3) Across lower line (A-A) in Figs. b and c. (e) Entire egg-pod of *Spathosternum prasiniferum*. (f) Same, with the wall partly removed from lateral side to show arrangement of eggs. (g) Transverse section of egg-pod of *Spathosternum prasiniferum*: (1) Across upper line (A-A) in Fig. f; (2) Across middle line (B-B); (3) Across another middle line (C-C); (4) Across lower line (D-D).

ap., apex of egg-pod; ba., base of egg-pod; ca., cap of egg-pod; eg., egg; o.w., outer wall of egg-pod; sp. ap., spongy secretion at apex of egg-pod; sp. s., syongy secretion in between eggs.

Egg-laying : In insectary, eggs laid in sandy-loam ; in field in hard soil ; eggs laid 2.5-6.7 cms. below soil-surface. Egg-laying occurring in Dehra Dun from 3rd week July to 1st week August.



TEXT-FIG. 5.—Eggs and egg-pods of *Hieroglyphus concolor* Herbst.

(a) Entire egg-pod. (b) Same, with the wall partly removed from concave side to show arrangement of eggs (cf. c). (c) Same, with the wall of convex side removed to show arrangement of eggs, (cf. b). (d) An egg-pod of abnormal size without spongy mass at apex of egg-pod. (e) Transverse section of egg-pod across lower line (A-A) in Fig. b. (f) Same, across upper line (B-B) in Fig. c.

ap., apex of egg-pod ; ba., base of egg-pod ; ca., cap of egg-pod ; eg., egg ; o.w., outer wall of egg-pod ; sp. ap., spongy secretion at apex of egg-pod ; sp. s., spongy secretion in between eggs.

6. *Hieroglyphus concolor* Herbst

(Text-fig. 5 a-f)

General : Thirty-one egg-pods examined. Pods very rough, tough and hard ; long, usually straight or bent in middle, sometimes broad (Text-fig. d) ; base round or subconical ; apex flat, provided with a hard smooth cap above eggs. Length of pod, 3.25-5.5 cms. ; width, 0.95-1.65 cms. Outer wall dirty brown ; internally, the secreted material above and around eggs dark brown. Outer wall consisting of hard secreted material, which is hard and rough due to impregnation of small bits of stones and coarse sand. Internally, one-third of top section filled with secreted material, which is hard, compact and easily detachable ; below it, with a definite hard, smooth, concave cap above the eggs ; below the cap, two-thirds of remaining egg-section surrounded by thick layers of cemented material ; a thick layer of such cemented material also lying in between eggs ; no thick pad at base of pod.

With 62-84 eggs in a pod. Eggs near base arranged vertically at right angles ; remaining eggs tending to slope towards pod-wall.

Eggs : Length, 3.6-4.07 cms. ; width, 0.9-1.0 cms. Thick, subcylindrical, straight, rarely bent in middle ; anterior pole round ; posterior tapering from micropylar ring, slightly round or flat at extremity ; yellowish brown to dark brown.

Egg-laying : Both in insectary and field eggs laid in sandy-loam ; eggs laid 4.0-6.5 cms. below soil-surface. Egg-laying occurring in Dehra Dun from 3rd week July to 2nd week September (maximum in 1st week August).

7. *Hieroglyphus nigrorepletus* Bolivar

(Text-fig. 6 a-c)

Husain and Roonwal (1933) studied the egg-structure and micropylar apparatus of this species, while Roonwal (1945) studied other aspects in its life-history. I have studied, only the composition of egg-pod and the period of egg-laying in the insectary in Dehra Dun.

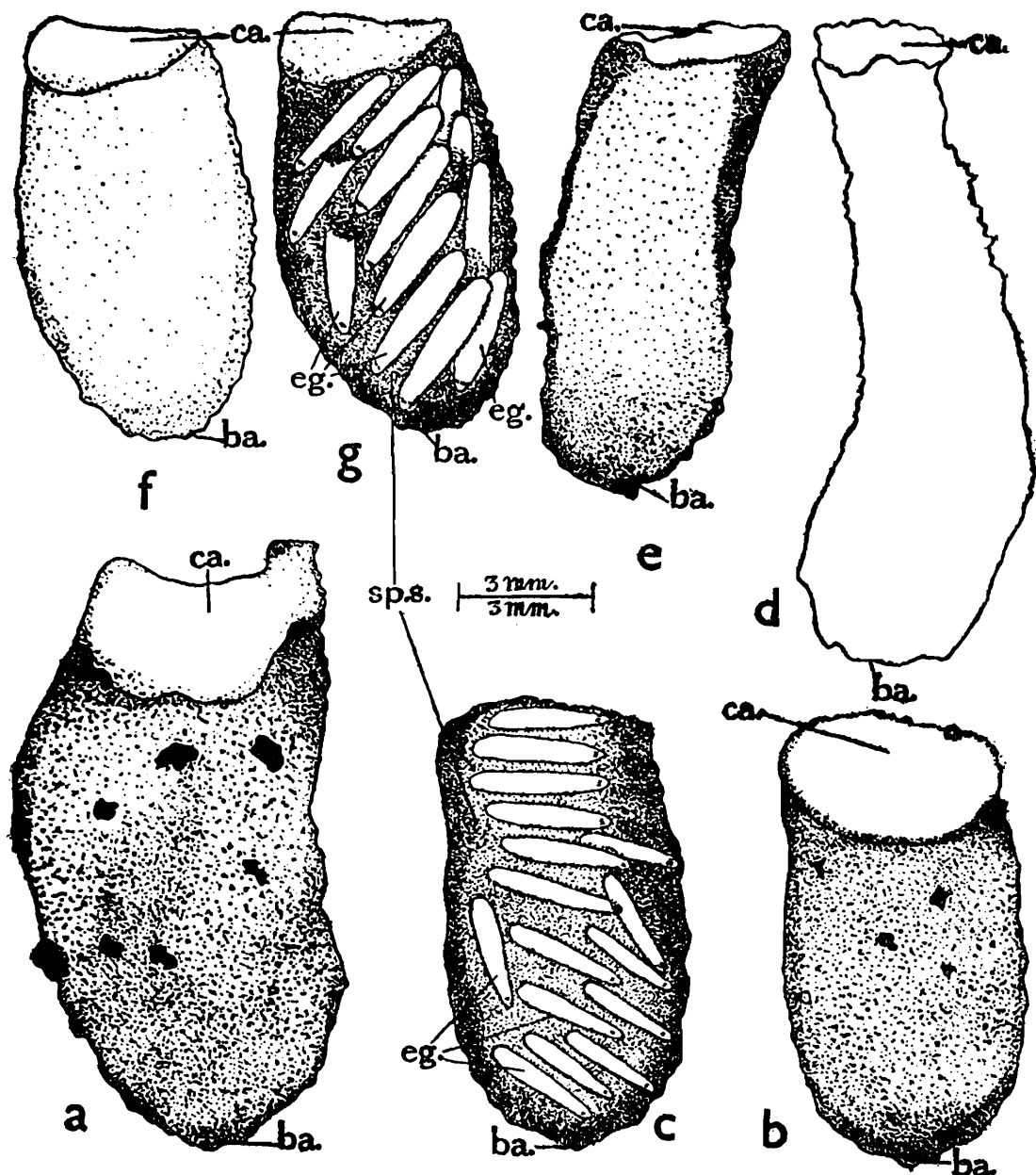
Egg-pod similar to *H. concolor* (see above), with a definite hard, smooth, concave cap ; hard cement-like, dark brown secreted material above and around eggs.

Egg-laying : In insectary, eggs laid in sandy-loam ; eggs laid 3.8-7.2 cms. below soil-surface ; sometimes dropped either on the glass chimney or on soil-surface. Egg-laying occurring in Dehra Dun from 30th July to 4th December (in 1953).

8. *Hieroglyphodes assamensis* Uvarov

(Text-fig. 6 f-g)

General : One egg-pod examined. Pod very rough and hard ; short, globular or broad in middle ; base round ; apex flat, provided with a hard concave cap above eggs. Length of pod 1.6-1.7 cms. ; width 0.8-1.7 cms. Outer wall sand coloured ; internally, secreted material above and around eggs dark brown. Outer wall consisting of very hard, cemented material similar to *H. concolor* in all respects, except hard mass above cap absent.



TEXT-FIG. 6.—Eggs and egg-pods of *Hieroglyphus nigrorepletus* Bolivar, *Hieroglyphodes assamensis* Uvarov and *Hieroglyphus banian* Fabricius.

(a) Entire egg-pod of *Hieroglyphus nigrorepletus* abnormal size. (b) Same, normal size. (c) Same, with the wall partly removed from lateral side to show arrangement of eggs. (d) Entire egg-pod of *Hieroglyphus banian* (from Dehra Dun). (e) Same, another. (f) Entire egg-pod of *Hieroglyphodes assamensis*. (g) Same, with the wall partly removed from lateral side to show arrangement of eggs.

ba., base of egg-pod ; *ca.*, cap of egg-pod ; *eg.*, egg ; *sp. s.*, spongy secretion in between eggs.

With about 28 eggs in a pod ; eggs arranged in a slanting position and slanting towards pod-wall (Text-fig. 6 g), with the micropylar end down.

Eggs : Length, 5.2-5.95 mm. ; width, 1.1-1.35 mm. Thick, sub-cylindrical, swollen in middle ; both anterior and posterior ends semi-round ; dark brown.

Egg-laying : In insectary, eggs laid in sandy-loam ; eggs laid 7.2 cms. below soil-surface. Egg-laying observed in one case only (4th August, 1953) in Dehra Dun.

9. Parahieroglyphus bilineatus Bolivar

(Text-fig. 7 e-h)

General : Eighty egg-pods examined. Pods very hard and rough ; short, straight globular ; base round ; apex flat, provided with a hard, smooth, concave, brown cap. Length of pod, 1.2-1.45 cms. ; width, 0.45-0.58 cms. Outer wall dirty brown ; internally, the secreted material above and around eggs dark brown. Outer wall consisting of hard secretion, very rough and cement-like due to adherence of sand and small stones and sometimes a covering of grasses and leaves. Internally, top-section (1.0-1.8 cms. above the eggs) filled with hard, compressed, densely-meshed secretion ; little more than two-thirds of the remaining lower or egg-section surrounded by a similar layer of secreted material ; a thin layer of such hard material also lying in between eggs, with a thin cemented pad at base of pod.

With 28-40 eggs in a pod. Eggs near base arranged vertically at right angles to base ; remaining eggs tending to slope towards pod-wall (Text-fig. 7 f, g).

Eggs : Length, 3.8-4.5 mm. ; width, 0.9-1.2 mm. Thick, sub-cylindrical ; usually bent in middle, sometimes near at the micropylar end ; anterior pole rounded ; tapering from micropylar region towards posterior pole ; brownish yellow to dark brown.

Egg-laying : In insectary, eggs laid in sandy-loam ; in field, in sandy soil ; eggs laid 3.0-7.2 cms. below soil-surface. Egg-laying occurring in Dehra Dun from 2nd week August to 1st week October.

10. Spathosternum prasiniferum Walker

(Text-fig. 4 e-g)

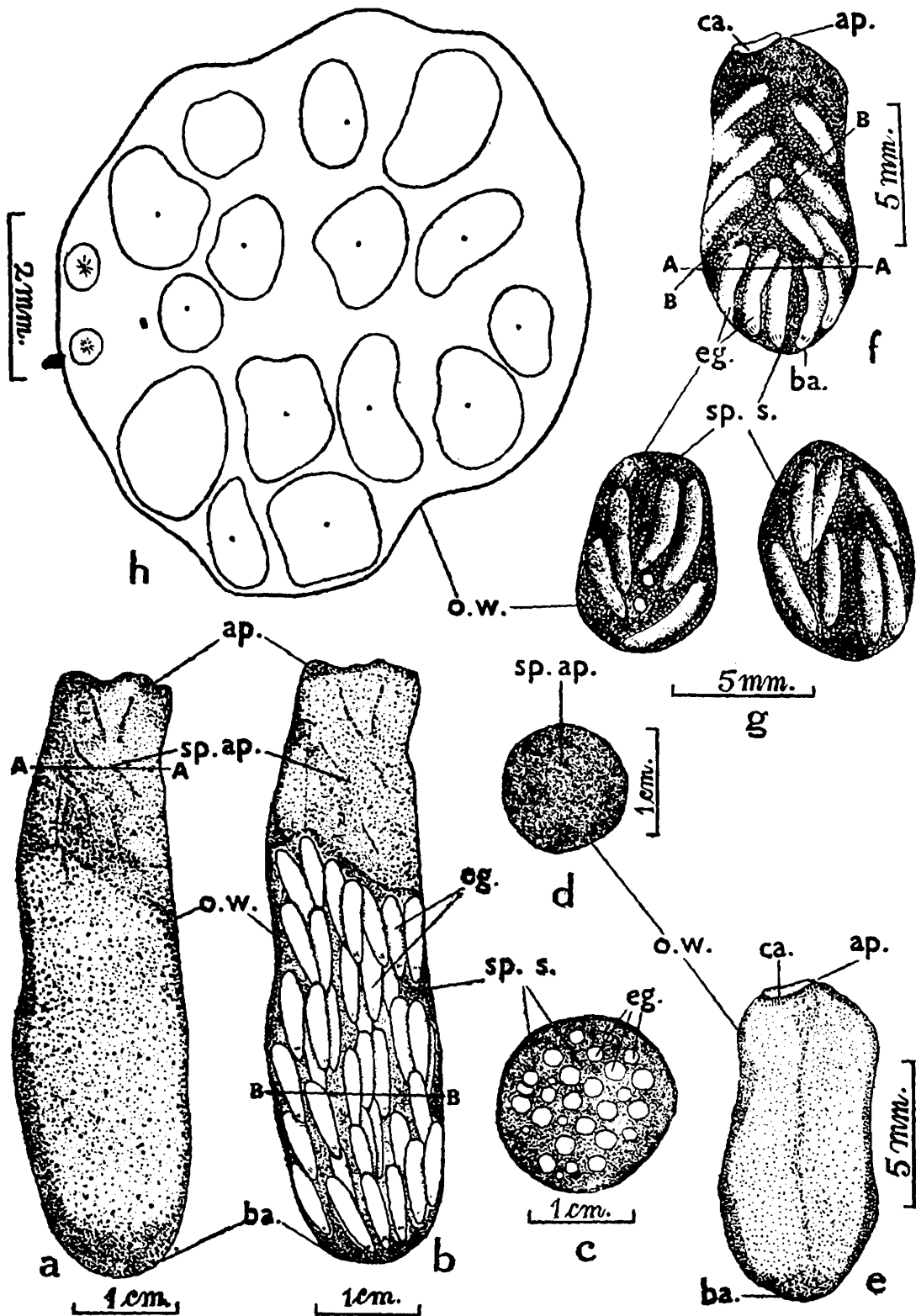
General : Fifty-five egg-pods examined. Pods rough, not fragile but spongy ; very short, irregular in shape, either straight or bent in middle ; base usually broad and round ; sometimes swollen in middle ; apex subconical or conical, provided with a thin membranous concave, ash-gray cap. Length, 0.59-1.7 cms. ; width, 0.4-0.5 cms. Outer wall earth-coloured ; internally, spongy material above eggs shiny pale green, around eggs yellowish green. Outer wall consisting of compressed thin layer of spongy secretion very thin near top, quite thick at the base and rough due to adherence of fine sand particles and bits of stones. Internally, one-third of top section filled with spongy material, with clear, hexagonal spaces or cells ; two-thirds of the remaining lower or egg-section surrounded by a similar thin layer of spongy material coarse-meshed, with no clear hexagonal spaces ; lining of secreted spongy mass in between eggs seen only here and there ; but a thick spongy pad at base of pod always present.

With 17-28 eggs in a pod. On convex (outer) side, eggs arranged vertically at right angles to the base in rows of twos near base, threes in middle and again twos at upper level ; on concave (hollow) side, eggs tending to slope towards the pod-wall.

Eggs : Length, 3.5-4.7 mm. ; width, 1.15-1.35 mm. ; thin, subcylindrical, straight or slightly curved.

Egg-laying : In insectary, eggs laid in sandy-loam ; in field, in damp sandy-loam along irrigation channels and banks of canals ; eggs laid 2.0-3.5 cms. below soil-surface. Egg-laying occurring in Dehra Dun

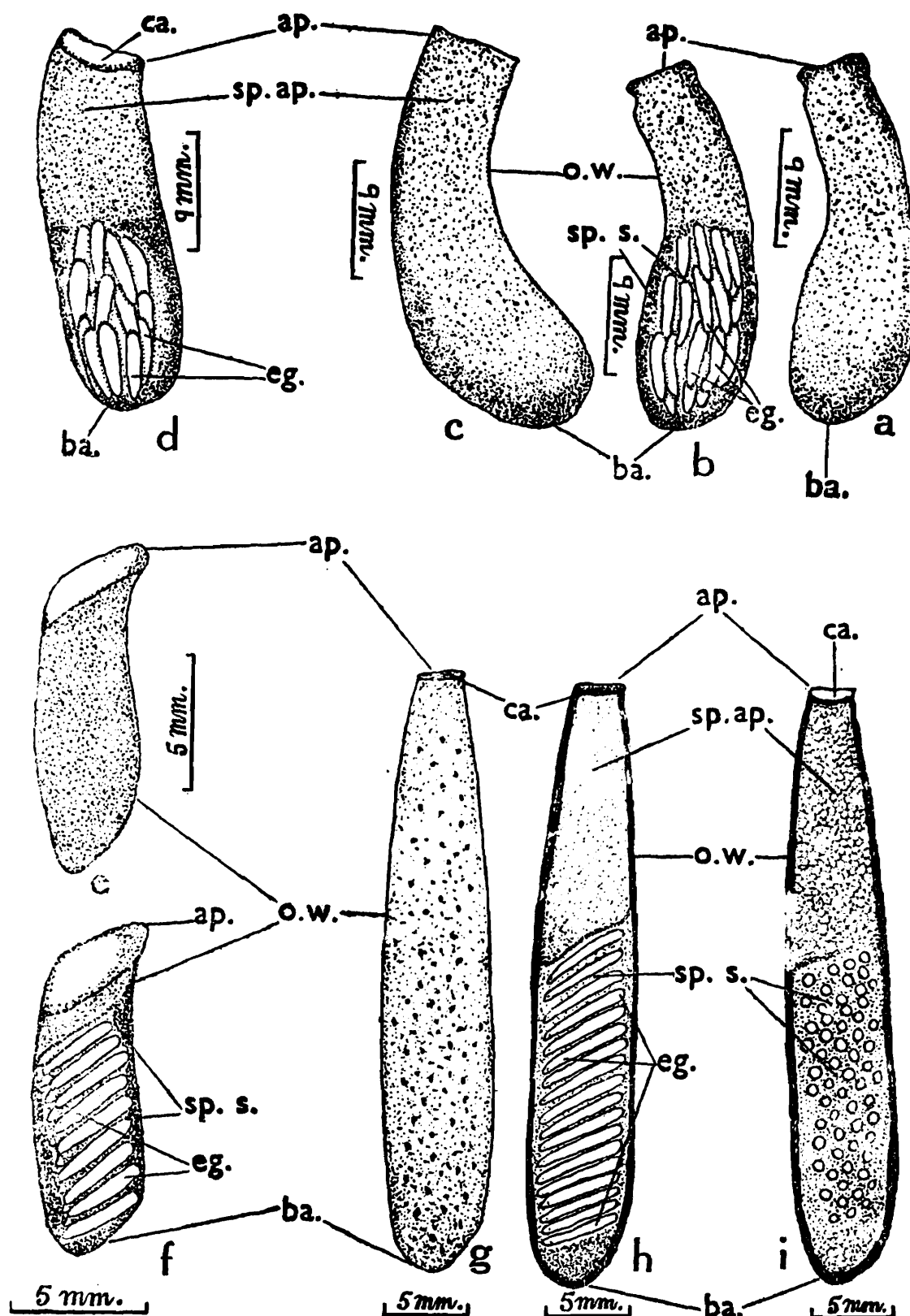
from 1st week May to 3rd week August (sometimes upto 1st week September), in insectary.



TEXT-FIG. 7.—Eggs and egg-pods of *Aularches punctatus* Drury and *Parahieroglyphus bilineatus* Bolivar.

(a). Entire egg-pod of *Aularches punctatus*. (b). Same, with the wall partly removed from lateral side to show arrangement of eggs. (c). Transverse section of egg-pod of *A. punctatus* across lower line (B-B) in Fig. b. (d). Same, across upper line (A-A) in Fig. a. (e). Entire egg-pod of *Parahieroglyphus bilineatus*. (f). Same, with the wall partly removed from lateral side to show arrangement of eggs. (g). Arrangement of eggs of *P. bilineatus* shown in two planes of the pod broken through the line (B-B) in Fig. f. (h). Transverse section of egg-pod of *P. bilineatus* across lower line (A-A) in Fig. f.

ap., apex of egg-pod ; ba., base of egg-pod ; ca., cap of egg-pod ; eg., egg ; o.w., outer wall of egg-pod ; sp. ap., spongy secretion at apex of egg-pod ; sp. s., spongy secretion in between eggs.



TEXT-FIG.8.—Eggs and egg-pods of *Xenocatantops humilis humilis* Serville, *Oedaleus abruptus* Thunberg and *Acrida gigantea* Herbst.

(a). Egg-pod of *Xenocatantops humilis humilis*. (b). Same, with the wall partly removed from lateral side to show arrangement of eggs. (c). Same, typical type. (d). Same, with the wall partly removed from convex side to show arrangement of eggs. (e). Entire egg-pod of *Oedaleus abruptus*. (f). Same, with the wall partly removed from lateral side to show arrangement of eggs. (g). Egg-pod of *Acrida gigantea*. (h). Same, with the wall partly removed from lateral side to show arrangement of eggs. (i). Vertical section of egg-pod of Fig. g.

ap., apex of egg-pod ; ba., base of egg-pod ; ca., cap of egg. ; eg., egg ; o.w., outer wall of egg-pod ; sp. ap., spongy secretion at apex of egg-pod ; sp. s., spongy secretion in between eggs.

11. *Xenocatantops humilis humilis* Serville(Text-fig. 8 *a-d*)

General : Twenty-eight egg-pods examined. Pods rough, fragile, spongy, short, broad, straight or curved in middle (almost C-shaped) ; base round ; apex ending abruptly, flat and without any cap. Length of pod 1.7-2.8 cms. ; width 0.5-0.6 cm. Outer wall dirty clay coloured ; internally, almost all frothy mass above eggs pinkish white, and around eggs light brown to brownish ash. Outer wall consisting of thin, frothy secretion, rough, due to adherence of fine sand particles and bits of stones. Internally, half of top section filled with frothy, fragile, secretion ; half of the remaining lower or egg-section surrounded by coarse-meshed, thick, frothy pad ; lining of secreted material in between eggs almost absent.

With 23-31 eggs in a pod. Eggs usually arranged vertically at right angles to the base one above the other ; at top a few eggs tending to slope a little towards pod-wall (Text-fig. 8 *b, d*).

Eggs : Length, 3.7-4.2 mm. ; width, 0.8-1.2 mm. Thin, cylindrical, straight ; a bit swollen and round at the anterior pole, subconical at the posterior.

Egg-laying : In insectary, eggs laid in sandy-loam ; in field, in light soil under shade of trees and bushes ; eggs laid 4.5-6.3 cms. below soil-surface. Egg-laying occurring in Dehra Dun from last week August to last week October.

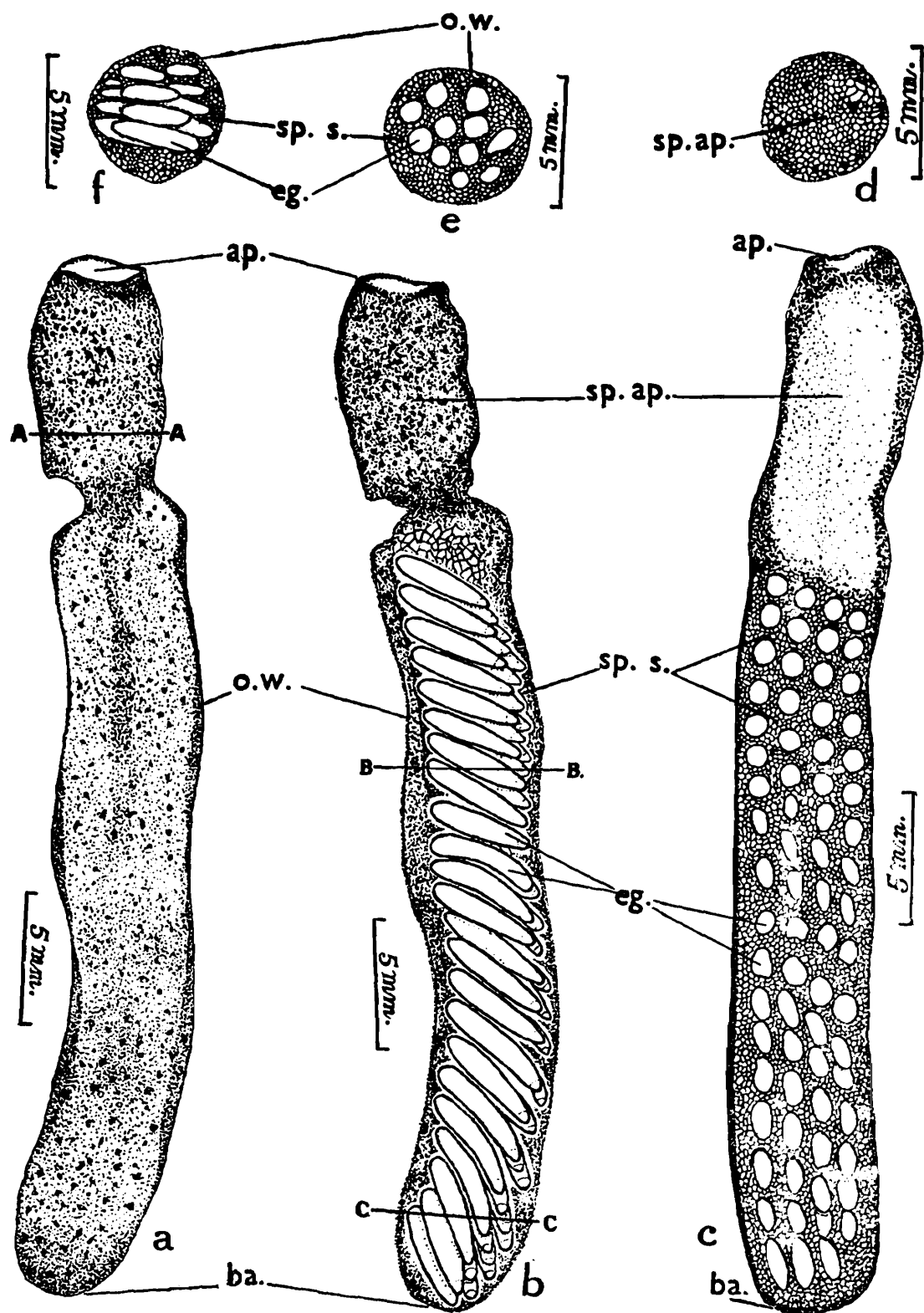
Subfamily (iii) *OEDIPODINAE*12. *Gastrimargus transversus* Thunberg(Text-fig. 9 *a-f*)

General : Twelve egg-pods examined. Pods long, elongated, straight, sometimes bent at base ; base round ; in 9 out of 12 pods examined, a constriction present near the top ; apex flat, provided with a small lid or cap. Length of the pod 3.9-4.8 cms. (in one case 5.7 cm.) ; width 0.45-0.6 cm. Outer wall pink to pinkish brown ; internally, frothy mass above eggs, salmon white, and around eggs pinkish brown. Outer wall consisting of a compressed layer of frothy secretion, thin near the top, thick at the base ; rough, due to adherence of fine sand particles and sometimes fragments of leaves. Internally, one-third of top section filled with finely-meshed frothy secretion ; two-thirds of the remaining lower or egg-section surrounded by compressed thin layers of fragile froth.

With 69-94 (mostly 83-85) eggs in a pod. Eggs arranged obliquely one above the other, and sloping towards the pod-wall, with nearly 16-18 eggs seen on two sides only.

Eggs : Length, 4.6-5.15 mm. ; width, 1.0-1.1 mm. ; thin, straight ; subconical at the anterior pole, tapering from micropylar ring to extremity at the posterior pole ; yellowish pink.

Egg-laying : In insectary, eggs laid in sandy-loam ; in field, in clayey soil ; eggs laid 3.8-6.4 cms. (in one case 7.5 cms.) below soil-surface. Egg-laying occurring from 2nd week June to 1st week September.



TEXT-FIG. 9.—Eggs and egg-pods of *Gastrimargus transversus* Thunberg.

(a). Entire egg-pod. (b). Same, with the wall partly removed from lateral side to show arrangement of eggs. (c). Vertical section of egg-pod of Fig. b. (d). Transverse section of egg-pod across upper line (A-A) in Fig. a. (e). Same, across middle line (B-B) in Fig. b. (f). Same, across lower line (C-C) in Fig. b.

ap., apex of egg-pod ; ba., base of egg-pod ; ca., cap of egg-pod ; eg., egg ; o.w., outer wall of egg-pod ; sp. ap., spongy secretion at apex of egg-pod ; sp. s., spongy secretion in between eggs.

13. *Oedaleus abruptus* Thunberg

(Text-fig. 8 e-f)

General : Five egg-pods examined. Pods rough, fragile, short ; bent at both ends ; base subconical ; apex conical or flat. Outer wall dirty yellowish ; internally, frothy mass above and around eggs yellowish white. Outer wall consisting of very thin compressed layer of fragile froth. Internally, one-third of top-section filled with finely-meshed froth ; two-thirds of the remaining lower or egg-section surrounded by thin layer of frothy secretion, lining of secreted material in between eggs wanting.

With 18-27 eggs in a pod. Eggs arranged obliquely and sloping towards pod-wall.

Eggs: Length, 3.25-4.15 mm.; width, 0.85-0.95 mm.; thin, long, slender, straight, swollen and round at the anterior pole ; tapering from micropylar ring to extremity at the posterior pole ; dirty yellowish.

Egg-laying: In field eggs laid in hard soil along edges of gardens, tennis lawns, etc. ; eggs laid 2.5-3.5 cms. below soil-surface. Egg-laying occurring in Dehra Dun from 3rd week June to last week September.

Subfamily (iv) *PYRGOMORPHINAE*14. *Aularches punctatus* Drury

(Text-fig. 7 a-d)

General: Seventeen egg-pods examined. Pods very smooth, fragile, long, cylindrical ; almost all straight, sometimes bent in middle ; base wide and round ; apex usually flat, sometimes subconical and without any cap at top. Length of the pod 5.2-9.0 cms. ; width, 1.2-1.9 cms. Outer wall dirty pink ; internally, apical frothy mass pink and about 2.0-2.5 cms. high ; below this, the froth dark pink. Outer wall consisting of thin, smooth layer of froth. Internally, approximately one-third of top-section filled with fragile frothy material composed of hexa- or septagonal empty spaces or cells ; two-thirds of the remaining lower or egg-section surrounded by very thin coarsely-meshed froth with clear empty spaces. A thin layer of secreted material also lying in between eggs, with a thick frothy pad at base of pod always present.

With 96-120 eggs in a pod. Eggs arranged vertically at right angles to the base, and lying one above the other (Katiyar, 1955). One or two eggs near top tending to slope towards pod-wall (Text-fig. 7 b).

Eggs: Length, 7.0-7.25 mm.; width, 1.8-2.0 mm. Thin, subcylindrical, straight; anterior pole round ; posterior pole tapering from micropylar ring but flat at extremity; translucent yellow in ovaries, yellow after oviposition, and later on changing to dark brown.

Egg-laying : In insectary, eggs laid in sandy-loam ; eggs laid 6.2-7.4 cms. below soil-surface ; in field also in sandy-loam, and especially damp places ; if such places not available, the female not ovipositing at all, but dying without doing so, eggs laid in field 2.5-7.8 cms. below soil-surface. Egg-laying occurring in insectary, in Dehra Dun, from 15th September to 14th October ; in the field around Dehra Dun, from 10th September to 1st October mostly during 2nd week September.

KEY TO THE IDENTIFICATION OF EGG-PODS OF SOME INDIAN ACRIDIDAE

- 1 (8) Outer wall composed of cemented sandy material. Pods with a definite concave cap.
- 2 (7) The concave cap of the pod always concealed with cemented concretion (this cap is visible when concretion is removed).
- 3 (4) Pods short and globular, about twice as long as wide (length, 1.6-1.7 cms.; width, 0.8-1.0 cms.). *Hieroglyphodes assamensis* (Text-fig. 6 f,g).
- 4 (3) Pods elongate and almost cylindrical, much more than twice as long as wide.
- 5 (6) Eggs are arranged sloping towards the pod-wall and mostly parallel to the base near the cap. *Hieroglyphus nigrореpletus* (Text-fig. 6 a-c).
- 6 (5) Eggs are arranged vertically at right angles to base at the bottom and sloping towards pod-wall near the cap. *Hieroglyphus concolor* (Text-fig. 5 a-f).
- 7 (2) The concave cap of the pod usually well exposed (at most only slightly covered with a few soil particles adhered with secreted material); length, 1.2-1.4 cms.; width, 0.45-0.58 cm. *Parahieroglyphus bilineatus* (Text-fig. 7 e-h).
- 8 (1) Outer wall hard and rough without cemented concretions and without any definite concave cap.
- 9 (12) Arrangement of eggs widely differs both on concave (hollow) and convex (outer) sides of pods, though in a standard form in either side.
- 10 (11) Pods about 4 times as long as wide (length, 1.45-1.85 cms.; width, 0.45-0.6 cms.), each pod with 14-22 eggs. *Ceracris deflorata* (Text-fig. 2 e-h).
- 11 (10) Pods about 8 times as long as wide (length, 2.7-3.8 cms.; width, 0.35-0.5 cms.) each pod with 10-18 eggs. *Eyprepocnemis roseus* (Text-fig. 4 a-d).
- 12 (9) Arrangement of eggs similar both on concave and convex sides.
- 13 (24) Eggs arranged in one standard form either in an oblique or vertical style (in latter case, at most slightly different only at the upper level of eggs); without any cap.
- 14 (19) Eggs arranged obliquely one above the other, sloping towards pod-wall.
- 15 (18) Pod rough ; base round.
- 16 (17) Outer wall of pod dirty brownish-white; frothy mass above and around eggs light brown (length, 2.8-4.4 cms.; width, 0.55-0.65 cm.; 52-65 eggs in a pod). *Acrida gigantea* (Text-fig. 8 g-i).
- 17 (16) Outer wall of pod pink or pinkish brown ; frothy mass above eggs salmon-white and around eggs pinkish-brown (length, 3.9-4.8 cms.; width, 0.45-0.6 cm.; 69-94 eggs in a pod). *Gastrimargus transversus* (Text-fig. 9 a-f).
- 18 (15) Pod smooth ; base subconical (outer wall dirty yellowish ; frothy mass above and around eggs yellowish white ; length, 1.1-1.75 cms.; width, 0.35-0.5 cm.; 18-27 eggs in a pod). *Oedaleus abruptus* (Text-fig. 8 e,f).
- 19 (14) Eggs arranged vertically at right angles to base of pod.
- 20 (23) Pod throughout smooth or rough near base and smooth near apex.
- 21 (22) Pod throughout smooth ; outer wall dirty pink, frothy mass dark-pink (length, 5.2-9.0 cms.; width, 1.2-1.9 cms.; 81-120 eggs in a pod). *Aularches punctatus* (Text-fig. 7 a-d).

- 22 (21) Pod rough near base and smooth near apex ; outer wall dirty-clayey ; frothy mass yellowish white to light brown (length, 4.8-7.4 cms.; width, 1.1-1.38 cms.; 63-93 eggs in a pod). *Choroedocus insignis* (Text-fig. 3 a-g).
- 23 (20) Pod throughout rough (outer wall dirty-clayey ; frothy mass pinkish white to brownish ash ; length, 1.7-2.8 cms.; width, 0.5-0.6 cm.; 23-31 eggs in a pod). *Xenocatantops humilis humilis* (Text-fig. 8 a-d).
- 24 (13) Arrangement of eggs not in one standard form. Provided with membranous cap.
- 25 (26) Eggs arranged in 2-3 rows sloping towards the pod-wall. 8-9 eggs visible in one plane on either the concave (hollow) side or the convex (bulging) side of pod (outer wall dirty brown or pink ; frothy mass above pale clay yellow and around eggs pinkish brown ; length, 1.9-2.85 cms.; width, 0.4-0.6 cm.; 22-32 eggs in a pod). *Phlaeoba panteli* (Text-fig. 2 a-d).
- 26 (25) Eggs arranged vertically at right angles to the base in 2 rows near base, threes in middle and twos at upper level on convex (bulging side), eggs tending to slope towards pod-wall on concave or hollow side. (Outer wall earth coloured ; frothy mass above eggs shiny pale green and around eggs yellowish green ; length, 0.59-1.7 cms.; width, 0.4-0.5 cm.; 17-28 eggs in a pod). *Spathosternum prasiniferum* (Text-fig. 4 e-g).

V—STRUCTURE OF EGG-CHORION

(a) General

Very little is known about the sculpturing of the egg-chorion of the short-horned grasshoppers (family, Acrididae) of India. Some suggestions for the study of the egg-sculpturing of Acrididae were made by Plotnikov (1911, 1926) and by Uvarov (1928) who remarked that sculpturing might be of considerable importance in the identification of Acrididae. Husain and Roonwal (1933) studied the micropylar apparatus and chorionic sculpturing in some Indian species. Zimin (1935, 1938) studied the chorion of some Russian species and Morales Agacino (1951) of a few Spanish species. Roonwal, who studied in detail the egg-sculpturing of the Desert Locust, *Schistocerca gregaria* Forskal (1954b), and of the African Migratory Locust, *Locusta migratoria migratorioides* R. & F. (1936, 1954a), has concluded that there are two types of egg-walls in the Acrididae as regards chorionic sculpturing.

Chorionic sculpturing shows interesting characteristic structures which help in distinguishing eggs of different species of Acrididae and a study of this is, therefore, of much practical value for the systematists of the family. The present account deals with the egg-sculpturing of 10 Indian species.

For this study, freshly laid eggs were cleansed with water, then treated with 1-4 per cent KOH for a few hours and washed with water. Both the anterior and the posterior poles as well as the middle portion of the egg-chorion were cut off, cleansed of yolk, etc., stained with eosin (in alcohol) and a permanent balsam mount made on a slide. The following readings of the micropylar canals have been taken for each species :— (i) Total length of micropylar canals from mouth (outer opening) to the fine pore (inner opening) ; (ii) width of the mouth (outer opening) of the canal.

(b) *Structure of the egg-chorion*

The egg-chorion of the following 10 species was studied :—

Subfamily *ACRIDINAE*

1. *Acrida gigantea* Herbst
2. *Ceracris deflorata* Brunner
3. *Phlaeoba panteli* Bolivar

Subfamily (ii) *CATANTOPINAE*

4. *Choronedocus insignis* Thunberg
5. *Eyprepocnemis roseus* Uvarov
6. *Parahieroglyphus bilineatus* Bolivar
7. *Xenocatantops humilis humilis* Serville

Subfamily (iii) *OEDIPODINAE*

8. *Gastrimargus transversus* Thunberg

Subfamily (iv) *PYRGOMORPHINAE*

9. *Aularches miliaris* Linnaeus (Material from Ceylon)
10. *Aularches punctatus* Drury

The following is a description of the chorionic sculpturing. The egg has been divided for this purpose into 3 parts, viz., the anterior pole, the middle portion and the posterior pole.

Subfamily (i) *ACRIDINAE*1. *Acrida gigantea* Herbst

(Text-fig. 10 a-e)

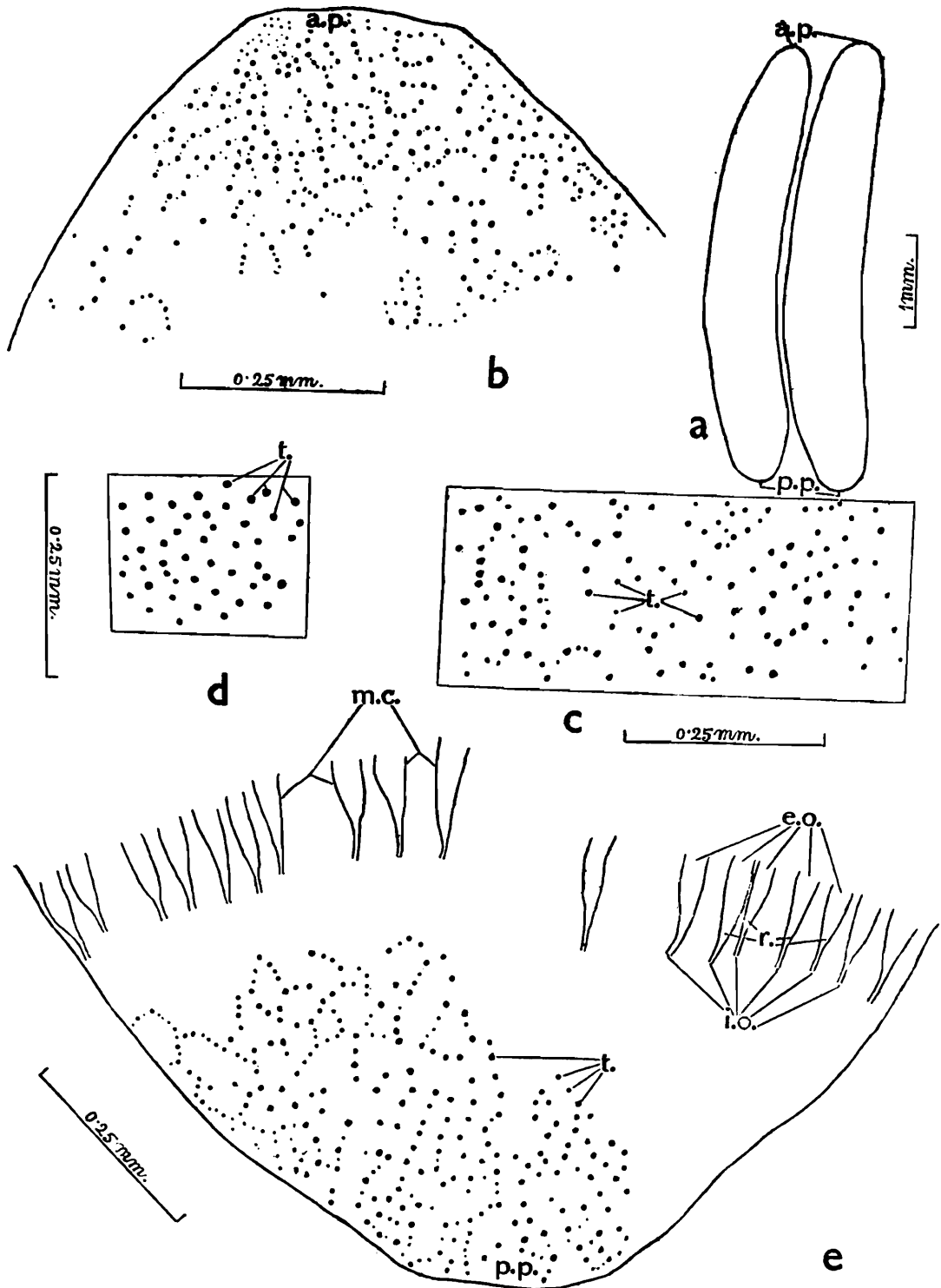
Anterior pole (Text-fig. 10 b).—Chorion of the anterior pole shows a large number of small round, dot-shaped tubercles, which differ greatly in size ; tubercles arranged in irregular pentagonal and hexagonal patterns, though definite ridges are absent.

Middle chorion (Text-fig. 10 c-d).—Middle chorion showing a number of rounded, dot-shaped tubercles but comparatively bigger than those present at either of the poles ; more distinctly and sharply of pentagonal and hexagonal.

Posterior pole (Text-fig. 10 e).—Sculpturing at this pole similar to that of anterior pole, except that the tubercles bigger than those at anterior pole and smaller than those in the middle region. Besides this, a ring of micropylar canals ; 41-52, pipette-shaped canals present which narrow down abruptly to form a fine tubular portion. The canals measure as follows :—

Total length : 100-140 μ (average 118 μ).

Width of mouth: 20-40 μ (average 29 μ).

TEXT-FIG. 10.—Egg-wall of *Acrida gigantea* Herbst.

(a). Two eggs in side view. (b). Surface view of the egg-wall near the anterior pole of the egg showing tubercles making polygons. (c). Surface view of chorion from the middle of egg showing different types of rounded tubercles. (d). Same, more enlarged. (e). Surface view of the egg-wall near the posterior pole of an egg showing the ring of micropylar canals. Note presence of tubercles.

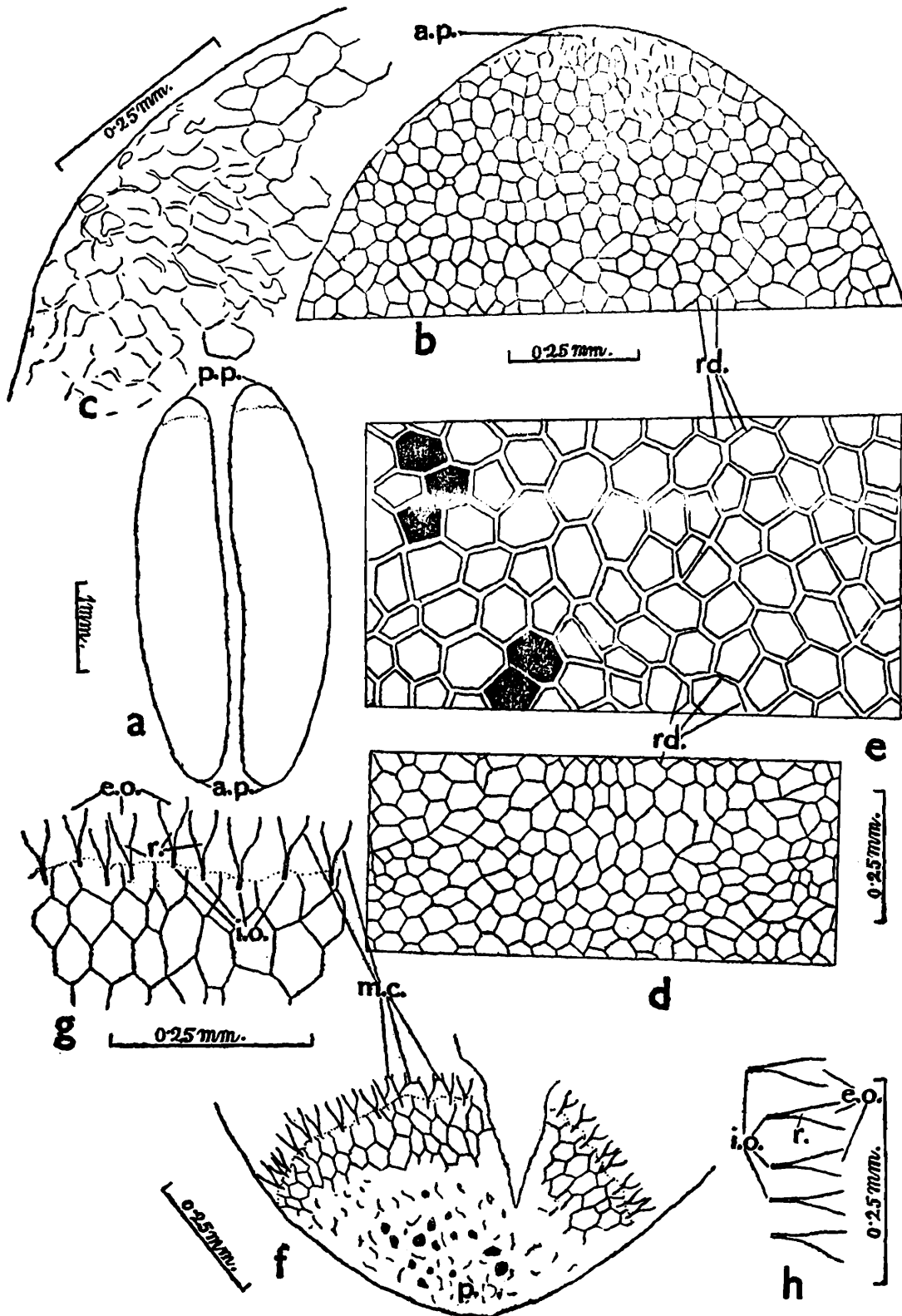
ap., anterior pole of egg ; *e.o.*, external opening of micropylar canal ; *i.o.*, internal opening of micropylar canal ; *m.c.*, micropylar canal ; *p.p.*, posterior pole of egg ; *r.*, roof of micropylar canal ; *t.*, tubercles or protuberances of endochorion of egg-wall.

2. *Ceracris deflorata* Brunner

(Text-fig. 11 *a-h*)

Anterior pole (Text-fig. 11 *b,c*).—Anterior pole presenting a mosaic pattern of pentagonal and hexagonal polygons outlined by ridges of the endochorion, but tubercles absent. At the extremity of the pole, however, no definite pattern except for a few scattered ridges or lines.

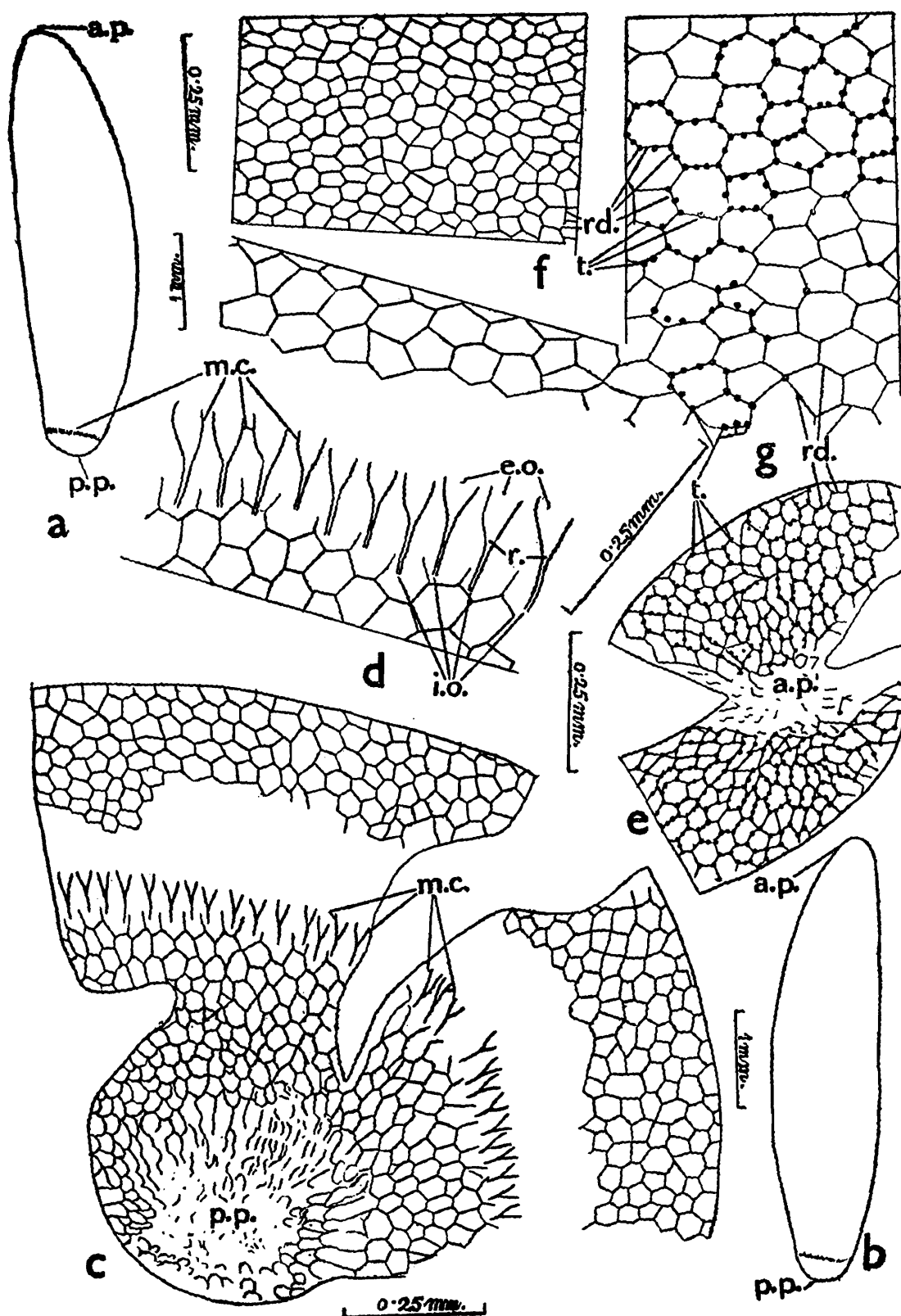
Middle chorion (Text-fig. 11 *d, e*).—Here again the sculpturing showing the mosaic pattern of pentagonal and hexagonal cells outlined by definite straight ridges. The spaces enclosed by the ridges appearing



TEXT-FIG. 11.—Egg-wall of *Ceracris deflorata* Brunner.

(a). Two eggs in side view. (b). Surface view of egg-wall near anterior pole of egg. Note absence of "dots" (cf. posterior pole). (c). Same, at anterior pole enlarged. (d). Surface view of the chorion from the middle portion of egg. (e). Same, enlarged, showing ridges and polygonous areas. (f). Surface view of egg-wall near the posterior pole, showing the micropylar canals and the sculpturing. Note "dots" at the pole (cf. anterior pole). (g). Surface view of a portion of egg-wall at posterior pole. enlarged. (h). Surface view of 5-micropylar canals enlarged.

a.p., anterior pole of egg ; *e.o.*, external opening of micropylar canal ; *i.o.*, internal opening of micropylar canal ; *m.c.*, micropylar canal ; *p.p.*, posterior pole of egg ; *r.*, roof of micropylar canal ; *rd.*, ridges of endochorion of egg.

TEXT-FIG. 12.—Egg-wall of *Phlaeoba panteli* Bolivar.

(a) and (b). Eggs in side view. (c). Surface view of egg-wall near the posterior pole, showing the micropylar canals and sculpturing. Note absence of rounded tubercles. (d). Same, enlarged to show a few micropylar canals and their position in between egg-sculpturing. (e). Surface view of the egg-wall near anterior pole, showing sculpturing. Note presence of rounded tubercles and their arrangement. (f). Surface view of chorion from middle portion of egg. (g). Same, much enlarged to show rounded tubercles and ridges.

a.p., anterior pole of egg ; *e.o.*, external opening of micropylar canal ; *i.o.*, internal opening of micropylar canal ; *m.c.*, micropylar canal ; *p.p.*, posterior pole of egg ; *r.*, roof of micropylar canal ; *rd.*, ridges on endochorion of egg-wall ; *t.*, tubercles or protuberances of endochorion of egg-wall.

thick and translucent structures while the trabeculae between these thin and transparent as shown in an enlarged view in Fig. 11e, the thickness being shown only in a few cells shaded by small dots.

Posterior pole (Text-fig. 11 f-h).—Sculpturing here marked by the pentagonal and hexagonal cells only near and around the micropylar canals but such cells absent beyond the mouth of the canals and at the extremity of the pole. In the latter region a few thick patches present. The micropylar canals, which number about 48-51, arranged in a ring, the distances between each two canals irregular (Text-fig. 11 f) ; these more or less funnel-shaped with a fine tubular part. The canals measure as follows :—

Total length : 70-100 μ (average 86 μ).

Width of mouth : 20-40 μ (average 31 μ).

3. *Phlaeoba panteli* Bolivar

(Text-fig. 12 a-g)

Anterior pole (Text-fig. 12 b).—Chorion of anterior pole presenting a mosaic pattern of regular penta- and hexagonal cells outlined by ridges ; cells longer than broad towards extremity of the pole, and at pole itself only a few ridges present. Small dot-like tubercles present at each corner of the cells, and also in middle of the ridge joining two corners.

Middle chorion (Text-fig. 12 g).—Sculpturing showing a regular pattern of hexagonal (occasionally pentagonal) cells ; cells longer than broad ; ridges thinner than those at anterior pole ; tubercles as at anterior end, but more prominent and occasionally with two tubercles between two corners.

Posterior pole (Text-fig. 12 c-d).—A sculpturing of hexagonal cells present near the inner openings of micropylar canals but absent near the mouth ; an smooth unsculptured area present in the level of the ring of micropylar canals. Cell ridges towards extremity of pole curved instead of straight ; at the pole only a few curved or bent ridges present ; tubercles wanting. Micropylar canals funnel-shaped and similar to those of *Ceracris deflorata* but fine tubular part longer in former ; 51-62 canals present, arranged in a ring ; measurements of canals :—

Total length : 90—120 μ (average 111 μ).

Width of mouth : 30-40 μ (average 35 μ).

Subfamily (ii) *CATANTOPINAE*

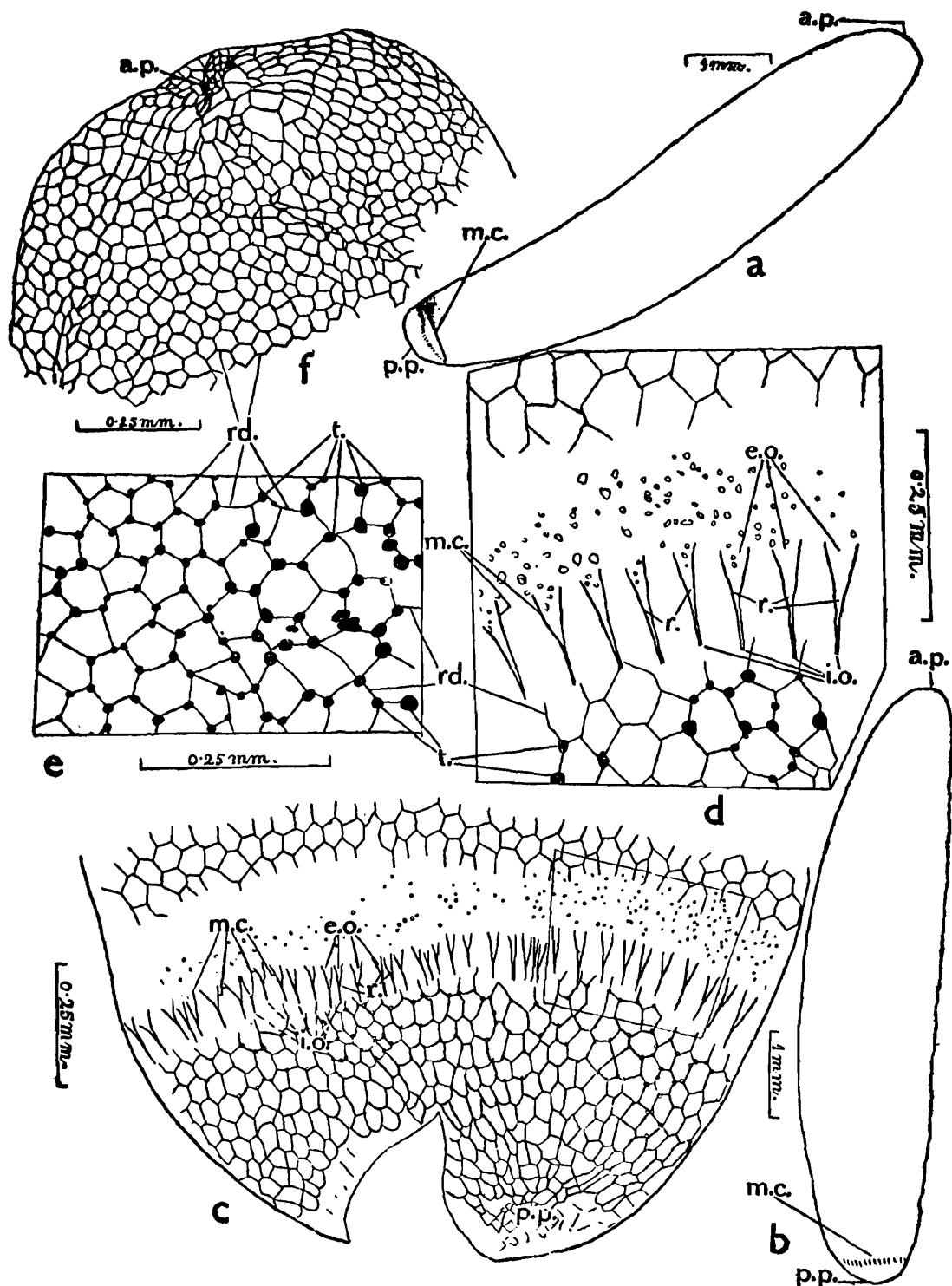
4. *Choroedocus insignis* Thunberg

(Text-fig. 13 a-f)

Anterior pole (Text-fig. 13 f).—Sculpturing at this pole presenting tetra-, penta- and hexagonal polygons, outlined by ridges. At extremity of egg only tetragonal cells present ; cells longer than broad ; at places ridges curved or bent ; tubercles wanting.

Middle chorion (Text-fig. 13 e).—Middle chorion also showing tetra-, penta- and hexagonal polygons outlined by straight ridges. Tubercles of irregular shapes ; oval, round dot-shaped, etc., appear thick translucent, at each corner of cells, and also sometimes within cells away from ridges.

Posterior pole (Text-fig. 13 c).—Sculpturing showing a mosaic pattern of penta- and hexagonal cells outlined by straight ridges near inner openings of micropylar canals, but absent near the body of canals and beyond them ; smooth unsculptured area present in the level of the



TEXT-FIG. 13.—Egg-wall of *Choroedocus insignis* Thunberg.

(a) and (b). Egg in side view. (c). Surface view of egg-wall near the posterior pole showing the ring of micropylar canals and sculpturing. Note presence of irregularly rounded tubercles. Dots towards external opening of the canals (d). Same, enlarged only a rectangular portion indicated in Fig. c, to show structure of tubercles and dots both at internal and external openings of the micropylar canals respectively. (e). Surface view of the chorion from the middle portion of egg showing ridges and tubercles of different sizes. (f). Surface view of egg-wall near the anterior pole, showing different sculpturing than at posterior pole. Note absence of tubercles.

a.p., anterior pole of egg ; e.o., external opening of micropylar canal ; i.o., internal opening of micropylar canal ; m.c., micropylar canal ; p.p., posterior pole of egg ; r., roof of micropylar canal ; rd., ridges of endochorion of egg-wall ; t., tubercles or protuberances of endochorion of egg-wall.

micropylar canals as in *Phlaeoba panteli*. In former small, rounded, dot-shaped structure present in smooth unsculptured area beyond the mouth of micropylar canals, absent in latter. At extremity of pole, penta- and hexagonal cells present, longer than broad ; ridges curved. Dot-shaped tubercles thin, transparent, present at each corner of cells near inner openings of canals ; tubercles wanting at extremity. Micropylar canals funnel-shaped ; narrow down to form a fine long tubular portion ; 34-38 canals present ; measurements of canals :—

Total length : 110-150 μ (average 132 μ).

Width of mouth : 20- 40 μ (average 34 μ).

5. *Eyprepocnemis roseus* Uvarov

(Text-fig. 14 *a-h*)

Anterior pole (Text-fig. 14 *g-h*).—A mosaic pattern of small penta- and hexagonal cells ; elongated towards extremity of pole ; cells outlined by straight ridges ; ridges vary in length. Small, rounded, knob-like tubercles present within cells, visible in magnified view only.

Middle chorion (Text-fig. 14 *e-f*).—Sculpturing showing penta- and hexagonal cells similar to that of anterior pole, except that tubercles present at each corner of cells unlike at anterior pole where tubercles present within cells.

Posterior pole (Text-fig. 14 *b-d*).—A mosaic pattern of penta- and hexagonal cells at extremity of pole. An smooth unsculptured area present beyond ring of micropylar canals, only with very small granules inside and just above mouth of micropylar canals. Small, rounded, knob-shaped tubercles present at each corner of the cells at the extremity of pole ; only one or two tubercles present here and there near inner openings of micropylar canals. Micropylar canals funnel-shaped, each tapers gradually into a fine narrow pore ; 41-56 canals present, arranged in a ring ; measurements of canals :—

Total length : 120-180 μ (average 130 μ).

Width of mouth : 40-70 μ (average 48 μ).

6. *Parahieroglyphus bilineatus* Bolivar

(Text-fig. 15 *a-f*)

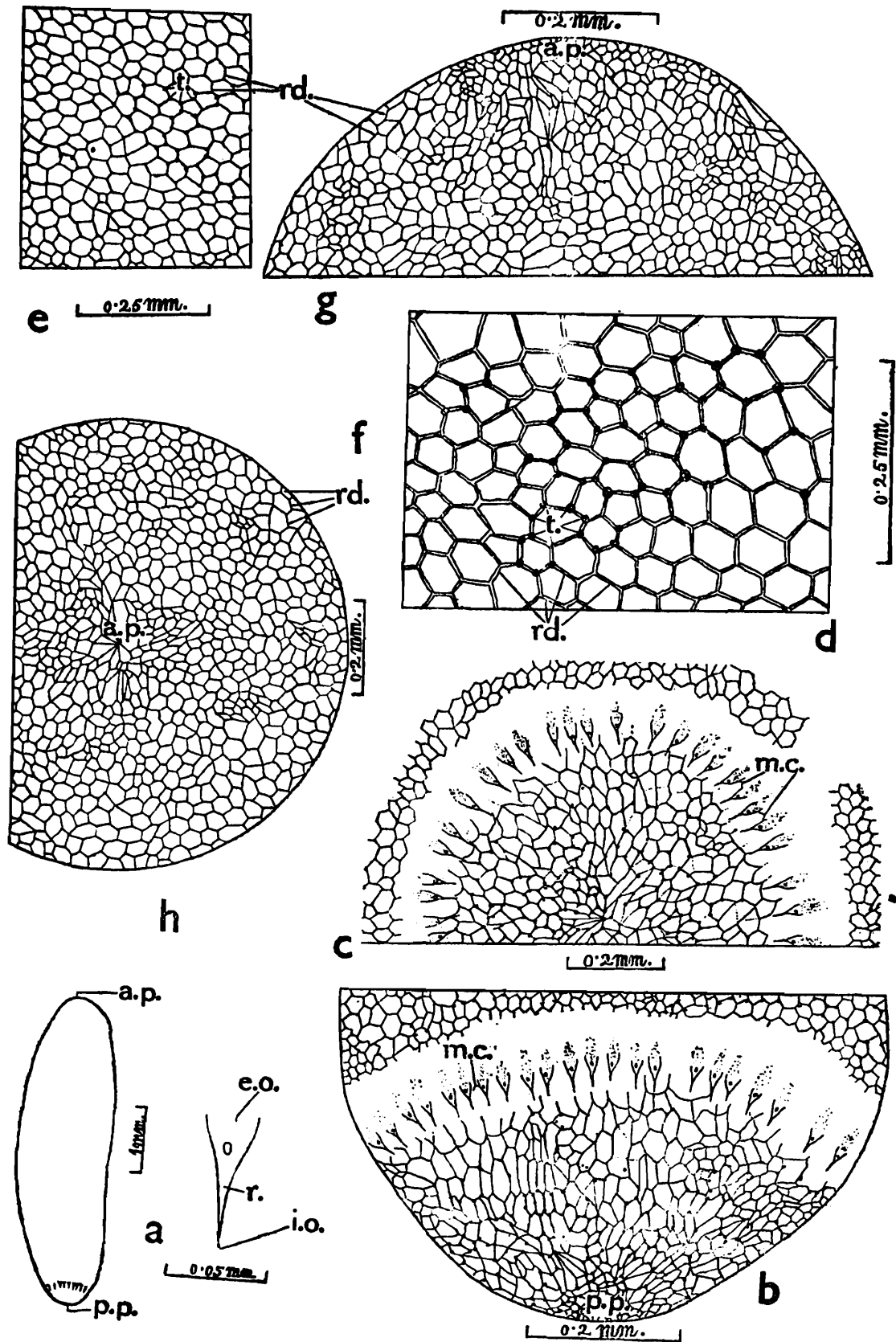
Anterior pole (Text-fig. 15 *b*).—Chorion of anterior pole showing no definite pattern of polygons outlined by ridges, but numerous, very small, dot-like, transparent tubercles scattered irregularly ; tubercles at places forming concentric or intersecting polygons.

Middle chorion (Text-fig. 15 *c*).—Here again mosaic pattern of polygons wanting as at anterior pole, but tubercles form a pattern of concentric and intersecting polygons at some places ; tubercles fewer in number than that present at both anterior and posterior poles.

Posterior pole (Text-fig. 15 *d-f*).—At this pole numerous small, dot-like transparent tubercles present in patches at extremity, a few bent or curved small lines or ridges present towards micropylar canals. Micropylar canals number 36-43 ; measurements of canals :—

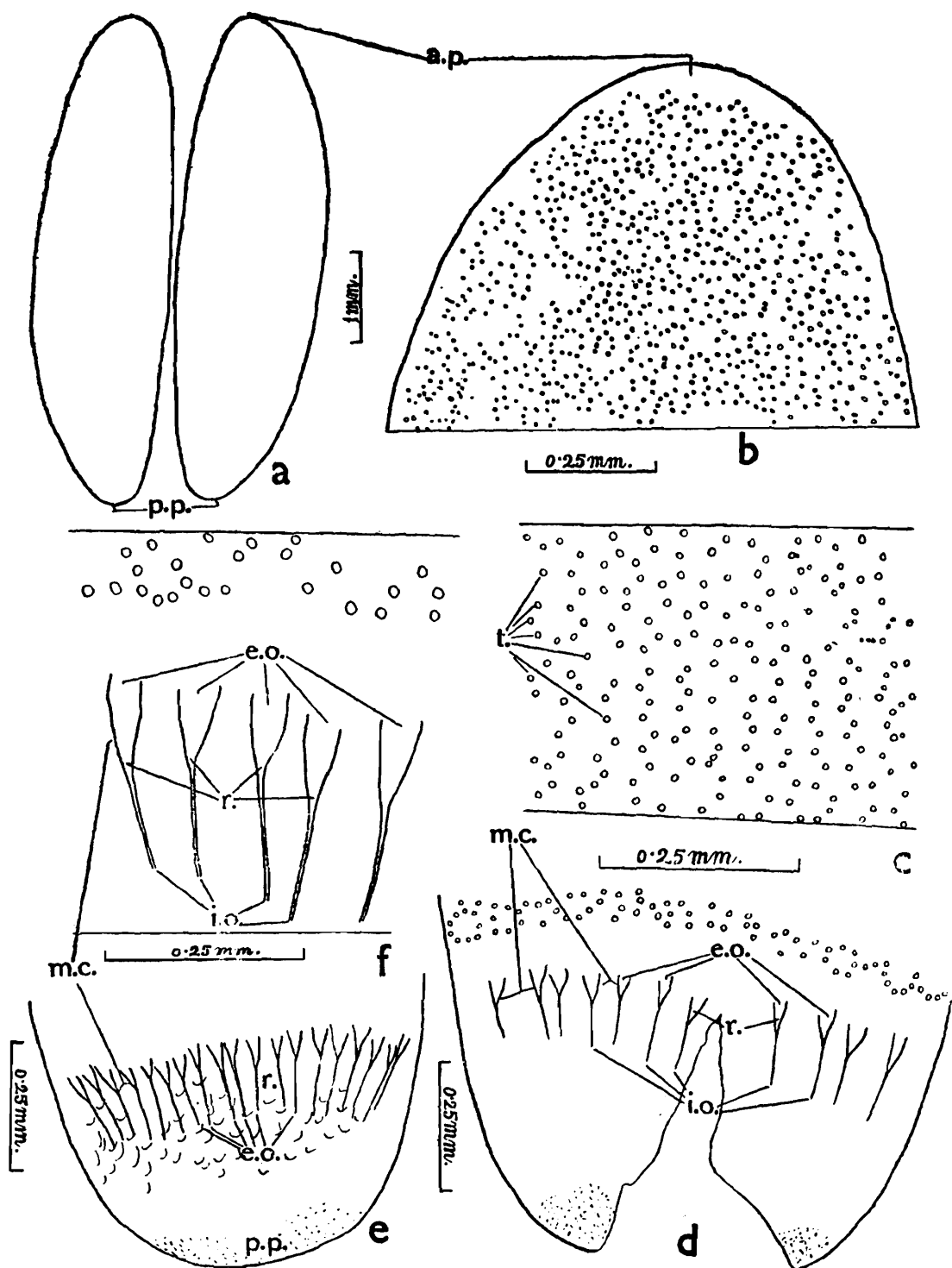
Total length : 240-260 μ (average 250 μ)

Width of mouth : 40-50 μ (average 44 μ).

TEXT-FIG. 14.—Egg-wall of *Eyprepocnemis roseus* Uvarov.

(a). Egg in side view. (b). Surface view of egg-wall near the posterior pole showing the ring of micropylar canals and sculpturing. Note presence of rounded tubercles. (c). Same, a portion from top. One micropylar canal enlarged. (see below). (e). Surface view of the chorion from the middle of egg showing ridges and tubercles at the corners of the polygons. (f). Same, a portion more enlarged. (g). Surface view of egg-wall near the anterior pole showing difference in sculpturing than at posterior pole. Note absence of tubercles. (h). Same, a portion from top.

a.p., anterior pole of egg ; *e.o.*, external opening of micropylar canal ; *i.o.*, internal opening of micropylar canal ; *m.c.*, micropylar canal ; *p.p.*, posterior pole of egg ; *r.*, roof of micropylar canal ; *rd.*, ridges of endochorion of egg-wall ; *t.*, tubercles or protuberances of egg-wall.



TEXT-FIG. 15.—Egg-wall of *Parahieroglyphus bilineatus* Bolivar.

(a). Two eggs in side view. (b). Surface view of the egg-wall near the anterior pole showing only tubercles. (c). Surface view of the chorion from the middle of egg showing only circular tubercles. (d). Surface view of egg-wall near the posterior pole showing the ring of micropylar canals and tubercles towards external openings of the canals. (e). Same, another posterior pole showing a few lines near internal openings of the canals. (f). Surface view of 5-micropylar canals, enlarged.

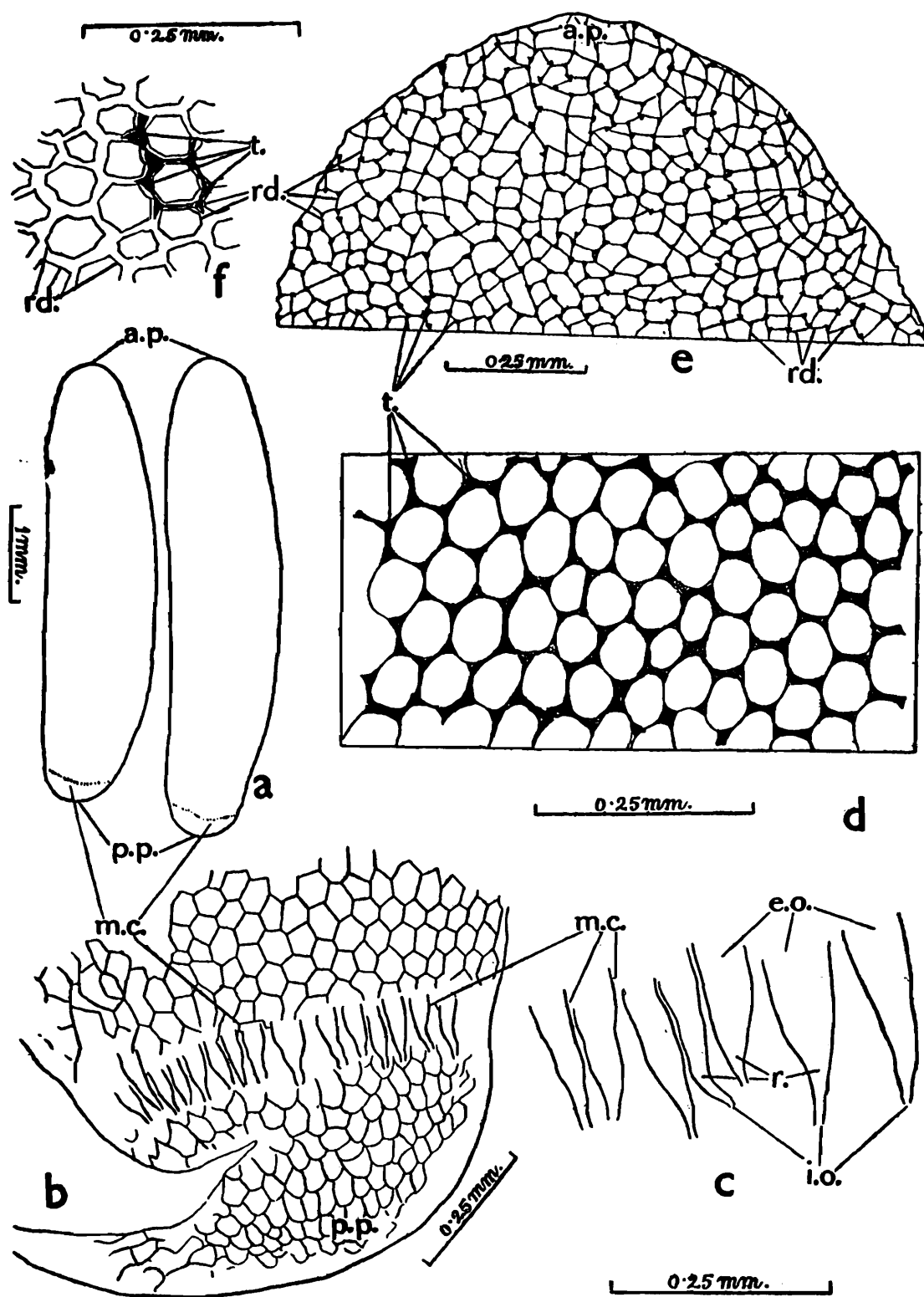
a.p., anterior pole of egg ; *e.o.*, external opening of micropylar canal ; *i.o.*, internal opening of micropylar canal ; *m.c.*, micropylar canal ; *p.p.*, posterior pole of egg ; *r.*, roof of micropylar canal ; *t.*, tubercles or protuberances of endochorion of egg-wall.

7. *Xenocatantops humilis humilis* Serville

(Text-fig. 16 a-f)

Anterior pole (Text-fig. 16 e-f).—Mosaic pattern of tetra-, penta-, hexa- and septagonal cells outlined by ridges present up to extremity of pole. Small, triangular, tubercles present at each corner of cell. n

magnified view apices of tubercles join with the adjacent ones (Text-fig. 16f).



TEXT-FIG. 16.—Egg-wall of *Xenocatantops humilis humilis* Serville.

(a). Two eggs in side view. (b). Surface view of egg-wall near the posterior pole showing the ring of micropylar canals and the sculpturing. Note absence of rounded tubercles. (c). Surface view of 7 micropylar canals, enlarged. (d). Surface view of the chorion from the middle portion of egg, showing somewhat triangular tubercles interlacing each other on the ridges of the endochorion of egg-wall. (e). Surface view of the egg-wall at the anterior pole showing sculpturing different than at posterior pole. Note presence of short triangular tubercles. (f). Same, a portion more enlarged.

a.p., anterior pole of egg ; *e.o.*, external opening of micropylar canal ; *i.o.*, internal opening of micropylar canal ; *m.c.*, micropylar canal ; *p.p.*, posterior pole of egg ; *r.*, roof of micropylar canal ; *rd.*, ridges on endochorion of egg-wall ; *t.*, tubercles or protuberances of endochorion of egg-wall.

Middle chorion (Text-fig. 16 *d*).—Only triangular tubercles prominent ; apices of tubercles join with adjacent ones forming oval-shaped cells of different diameters.

Posterior pole (Text-fig. 16 *b, c*).—A mosaic pattern of cells with curved or bent ridges present from inner openings of micropylar canals to extremity of pole ; triangular tubercles wanting. Micropylar canals long with no definite form ; inner openings of canals not fine and narrow as in other species of Acrididae studied above ; 38-42 canals present ; measurements of canals :—

Total length : 170-220 μ (average 186 μ).

Width of mouth : 40-70 μ (average 56 μ).

Subfamily (iii) *OEDIPODINAE*

8. *Gastrimargus transversus* Thunberg

(Text-fig. 17 *a-e*)

Anterior pole (Text-fig. 17 *b*).—Chorion of anterior pole showing on mosaic pattern of cells outlined by ridges, but only numerous dots of irregular shapes and sizes present.

Middle chorion (Text-fig. 17 *c*).—Here also only dot-like structures of various shapes and sizes present as at anterior pole, but are more prominent.

Posterior pole (Text-fig. 17 *d, e*).—Number of dot-like tubercles very few at posterior pole than at anterior pole ; tubercles present only near inner openings of micropylar canals. A few curved ridges or lines present here and there beyond micropylar canals upto extremity of pole. Micropylar canals neither funnel-shaped nor pipette-shaped but tapering right from mouth upto the fine narrow pore ; 36-44 canals present ; measurements of canals :—

Total length : 80-90 μ (average 87 μ).

Width of mouth : 20-30 μ (average 27 μ).

Subfamily (iv) *PYRGOMORPHINAE*

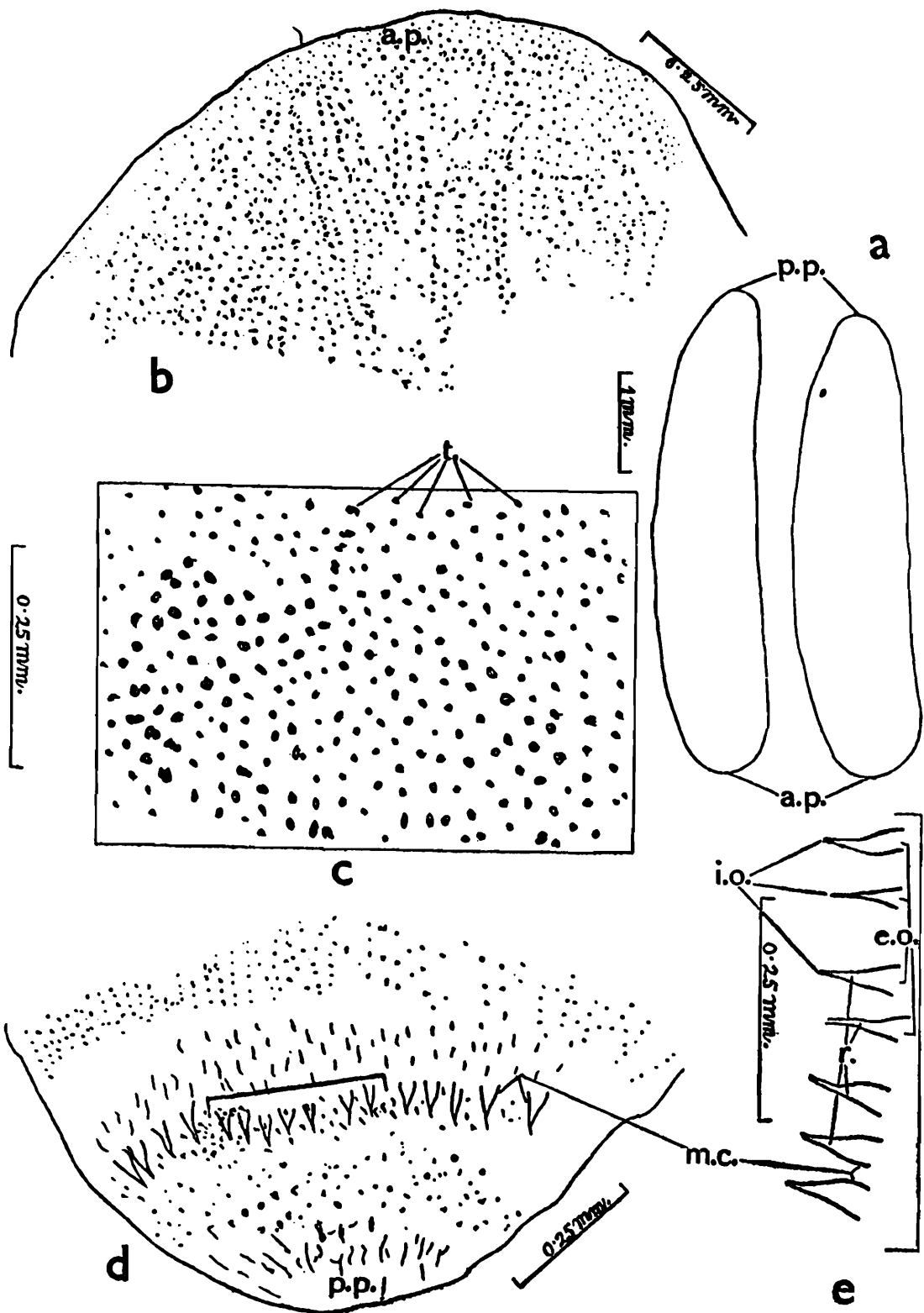
9. *Aularches miliaris* Linnaeus

(Text-fig. 18 *a-f*)

Anterior pole (Text-fig. 18 *f*).—Sculpturing presenting a mosaic pattern of tetra-, penta- and hexagonal cells outlined by straight ridges of various lengths towards extremity of pole ; ridges bent instead of straight ; no cellular sculpturing at pole.

Middle chorion (Text-fig. 18 *d, e*).—Here again similar cells present as at anterior pole, except that narrow spaces or trabeculae present between ridges of two adjacent cells. Long, straight, single tipped (or bent at tip) spine-like tubercles present at each corner of the cells.

Posterior pole (Text-fig. 18 *b, c*).—A mosaic pattern of different types of cells present right from middle of chorion to extremity of pole, very unlike other species of Acrididae studied so far ; cells vary much

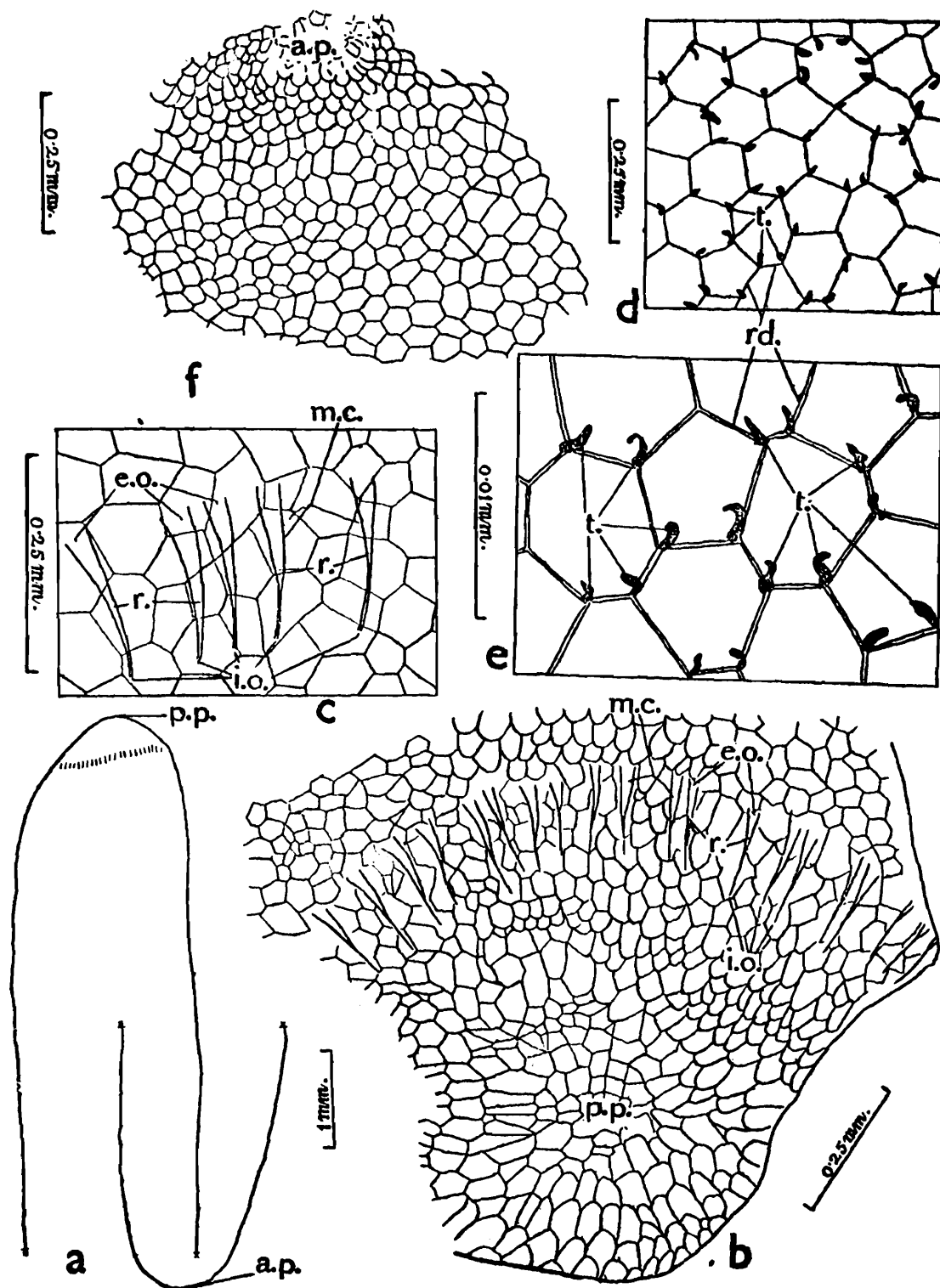


TEXT-FIG. 17.—Egg-wall of *Gastrimargus transversus* Thunberg.

(a). Two eggs in side view. (b). Surface view of the egg-wall near the anterior pole. Note only numerous tubercles. (c). Surface view of the chorion from the middle of egg showing irregularly distributed tubercles. (d). Surface view of the egg-wall at the posterior pole showing the ring of micropylar canals. Note absence of tubercles, but many noted at anterior pole. (e). Same, 7-micropylar canals, enlarged.

a.p., anterior pole of egg ; *e.o.*, external opening of micropylar canal ; *i.o.*, internal opening of micropylar canal ; *m.c.*, micropylar canal ; *p.p.*, posterior pole of egg ; *r.*, roof of micropylar canal ; *t.*, tubercles or protuberances of endochorion of egg-wall.

in shape and size, viz., with curved and bent ridges forming oval-shaped cells near inner openings of micropylar canals ; with long and straight ridges, cells longer than broad near extremity of pole. Micropylar



TEXT-FIG. 18.—Egg-wall of *Aularches miliaris* Linnaeus.

(a). Side view of an egg in two portions. (b). Surface view of egg-wall near the posterior pole showing the ring of micropylar canals, and the sculpturing. Note absence of tubercles. (c). Surface view of 5-micropylar canals. (d). Surface view of the chorion from the middle of egg showing typical spiniform tubercles and ridges. (e). Same, more enlarged. (f). Surface view of the portion of the egg-wall at the anterior pole of egg. Note absence of tubercles.

a.p., anterior pole of egg ; e.o., external opening of micropylar canal ; i.o., internal opening of micropylar canal ; m.c., micropylar canal ; p.p., posterior pole of egg ; r., roof of micropylar canal ; rd., ridges of endochorion of egg ; t., tubercles of endochorion of egg-wall.

canals forming tubular structures and terminating abruptly in very fine pore ; 44-49 canals present ; measurements of canals :—

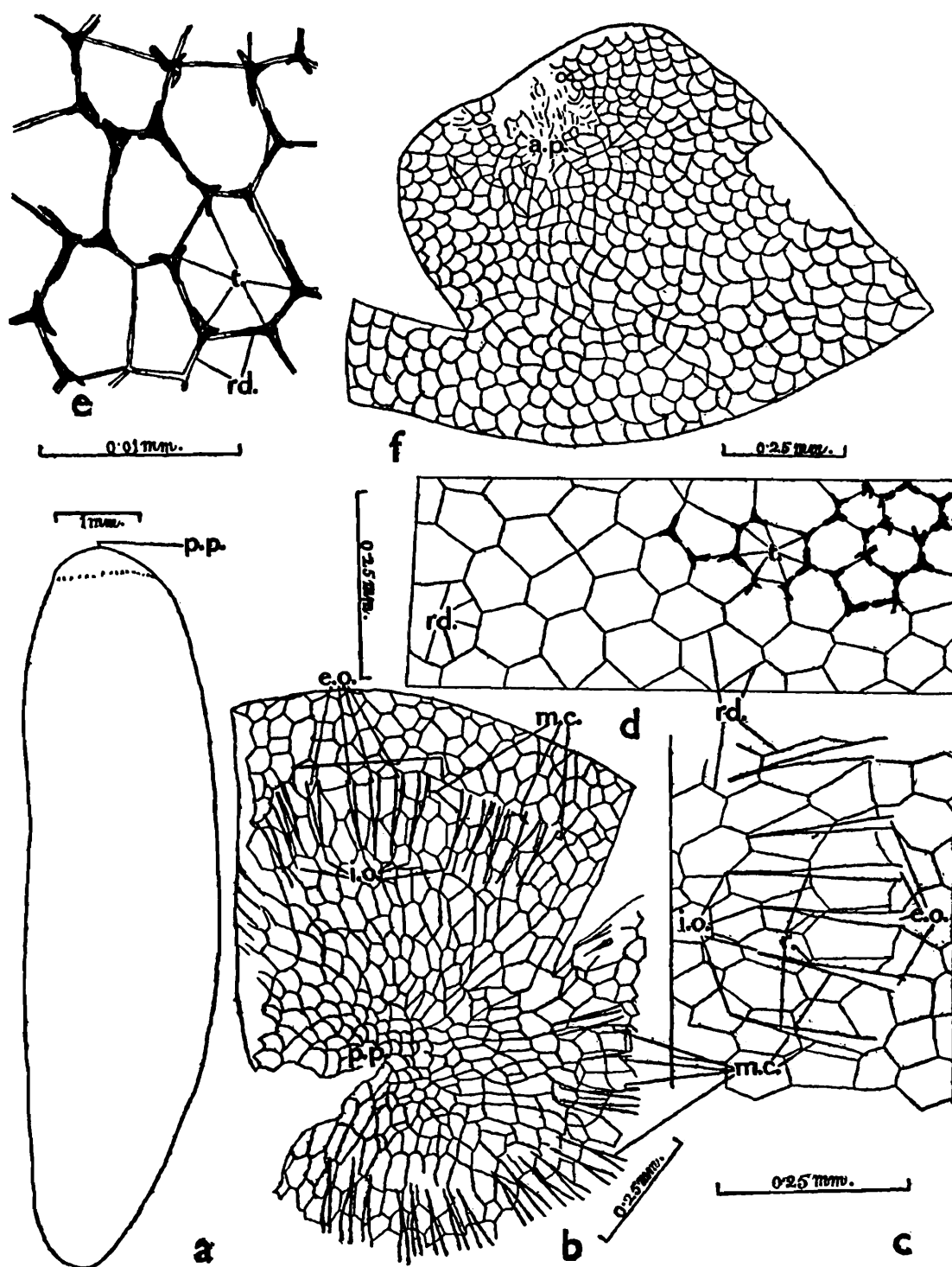
Total length : 170-190 μ (average 178 μ).

Width of mouth : 20-30 μ (average 26 μ).

10. *Aularches punctatus* Drury

(Text-fig. 19 a-f)

Sculpturing at both anterior and posterior poles as well as in middle chorion very similar to that of *Aularches miliaris*, but differing, firstly in structure of spines (tubercles) present in middle chorion, and secondly in number, size and shape of micropylar canals.

TEXT-FIG. 19.—Egg-wall of *Aularches punctatus* Drury.

(a). Egg in side view. (b). Surface view of egg-wall near the posterior pole showing the ring of micropylar canals and sculpturing. Note absence of tubercles. (c). Same, 6-micropylar canals, enlarged. (d). Surface view of chorion from the middle of egg showing typical trifurcated tubercles and ridges. (e). Same, more enlarged. (f). Surface view of egg-wall near the anterior pole showing different sculpturing than at posterior pole. Note absence of tubercles.

a.p., anterior pole of egg ; e.o., external opening of micropylar canal ; i.o., internal opening of micropylar canal ; m.c., micropylar canal ; p.p., posterior pole of egg ; r., roof of micropylar canal ; rd., ridges of endochorion of egg-wall ; t., tubercles or protuberances of endochorion of egg-wall.

Middle chorion : Long and trilobed tubercles present at each corner of cells.

Posterior pole : 43-47 canals present ; measurements of canals :—

Total length : 190-230 μ (average 193 μ).

Width of mouth : 20-40 μ (average 23 μ).

VI—SUMMARY

1. The mode of oviposition in the following 14 species of Indian Acrididae has been studied :—

Ceracris deflorata, *Phlaeoba panteli*, *Choroedocus insignis*, *Choroedocus* sp., *Eyprepocnemis roseus*, *Hieroglyphus banian*, *H. nigrореpletus*, *Parahieroglyphus bilineatus*, *Schistocerca gregaria*, *Spathosternum prasiniferum*, *Xenocatantops humilis*, *Locusta migratoria migratorioides*, *Aularches punctatus* and *Chrotogonus concavus*.

2. The mode of oviposition falls under 3 different categories. Each of these categories is correlated with the mode of copulations (Modes I, II and III respectively, as discussed earlier).

3. An ecological study of oviposition, especially in relation to the soil, has been made in 20 species of north Indian Acrididae.

4. Detailed morphological study of the egg-pods and eggs of 14 north Indian species of Acrididae has been done, and a key to the identification provided on the basis of their characteristic descriptions.

5. A detailed study of the sculpturing of the egg-chorion of 10 species of north Indian Acrididae has been done. On this basis it is possible to distinguish the eggs of various species.

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A REVIEW OF THE SUBGENUS *THERMOCYCLOPS* KIEFER OF THE GENUS *MESOCYCLOPS* SARS, WITH A DESCRIPTION OF A NEW FORM OF *MESOCYCLOPS* (*THERMOCYCLOPS*) *SCHMEILI* POPPE AND MRÁZEK (CRUSTACEA : COPEPODA)

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(With 5 Text-figures)

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I—INTRODUCTION

A preliminary examination of a small collection of examples of a species of the genus *Mesocyclops* Claus indicated that I had before me a form that did not appear to correspond exactly to any hitherto known species, differing in small details of structure from those previously recorded, though it clearly belonged to the subgenus *Thermocyclops* Kiefer. In 1930 the late Dr. Calman in his Presidential Address to the Zoology Section of the British Association for the Advancement of Science remarked, “It may be a counsel of perfection to suggest that no one should introduce a specific name without undertaking at least a partial revision of the genus including it, but there are very many instances, where the multiplication of species might with advantage be postponed until we learn something about those that are supposed to be ‘known’ ” Gurney (1931, p. 27) pointed out that in our study of the genus *Cyclops* (s. lat.) we had at that time reached a stage where extensive and detailed study had resulted in the creation of a number of subspecies and varieties, often based on minute differences, being described in any given species : and that it is impossible correctly to judge of the value of such small differences until we know the range of variation that may be found in such a species, firstly in a stable environment and secondly in environments of rather different characters and he (*loc. cit.*, p. 29) points out that “The probability seems to be that further investigation would show that the subspecific characters are merely manifestations of individual variability throughout the range of the species” This point of view becomes even more important when we have to consider those groups in which the so-called species and subspecies are separated from one another by such differences in details of structure as may well be due

to a slight variation in the rate of development and these, in turn, possibly be due to slight seasonal differences in the environment in which the examples were living. Gurney (1933, p. 301) sums up the position as it then existed in the following words : " No less than 27 species of *Thermocyclops* have now been described, several of which differ less from typical *C. hyalinus* than some of these Indian and African specimens do and it seems there need be no end to the number that may be described in future, if reliance is placed on minute differences in lengths of segments, spines and setae " Lowndes (1934, p. 83) remarked, " That taxonomy is getting to an impossible state must be recognised by almost everyone " and a little later (*loc. cit.*, p. 88) he sums up the situation by remarking, " as Taxonomy progresses, more and more detail is incorporated with the result that specific distinctions, unless they are carefully tested by breeding experiments, become more and more unreliable " Lindberg (1942, p. 149) quotes Chappuis (I have been unable to check this reference) as saying regarding Lowndes' views that this author appears to have arrived at the paradoxical conclusion that the more detailed the description of an animal, the more the animal becomes unrecognisable or in other words the better defined species is that which is known only from a single specimen. Kiefer (1952, p. 18) points out that the fundamental concept of taxonomy is the species concept and that, in the Linnaean tradition, the description of a species applies only to a single individual, the " Type " As descriptions become more and more detailed it equally becomes more and more obvious that no two individuals are identical and the most minute details of structure become individualistic and not specific, as, for instance, the finger-prints of a human being.

In a study of the subfamily Cyclopinae of the family Cyclopidae the taxonomist is faced with a difficult problem. In 1929 Kiefer divided the genus *Mesocyclops* Sars into two subgenera, *Mesocyclops* (s. str.) and *Thermocyclops* Kiefer, with at that time five species in the former and fifteen in the latter. But already the subdivision of the species into subspecies had begun and *Mesocyclops leuckarti* Claus had been divided into the following subspecies :—

Mesocyclops (Mesocyclops) leuckarti leuckarti (Claus)

„	„	„	<i>bodanicola</i> Kiefer
„	„	„	<i>aequatorialis</i> Kiefer
„	„	„	<i>edax</i> (Forbes)

and since then the following subspecies and forms have been added :—

Mesocyclops leuckarti decannensis Lindberg

„	„	<i>pehpeiensis</i> Hu
„	„	forma <i>fortii</i> Mann
„	„	forma <i>pilosa</i> Kiefer

In 1933 Gurney called attention to the difficulty experienced in distinguishing between the various species that were then known and he pointed out that in the genus *Mesocyclops* (s. lat.) there were as many as 35 recorded species.

II—THE SUBGENUS *THERMOCYCLOPS*

At the present day there are as many as 47 species and subspecies in the subgenus *Thermocyclops*, namely :—

1. *Mesocyclops (Thermocyclops) analogus* Kiefer
2. " " *asiaticus* Kiefer
3. " " *brehmi* Kiefer
4. " " *brevifurcatus* Harada
5. " " *conspicuus* Lindberg
6. " " *crenulatus* Brehm
7. " " *dybowski* (Lande)
8. " " *emini* (Mrázek)
9. " " *hyalinus* (Rehb.) *hyalinus* (s. str.)
10. " " " *consimilis* Kiefer
11. " " " *macrolasius* Kiefer
12. " " " *ndalaganus* Kiefer
13. " " " *kivuensis* Kiefer
14. " " " *persicus* Lindberg
15. " " *ianthinus* Harada
16. " " *incisus* Kiefer
17. " " *infrequens* Kiefer *infrequens* (s. str.)
18. " " *infrequens* Kiefer *nigerianus* Kiefer
19. " " *infrequens* Kiefer *eduardanus* Kiefer
20. " " *inopinus* Kiefer
21. " " *inversus* Kiefer
22. " " *iwoyiensis* Onabamiro
23. " " *macracanthus* Kiefer
24. " " *mahéensis* Lindberg
25. " " *microspinulosus* Lindberg
26. " " *minutus* Kiefer
27. " " *mongolicus* Kiefer
28. " " *neglectus* (Sars) *neglectus* (s. str.)
29. " " " *decipiens* Kiefer
30. " " " *prolatus* Kiefer
31. " " " *nigerianus* Kiefer
32. " " *oblongatus* Sars

- | | | |
|-----|--|--|
| 33. | <i>Mesocyclops (Thermocyclops) oithonoides</i> | (Sars) |
| 34. | „ | „ <i>operculatus aberrans</i> Lindberg* |
| 35. | „ | „ <i>operculifer</i> Kiefer <i>operculifer</i> (s. str.) |
| 36. | „ | „ <i>pachysetosus</i> Lindberg |
| 37. | „ | „ <i>retroversus</i> Kiefer |
| 38. | „ | „ <i>rylovi</i> Smirnov |
| 39. | „ | „ <i>schmeili</i> (Poppe and Mrázek) <i>schmeili</i> (s. str.) |
| 40. | „ | „ <i>schmeili</i> (Poppe and Mrázek) <i>hastatus</i> Kiefer |
| 41. | „ | „ <i>schuurmanae</i> Kiefer |
| 42. | „ | „ <i>stephanides</i> Kiefer |
| 43. | „ | „ <i>tenuis</i> Kiefer |
| 44. | „ | „ <i>taihokuensis</i> Harada |
| 45. | „ | „ <i>tinctus</i> Lindberg |
| 46. | „ | „ <i>trichophorus</i> Kiefer |
| 47. | „ | „ <i>vermifer</i> Lindberg |

In many of these species the male is unknown and in others it is represented by only relatively few examples. Since no males were present in the collection under investigation I have confined my study to the females only of the subgenus.

In those species in which a sufficient number of individuals has been subjected to careful examination it is clear that each character may exhibit a considerable degree of variation ; and it is impossible to judge of the value of such small differences as criteria for the differentiation of species until we know the range of variation that may be found in such a species, first, in a given environment of a stable character and, secondly, in environments of different characters. Lowndes (1934, p. 85) has stated that “one will find that the amount of variation is in no way proportional to the area of distribution” : but Lindberg (1938, p. 213), after a wide experience of individuals of what he believes to be one species, taken in the same or in different localities, has stated that examples taken simultaneously in a single locality exhibit relatively little variation but that one finds considerably greater variation between animals taken in different localities and even in those taken in the same locality but at different times of the year, as in the dry or wet seasons.

Van Oye (1926) pointed out that in his study of the plankton of the rivers of the Belgian Congo he found that with the seasonal changes in the character of the water and especially of the amount of rain-fall, which brought increased amounts of nutritive material, there resulted a corresponding change in both the qualitative and quantitative character of the plankton, which exhibited a double rise and fall, the rise and fall of the zooplankton following about 8 to 15 days after that of the phytoplankton. Pruthi (1932) and I (Sewell, 1934) carried out a series of observations on

* Lindberg under the name *operculatus aberrans* and in his account states that this form showed a close resemblance to the species described by Kiefer under the name *operculifer*. The correct name for this form should be *operculifer aberrans*.

the character of the water and the plankton of the Tank in the Indian Museum compound during 1929-1931 and found similar changes, and that in both the Diaptomidae and the Cyclopidae there was a double annual change in the size of the individuals of the same species, both in males and females, and that in the numbers of ova that were being produced there was a maximum in the winter months, October-December, and some indication of a second rise in the reproduction rate in the hot weather months of March-May. Mann (1940) has pointed out that the final differentiation of the various species of Cyclopids can only be determined after the careful examination of a large number of examples and he shows that the proportions of the furcal rami, the distal segment of the endopod of the 4th leg, and the proportions of the inner to the outer spine on this segment or of the inner spine to the length of the segment may vary from one year to another in the same habitat or from one habitat to another, even when close to and not dissimilar in character.

The differentiation of the species and subspecies in this subgenus is largely based on a number of relatively small differences, many of them being measurements of different parts of the body. Both Lindberg (1942, p. 145) and Kiefer (1952) have given lists of the structural features on which they have relied for the determination of the species of the subgenus *Thermocyclops*, and I give these below :—

1. The total length of the animal and the relative proportions of the various segments of both the anterior and posterior regions of the body.
2. The position of the furcal rami, parallel or divergent, and the proportional measurements of their length and breadth.
3. The relative lengths of the furcal setae.
4. The length of the antennule and of its various segments.
5. The number of setae on the penultimate segment of the antenna.
6. The proportions of length to breadth of the distal segment of the endopod of the 4th leg.
7. The proportion of length of the distal segment of the endopod of the 4th leg and the length of the innermost of the two distal spines on the segment, or of these spines to each other.
8. The character of the connecting lamella between the 4th pair of legs and the number of spines or the presence of hairs, or absence of both hairs and spines, on the rounded prominences of the distal margin.
9. The relative lengths of the inner spine and outer seta on the distal margin of the free segment of the 5th leg.
10. The form of the receptaculum seminis.
11. The number of ova in the egg-sac of the female.

I will, before I describe the new form, try and indicate to what extent we find in some of the characters given above a range of variation both in individual species and also between one species and another.

1. *The total length of the animal.*—Throughout the whole subgenus *Thermocyclops*, the individuals of which are of small size, there appears to be a steady and progressive change of body length :—

Species							Total length of body from forehead to tip of furcal ramus mm.
<i>M. (Th.) consimilis</i>	..	..					0·570—0·722
„ „ <i>retroversus</i>	..	..	..	..	..		0·60 —0·855
„ „ <i>operculatus aberrans</i>	..	..	..	..	..		0·605—0·650
„ „ <i>dybowskii</i>	..	..	..		..		0·65 —1·04
„ „ <i>iwoyiensis</i>		..		..		..	0·74 —0·86
„ „ <i>oithonoides</i>	..	..	..	..		..	0·75 —0·90
„ „ <i>neglectus</i>	..		..		..	..	0·750—0·940
„ „ <i>rylovi</i>	..	..	..		..	..	0·756—1·140
„ „ <i>emini</i>	..	..	..	..	..	..	0·79 —1·04
„ „ <i>vermifer</i>	..	..			..	..	0·779—1·074
„ „ <i>hyalinus</i>		..			..		0·80 —1·0
„ „ <i>asiaticus</i>	..		..		..		0·84 —0·92
„ „ <i>pachysetosus</i>	..	..	..	..	..	..	0·845—0·940
„ „ <i>schuurmanae</i>	..	..	..	..	..	..	0·893—0·959
„ „ <i>oblongatus</i>	..	..	..	.	..	..	0·90
„ „ <i>schmeili</i>	..	..	..	..	..	..	0·90 —1·083
„ „ <i>macracanthus</i>	..	..	..	..	..	..	0·92
„ „ <i>tinctus</i>	..	..	..	..	..	..	0·920—1·254
„ „ <i>mahéensis</i>	..	..	..	..	..	..	0·922—1·017
„ „ <i>asiaticus</i>			..	..	..	..	0·429—1·024
„ „ <i>decipiens</i>	..	.		..	..	..	not quite 10·
„ „ <i>brehmi</i>	..	..	..	..	..	..	1·0
„ „ <i>tenuis</i>	..	..	..	..	..	..	1·0
„ „ <i>trichophorus</i>	..	..	..		..	..	about 1·0
„ „ <i>nigerianus</i>	..	..	..	..	..	..	1·0
„ „ <i>operculatus</i>	..		..	..	..	..	1·0
„ „ <i>infrequens</i>	..	..	..	..	..	..	1·06 —1·10
„ „ <i>inopinus</i>	..	..		..	..	..	1·160
„ „ <i>conspicuus</i>	..		..	..	..	..	1·121—1·235
„ „ <i>microspinulosus</i>	.		..	..	..	..	1·178—1·306

In such species as have been recorded from a number of different localities we find, as might be expected, a considerable range in body length, as for instance in *vermifer* and *rylovi*; and it seems clear that there is no clean break in the total length of the animal as we pass from species to species throughout the whole series.

I have already indicated (*vide supra*, p. 72) that the size of these small crustacea may depend to some extent on the change of conditions present in their habitat during different seasons of the year, and the same doubtless is true of the various habitats in which they have been found. It also seems probable that a mere change of bodily size may be accompanied by definite changes in the relative proportions of various parts of the body.

2. *The proportional length of the furcal ramus and the proportions of its length to breadth.*—Lowndes (1932a, p. 282) has remarked that "the length of the caudal rami has always been considered an important specific character", but he showed that in a female of *Cyclops strenuus*, in which the ratio of length of body to length of furcal ramus was 1.0 : 0.124 and the proportional length to breadth of the furcal ramus was 7.3 : 1.0, the corresponding ratios in her offspring were 1.0 : 0.108-0.130, with an average of 0.121 in the proportions of length of body to length of furcal ramus and a proportion of length : breadth of the ramus that ranged from 4.35-6.40, with an average of 5.524. It would thus seem that these measurements can hardly be considered very reliable specific characters.

In the Calanoida I found (Sewell, 1932) that at each moult, while the whole body increased in length, the various segments exhibited differences among themselves, but the abdomen in almost every case increased in length in proportion to the anterior region, while the furcal ramus tended to decrease. One would expect to find that the same phenomenon was present in the Cyclopoida and in the present examples this does seem to be the case :—

Stage	Total length of animal	Proportional lengths of		
		Whole animal	Abdomen	Furcal ramus
IV ..	0.717 mm.	1000	305	95
V	0.90 mm.	1000	331	95
VI ..	0.95—1.05 mm.	1000	350	85.7

Thus, while the abdomen as a whole increases in proportion to the rest of the body at each moult, the furcal ramus becomes progressively shorter. One might expect to find traces of the same phenomenon in the adults of the same species.

Lowndes (1932b, p. 70), when commenting on the great variability of the length of the furcal ramus in closely allied species and even in individuals of the same species, remarks "if the rami are acting as a

heterogenic organ there should be some definite relationship between the length of the rami themselves and the total length of the animal. The data at our disposal is (*sic*) scanty, but such as there are shows that no such relationship exists. ” But he (*loc. cit.*, p. 77) later states that, “ now it would not be difficult to show that among *Cyclops* generally there is a very strong tendency among the females for an elongation of the caudal rami ” .and “ within a number of single species it would not be difficult to show that this tendency for the rami to elongate is very prevalent. Now, this elongation is unquestionably an aberrant feature. Nearly all the common species have forms with elongate rami and yet this elongation does not occur among the males”. As there are no males in the present collection I have therefore been unable to check the correctness of this last assertion. In the females, however, there does seem to be a definite connection between the total length of the animal and the proportional length and breadth of the furcal rami. Lowndes (*loc. cit.*) gives a number of measurements of examples of the genus *Cyclops*, and an analysis of these shows that with increasing size of the animal there is a quite clear tendency for the furcal ramus to be narrower in proportion to its length :—

Species with number of examples	Total length	Average proportions of furcal ramus	
		L.	B.
<i>Cyclops strenuus</i>			
7	<1.79 mm.	5.585	: 1.0
10	1.80—1.89	6.207	: 1.0
10	>1.90 .	6.786	: 1.0
<i>Leptocyclops speratus</i>			
5 . .	0.75—0.82 mm.	4.18	: 1.0
6 . .	1.00—1.36 . .	5.335	: 1.0
<i>Leptocyclops agilis</i>			
5 . . .	<1.0 mm. . .	3.94	: 1.0
7	>1.0 „ . . .	4.55	: 1.0
<i>Leptocyclops macruroides</i>			
3 .	1.03 mm. . .	6.3	: 1.0
3 . . „ .	1.04—1.25 mm. . .	7.0	: 1.0

Lindberg (1942) and Gurney (1933), fortunately, have given us detailed measurements of a number of individuals in various species and these show clearly that a change in body length is accompanied by changes in the proportions of the length to the breadth of the furcal rami :—

a. In *Eucyclops serrulatus* (Fischer) : (Lindberg, 1942, p. 88)

Body-length in mm.	0.80—0.99	1.0—1.99	1.1—1.19	1.2—1.30
Average L : B of the furcal ramus	4.70 : 1.0	4.98 : 1.0	5.30 : 1.0	5.78 : 1.0
No. of examples measured	17	20	7	6

Extreme range from 3.68 : 1.0 to 6.58 : 1.0

b. In examples of *Mesocyclops leuckarti* (Claus) : (Lindberg, 1942, p. 176)

Body-length in mm.	<1.199	1.200-1.299	1.300-1.399	1.400-1.499	>1.50
Average L : B of the furcal ramus	3.093 : 1.0	3.331 : 1.0	3.439 : 1.0	3.461 : 1.0	3.552 : 1.0
No. of examples measured	6	9	7	7	14

Extreme range from 2.68 : 1.0 to 4.24 : 1.0

c. In examples of *M. (Thermocyclops) rylovi* Smirnov : (Lindberg, 1942, p. 183)

Body-length in mm.	< 0.9	>0.9
Average L : B of the furcal ramus	3.314 : 1.0	3.407 : 1.0
No. of examples measured	5	12

Extreme range from 3.04 : 1.0 to 3.60 : 1.0

d. In examples of *M. (Thermocyclops) vermifer* Lindberg (1942, p. 185)

Body-length in mm.	0.70-0.79	0.80-0.89	0.90-0.99	1.0-1.1
Average L : B of the furcal ramus	3.10 : 1.0	2.95 : 1.0	2.91 : 1.0	2.88 : 1.0
No. of examples measured	1	6	12	9

Extreme range from 2.48 : 1.0 to 3.32 : 1.0

In the first three species noted above the furcal ramus tends to become longer in proportion to its breadth with an increasing total length of the animal ; but in the last instance, in *Thermocyclops vermifer*, the exact opposite appears to be the case. Incidentally this seems to provide another argument in favour of Lindberg's contention that *rylovi* and *vermifer* are different species. The proportions of length to breadth of the furcal ramus also appear to vary in the same species in different localities. Gurney (1933, p. 293) gives measurements of examples of *M. (Th.) leuckarti* (Claus) from various parts of the old world, and in different regions the average proportions of the ramus in length to breadth are as follows :—

	Europe	Palestine, Seistan and India	Ceylon, Rangoon and Sarawak
	3.427 : 1.0	3.396 : 1.0	2.708 : 1.0
	(13 examples)	(6 examples)	(4 examples)
Average body length	.. 0.97 mm.	1.08 mm.	0.95 mm.

and Lindberg (1935, p. 410) for his subspecies, *deccanensis*, from India gives the proportions as averaging 3.379 : 1.0, in 4 examples with a range of 2.88-4.03 : 1.0. Lindberg (1942, p. 143) has himself called attention to the difference in the proportions of the ramus in specimens taken in the south area of Iran and in those from the north region. He remarks, "La forme septentrionale, tout en étant plus petite, a aussi montré une furca plus courte que celle des animaux du Sud, et sa soie dorsal a été légèrement inférieure en longueur ; cette soie a parfois été fortement ciliée chez les échantillons du Sud "

3. *The relative lengths of the furcal setae*.—Previous observers have attributed considerable importance as an aid to the identification of a species to the proportional lengths of the furcal setae. Smirnov (1929) in his account of *Mesocyclops rylovi* laid great stress on the proportional lengths of seta 1 to 3 ; he remarks, "For the species described here the proportion of the innermost seta to the median seta is very characteristic, 1 : 1.43 or 1.0 to 1.75 " Between the lower and higher figure there is a range of 22.36 per cent. Gurney (1933, p. 64) has pointed out that great care must be exercised in attributing undue importance to such measurements, and points out that " absolute accuracy in measuring a seta is almost impossible. Setae are commonly so fine towards the end that it is not always possible to be sure that the end has been correctly seen, and it may have been broken or worn away " Below I give the average proportional lengths of the furcal setae in a number of species and subspecies, taking the length of the 2nd seta, the longest, as 100. In numbering the furcal setae I have followed the method used by Giesbrecht and followed by Kiefer, taking the innermost seta as seta 1 and the outermost on the external lateral border as seta 5, the dorsal accessory seta being seta 6 : it is unfortunate that Gurney in his Monograph of the British Fresh-water Copepoda (1933) reversed this method and numbered the setae from without inwards.

Species	Data from	Seta 1	2	3	4	5	6
<i>M. (Th.) operculatus aberrans</i>	Lindberg, 1951	17·04	100	68·97	15·935	..	16·72
„ „ Present specimens		25·14	100	76·6	15·38	6·52	16·14
„ „ <i>tinctus</i>	Lindberg, 1941, 1947 .	26·2	100	71·1	20·2	..	19·2
„ „ <i>schmeili hastatus</i> . . .	Kiefer, 1952 .	34·4	100	88·2	32·6	..	20·8
„ „ <i>dybowskii</i>	Gurney, 1933 . . .	36·8	100	75·3	20·9	..	23·2
„ „ <i>inopinus</i>	Kiefer, 1926	37·9	100	84·2	22·6	..	..
„ „ <i>schmeili schmeili</i>	Kiefer, 1952	39·8	100	81·3	22·6	..	16·9
„ „ <i>schuurmanae</i>	Lindberg, 1951	42·9	100	69·1	19·1	..	25·1
„ „ <i>pachysetosus</i>	Lindberg, 1951 .	43·8	100	93·95	29·5	..	25·1
„ „ <i>hyalinus consimilis</i>	Kiefer, 1952 .	45·75	100	80·54	23·585	..	26·89
„ „ <i>neglectus neglectus</i>	Lindberg, 1951	45·9	100	78·65	25·35	..	26·25
„ „ <i>trichophorus</i>	Kiefer, 1930	46·4	100	71·4	17·1	..	..
„ „ <i>twoylenis</i>	Onabamiro, 1952	48·13	100	68·19	20·27	..	20·53
„ „ <i>mahéensis</i>	Lindberg, 1941 .	49·8	100	63·2	18·0	..	37·2
„ „ <i>rylovi</i>	Lindberg, 1935	52·8	100	72·7	18·5	8·95	25·00
„ „ <i>infrequens infrequens</i>	Kiefer, 1952 . . .	53·04	100	76·8	22·52	..	21·58

Species	Data from	Seta 1	2	3	4	5	6
<i>M. (Th.) neglectus prolatus</i>	Kiefer, 1952	57·11	100	89·22	24·51	..	26·94
„ „ <i>vermifer</i>	Lindberg, 1935	58·8	100	78·5	20·8	9·7	25·2
„ „ <i>hyalinus persicus</i>	Lindberg	59·43	100	77·1	22·35	..	..
„ „ <i>infrequens decipiens</i>	Kiefer, 1952	62·78	100	80·72	22·18	..	24·44
„ „ <i>tenuis</i>	Lowndes, 1934	60·0	100	73	13	..	40
„ „ <i>oithonoides</i>	Gurney, 1933	64·2	100	71·9	21·5	..	..
„ „ <i>microspinulosus</i>	Lindberg, 1942	64·7	100	83·55	27·07	..	25·47
„ „ <i>hyalinus</i>	Mann, 1944	65·05	100	74·6	21·1	..	..
„ „ <i>infrequens nigerianus</i>	Kiefer, 1952	67·37	100	82·63	26·315	..	42·11
„ „ <i>retroversus</i>	Kiefer, 1952	67·89	100	84·05	26·41	..	45·44

Thus we have a steady and gradual increase in the proportional length of the 1st seta, as compared with the 2nd, from 17 to 68 a range of 58, whereas in setae 3 and 4 the range is only from 63 to 94 (31) in the former and from 15 to 33 (18) in the latter. The dorsal seta (seta 6) shows a gradual increase in length from 16·7 to 26·9 and then comes a clear break to 37·2 and then to 40 and 42 to 45·5.

A considerable range of variation is, however, present in a number of species and I give below the range of the proportional lengths of setae 1 and 2 in several :—

<i>M. (Th.) tinctus</i>	from	23·8 to 33·0 : 100
„ „ <i>dybowskii</i>	„	31·7 to 42·0 : 100
„ „ <i>schmeili</i> <i>hastatus</i>	„	33·0 to 35·77 : 100
„ „ <i>schmeili</i> <i>schmeili</i>	„	37·8 to 42·6 : 100
„ „ <i>mahéensis</i>	„	42·8 to 54·7 : 100
„ „ <i>vermifer</i>	„	55·5 to 61·6 : 100
„ „ <i>hyalinus</i>	„	55·9 to 74·5 : 100
„ „ <i>microspinulosus</i>	„	59·0 to 72·3 : 100

and, if I am right in attributing the present examples to *M. (Th.) schmeili* (s. lat.) then this species would appear to have a range from 33·07 to 45·5 : 100 and with *tinctus* forms an almost uninterrupted gradation from 23·8 to 42·6 and with *mahéensis* to 54·7 : 100.

In some species, of which examples have been recorded from several localities, and assuming that the identification of the individuals has been correct, there is or may be a great range of variation in different areas : Gurney (1933) provides a very good example of this among the specimens of *M. (Th.) hyalinus* (Rehberg) that he examined and measured from England, Egypt, India and Ceylon :—

Seta 1 : seta 2,	1·0 : 1·144 or 1·640	Calcutta, India.
	1·0 : 1·50	.. Sutton, Norfolk.
	1·0 : 1·727	Ceylon.
	1·0 : 1·795	Lahore, Pakistan.
	1·0 : 2·021	River Nile.
Seta 1 : seta 3,	1·0 : 1·215 or 1·249	Sutton, Norfolk.
	1·0 : 1·304	Ceylon.
	1·0 : 1·321 or 1·575	River Nile, Egypt.
	1·0 : 1·366 or 1·371	Calcutta, India.
	1·0 : 1·51	.. Lahore, Pakistan.

Lindberg (1938) in his examples of *hyalinus* from a number of different habitats in India found the range of variation in the relative proportions

of seta 4 to seta 6 to be as great as from 1·0 : 0·757-1·266 and in *vermifer* to range from 1·0 : 0·526-1·0.

4. *The length of the antennule.*—Turning now to a consideration of the various appendages, the antennule in all species of the subgenus *Thermocyclops* is in the adult composed of seventeen segments but there is a considerable range of variation in the total length of this appendage, not only in different species but in some cases even in specimens of the same species. I give below the differences in certain species of the length of the antennule in comparison with the anterior region of the body :—

1. The antennule reaches only to the hinder margin of the cephalothorax (=Ceph.+Th. I) :—

M. (Th.) neglectus Kiefer
 „ „ *rylovi* Smirnov
 „ „ *schmeili* Poppe and Mrázek (s. lat.)
 „ „ *trichophorus* Kiefer
 and the Present specimens

2. The antennule reaches to the middle of the 2nd thoracic segment :—

M. (Th.) conspicuus Lindberg
 „ „ *infrequens* Kiefer
 „ „ *microspinulosus* Lindberg
 „ „ *minutus* (Lowndes)
 „ „ *operculifer* Kiefer
 „ „ *operculatus aberrans* Lindberg
 „ „ *stephanides* Kiefer
 „ „ *tenuis* (Marsh)
 „ „ *tinctus* Lindberg

3. The antennule reaches to the hinder margin of the 2nd thoracic segment :—

M. (Th.) analogous Kiefer
 „ „ *decepiens* Kiefer
 „ „ *dybowskii* (Lande)
 „ „ *hyalinus* Rehberg
 „ „ *infrequens* Kiefer
 „ „ *microspinulosus* Lindberg
 „ „ *oblongatus* Sars
 „ „ *pachysetosus* Lindberg
 „ „ *schuurmanae* Kiefer
 „ „ *tinctus* Lindberg

4. The antennule reaches to the middle of the 3rd thoracic segment :—

M. (Th.) hyalinus var. *persicus* Lindberg
 „ „ *mahéensis* Lindberg
 „ „ *vermifer* Lindberg

5. The antennule reaches to the hinder margin of the 3rd thoracic segment :—

M. (Th.) asiaticus Kiefer
 „ „ *brehmi* Kiefer
 „ „ *macracanthus* Kiefer
 „ „ *retroversus* Kiefer
 „ „ *rylovi* Smirnov

6. The antennule reaches to the middle of the 4th thoracic segment :—

M. (Th.) mahéensis Lindberg
 „ „ *oithonoides* (Sars)
 „ „ *vermifer* Lindberg

7. The antennule reaches to the posterior border of the 4th thoracic segment :—

M. (Th.) emini Mrázek

8. The antennule reaches to the anterior border of the genital segment of the abdomen :—

M. (Th.) iwoyiensis Onabamiro

It will be noted that the same species occur in more than one category :— thus *rylovi* is present in 1 and again in 5 and *mahéensis* is present in 4 and 6. Lindberg (1938, p. 215) has called attention to the degree of variation that he found in examples of *M. (Th.) vermifer* and *hyalinus* and he has given a table showing the percentages present in these two species, which I reproduce below :—

Length of Antennule	<i>M. (Th.) vermifer</i>	<i>M. (Th.) hyalinus</i>
The posterior border of Th. 2	11.2%	70.0%
The anterior margin of Th. 3	22.4	10.0
The middle of Th. 3	50.7	6.7
The posterior border of Th. 3	15.7	3.3

The above examples had all been killed in formalin, and Lindberg remarks that in the live specimens of *vermifer* in many cases the antennule reached as far as the middle or even the posterior border of the 4th thoracic segment.

Minor differences may well be caused by different degrees either of growth during development or of contraction during death. Similar differences in the length of the antennule have been noticed in species of the other subgenus, *Mesocyclops* : Harding (1955, p. 224), has pointed out that in examples of *Mesocyclops meridianus* (Kiefer) different observers have recorded the length of the antennule as reaching :

- (1) beyond the cephalothorax (Th. 1) by the length of the last segment (Pesta),
- (2) to the distal edge of the 2nd trunk segment (Lowndes), and
- (3) to the middle of the 3rd thoracic segment :

and in the examples examined by him he found that the antennule varied from barely reaching the end of the cephalothorax to the end of the 2nd thoracic segment.

*6 and 7. *The proportions of length to breadth of distal segment of endopod of the 4th leg, etc.*—In instances such as those in which the differentiation of two species is based in part on the proportion of length to breadth of a particular segment of an appendage, such as the proportions of the terminal segment of the endopod of the 4th swimming leg or the proportional lengths of the two terminal spines, it is of the greatest importance that we should have an adequate knowledge of the extent to which individuals of the same species may vary among themselves in adults taken from the same habitat at the same or a different season of the year and also in those from different habitats, as well as of the changes that may take place during the course of development. I shall deal more fully with this point in the systematic part of this report : suffice it to say here that in the case of most of the species in the subgenus *Thermocyclops* the differences are small and the whole series exhibit a gradual transition from one end of the scale to the other, and the inter-specific differences between several so-called species may lie within the extreme limits of the intra-specific variation of a single species : where this occurs it is obvious that such data are useless as definite specific characters. In the proportional lengths of the inner and outer spines on the distal end of the terminal segment of the endopod of the 4th swimming leg it seems probable that a slight though progressive change may occur, as in the furcal rami

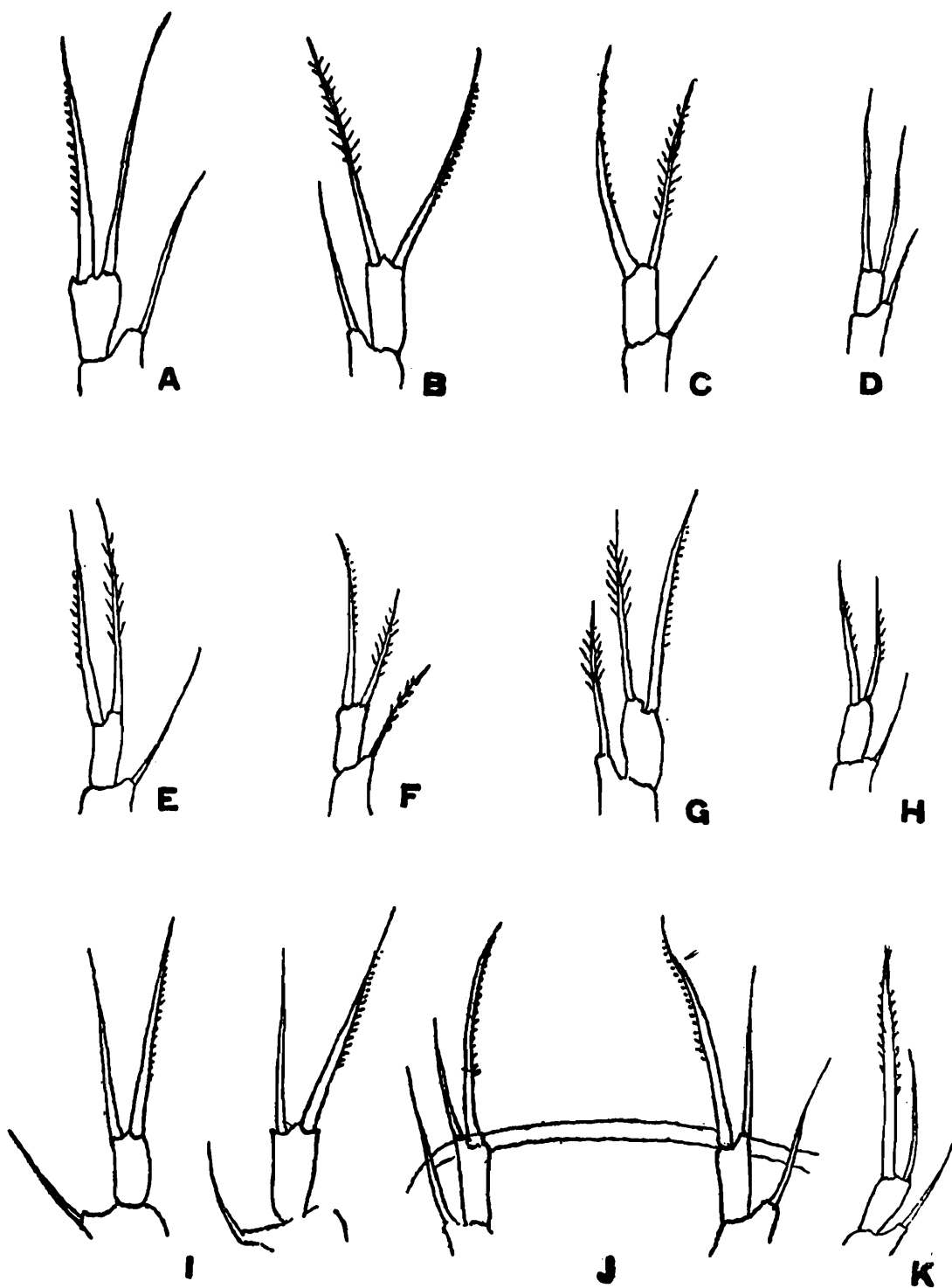
with an increase in size of the individual. Lindberg (1941, p. 264) has given the proportions of these spines in specimens of *M. (Th.) tinctus* and these range from 1.67 to 1.89 : 1.0 ; but if we take the proportions in specimens of three size groups and average the results we get are the following :

	Total length of specimen		
	920-980 μ	1107-1187 μ	1206-1254 μ
Proportion of inner spine to outer spine of endopod 3 of P ₄ .	1.744 : 1.0	1.777 : 1.0	1.794 : 1.0

8. *The character of the connecting lamella between the 4th pair of legs, etc.*—Another of the characters on which Kiefer places reliance in the diagnosis of species is the detailed structure of the connecting plate between the 4th pair of swimming legs. Lindberg (1942, pp. 145-151), however, in his comparison of the species *M. (Th.) rylovi* and *vermifer* is less convinced of the value of this structure and is of the opinion that with adequate collections of closely related forms from a sufficient number of habitats it will be necessary to suppress at least some of the so-called species and subspecies, since these will probably be found to come within the extreme limits of variation in one single species : he remarks that "C'est quand on dispose d'animaux nombreux, provenant d'un grand nombre de localités différentes que la distinction d'espèces cesse d'être simple et qu'on se rend compte de la valeur douteuse de certains traits de structure par suite de l'amplitude de leurs variations. Il en est ainsi notamment en ce qui concerne la lamelle basale de la quatrième paire de pattes, et aussi, mais à un moindre degré, pour le réceptacle séminal". Both Lindberg (*loc. cit.*, figs. 10 and 11) and Kiefer (1952, figs. 21-28) have given series of illustrations of this basal lamella in different species or subspecies, *rylovi*, *vermifer* and *hyalinus* and these show clearly that there may be a wide range of variation in individuals even from the same locality.

It has been stated that no taxonomist would create a new species on a single character, but Kiefer (1929, p. 78) has separated two subgenera of the genus *Mesocyclops*, namely, *Mesocyclops* Sars (s. str.) and *Thermocyclops* Kiefer, solely on the difference in the point of origin of the inner spine of the free segment of the 5th leg, this being situated on the inner border in *Mesocyclops* and on the distal margin in *Thermocyclops*. Gurney (1933, p. 287), commenting on Kiefer's proposal, remarks that "it may be admitted that there may be two subgroups, but they do not, in my opinion, require separation, and the sole distinguishing character is so trivial as to be almost inapplicable". As one's knowledge of the species of the subgenus *Thermocyclops* becomes more extensive it becomes clear that this inner spine in a number of species does not, strictly speaking, arise from the distal margin but from the inner border close to the distal inner angle of the segment (*vide* Text-fig. 1). Such a point of origin has clearly been shown by Sars (1913-18, pl. XXXVI, p. 5) in *Mesocyclops oithonoides*, which Kiefer has made the type of his new subgenus *Thermocyclops*, and this difference has been indicated by Gurney (1933, figs. 1889 and 1895) in two examples of what he considers to be *Cyclops hyalinus* from Norfolk, England and Lahore, Pakistan, respectively and in the first of these (fig. 1889) the point of origin of the inner spine

agrees closely with that of *Mesocyclops crassus* (vide Sars, 1913-18, Pl. XXXVII) which Kiefer regards as a synonym of *hyalinus*. Lowndes (1934) has figured the 5th leg in both *Mesocyclops meridianus* Kiefer (*loc. cit.*, fig. 8 a) and in *Mesocyclops tenuis* (*loc. cit.*, fig. 9 e) and he shows



TEXT-FIG. 1.—The 5th leg of various species of the subgenus *Thermocyclops*.

A. *hyalinus* (after Kiefer). B. *hyalinus* (after Gurney). C. *vermifer* (after Lindberg). D. *inopinus* (after Kiefer). E. *oithonoides* (after Sars). F. *mongolicus* (after Kiefer). G. *dybowski* (after Gurney). H. *dybowski* (after Sars). I. *schmeili*, f. *marmagoensis*, nov., from a larger specimen. J. *schmeili*, f. *marmagoensis*, nov., from a smaller one. K. *schmeili schmeili* (after Kiefer).

that in both of these species the inner spine of the 2nd segment of the 5th leg may arise at the end of the inner border of the segment close to distal inner angle exactly where it arises in some of the present specimens ; and yet Kiefer (1929) includes both these species in the subgenus

Mesocyclops. It would seem very doubtful that the distinction between these two subgenera can be maintained.

9. *The relative lengths of inner spine and outer seta of the free segment of 5th leg.*—Another point of difference in the species of *Thermocyclops* that has been utilised as a character for diagnosis are the proportional lengths of the inner spine and outer seta of the free segment : but here again we find that there is a gradual transition from one extreme, with the seta considerably shorter than the inner spine, to the other, in which the seta is longer than the spine (*vide infra*, p. 104).

10. *The form of receptaculum seminis.*—Kiefer, (1929, 1930) in his keys for the identification of the various species of the genus *Mesocyclops*, with its two subgenera *Mesocyclops* (s. str.) and *Thermocyclops*, has utilised differences in the form of the receptaculum seminis as the chief and almost the sole distinguishing character, and in later publications he (1936, p. 230) states that according to his experience, which he modestly claims to be not inconsiderable, the shape of the receptaculum seminis is one of the most trustworthy characters for the differentiation of species. Lindberg (1938, p. 213), after making a careful study of a large number of examples of the two species *vermifer* and *hyalinus*, is less dogmatic ; he concludes that the observed differences in the structure of this organ, taken in conjunction with other slight differences justified him in concluding that they were two distinct species : but he showed that both species exhibited very considerable degrees of variation, and he remarks, “Les auteurs, tel que Kiefer, qui attachent une importance fondamentale à les aspects même légèrement différents du receptacle seminal en vue de la distinction d’espèces, seront peut-être enclins à considérer que les divers types de receptacle seminal qui j’ ai donnes, correspondent à autant d’espèces distinctes” He goes on to point out that as long as only one of the two species was present in any given habitat, the form of the receptaculum seminis was of importance in determining to which species the individuals should be referred, but in some cases where the two forms existed together certain specimens exhibited forms that were intermediate between the true *hyalinus* and *vermifer* forms, and these specimens he explained as being probably hybrids. In an earlier paper (Lindberg, 1935, p. 413) when engaged in making a study of the form that he believed to be *M. (Th.) rylovi* Smirnov, but which he later described as a new species under the name *vermifer*, noted that the receptaculum seminis is “assez variable selon de degre de remplissage”. It seems possible that small differences in the form and dimensions of the seminal vesicle may be due, as suggested by Lindberg, to the degree of distension of the organ : if impregnation had occurred recently and before oviposition had taken place, the distension would be greater than at some later stage when some of the contents had been discharged to fertilise the ova.

11. *The number of ova.*—As regards the number of ova produced by each species, we have relatively little information :

Species	No. of ova in the ovisacs
<i>M. (Th.) vermifer</i>	not more than 6 to 9 in each sac.
„ „ <i>maheensis</i>	6 to 9 large eggs.
„ „ <i>microspinulosus</i>	the ovisacs appeared to contain few ova.
„ „ <i>asiaticus</i>	more than 10 ova.
„ „ <i>rylovi</i>	more than 15 to 20 in each sac.
„ „ <i>tinctus</i>	26 to 28 ova.

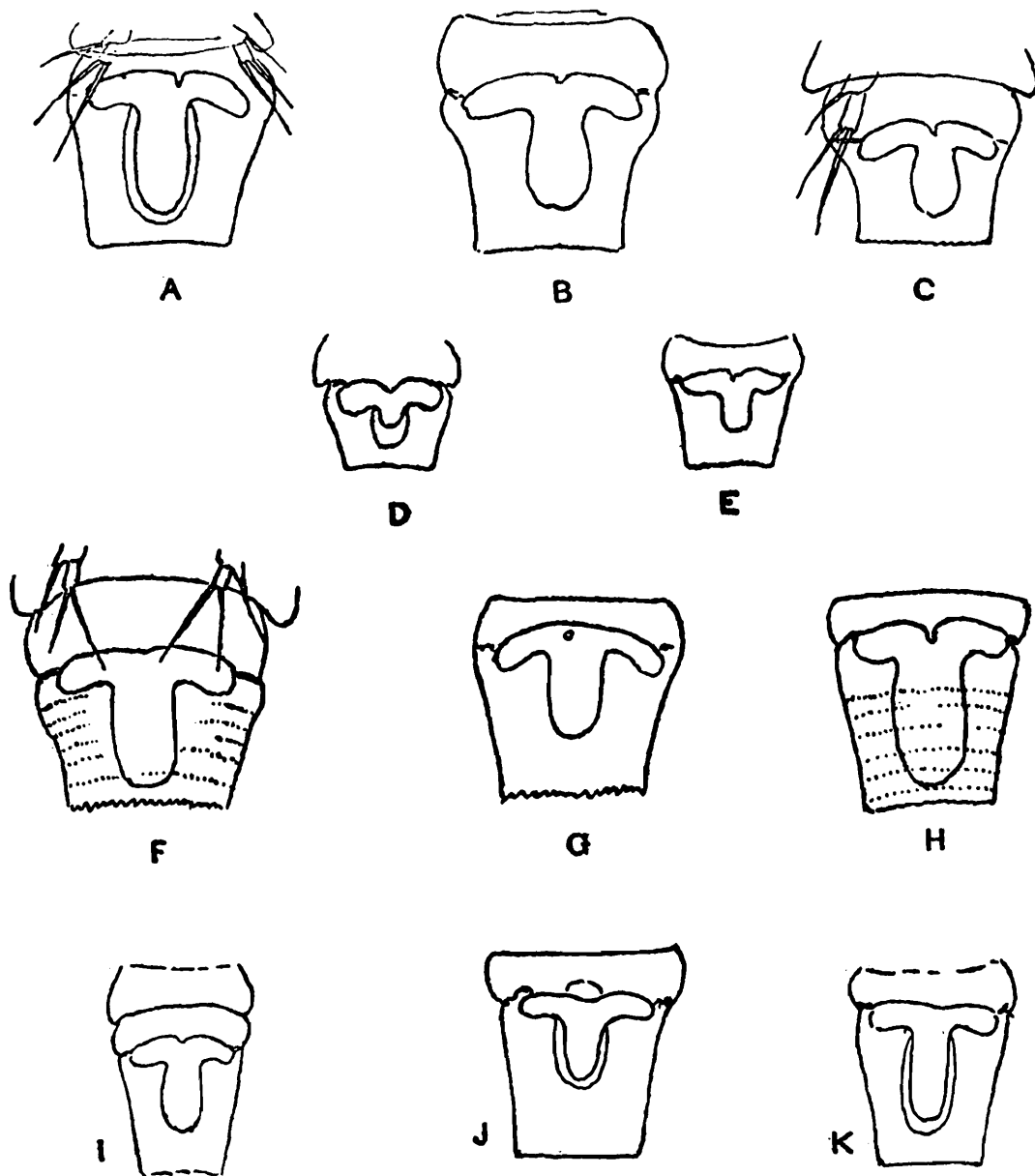
Such data are of little importance as a diagnostic character, for, as I have already pointed out, the number of ova carried may vary with the season of the year, and Lindberg (1941, p. 473) has recorded that examples of the female of the species *Cyclops strenuus divergens* may carry from 38 to as many as 104 ova and Gurney (1933, p. 298) states that the number of eggs in *hyalinus* is few and in *dybowskii* he figures (*loc. cit.*, fig. 1901) about 14 in each egg sac.

One character in the abdominal region that may perhaps be of some importance in helping to differentiate between species or at least between certain groups of species is the shape and dimensions of the genital segment: in certain species of the subgenus *Thermocyclops* the genital segment is noticeably short and broad, whereas in others it is markedly elongate. In the table below I give the proportions of length to breadth in a series of species:—

Species					Proportions of the genital segment: Length to breadth	
<i>M. (Th.)</i>	<i>tinctus</i>	Lindberg	.	.	0.73-1.10	: 1.0
„	„	Present examples	.	.	0.816-1.03	: 1.0
„	„	<i>schmeili hastatus</i>	Kiefer	.	0.909	: 1.0
„	„	<i>operculifer</i>	Kiefer	.	0.914	: 1.0
„	„	<i>operculatus aberrans</i>	Lindberg	.	0.87	: 1.0
„	„	<i>trichophorus</i>	Kiefer	.	0.94	: 1.0
„	„	<i>schmeili schmeili</i>	P. and M.	.	0.975	: 1.0
„	„	<i>conspicuus</i>	Lindberg	.	1.057	: 1.0
„	„	<i>inopinus</i>	Kiefer	.	1.08	: 1.0
„	„	<i>vermifer</i>	Lindberg	.	0.92-1.58	: 1.0
„	„	<i>hyalinus</i>	Kehberg	.	0.98-1.51	: 1.0
„	„	<i>rylovi</i>	Smirnov	.	1.02-1.22	: 1.0
„	„	<i>microspinulosus</i>	Lindberg	.	1.082-1.206	: 1.0
„	„	<i>dybowskii</i>	(Lande)	.	1.17	: 1.0
„	„	<i>iwoyiensis</i>	Onabamiro	.	1.4	: 1.0
„	„	<i>mahéensis</i>	Lindberg	.	1.488-1.65	: 1.0

In several species a considerable range of variation has been recorded; in *vermifer* Lindberg (1942) found a range of 0.92—1.58 : 1.0 and in *rylovi* between 1.02 and 1.22 : 1.0 and in the examples that I certified in 1934 as *rylovi* from 0.97—1.58 : 1.0. In the first group above *tinctus* has a range of 0.73—1.10 : 1.0 and the dimensions of the genital segment of all the other species in this group fall within these limits and the proportions of the first three species in the second group namely, *vermifer* and *hyalinus* and *rylovi* all overlap the highest proportions found in *tinctus*. In preserved material it is often a matter of considerable

difficulty to determine the form of the receptaculum seminis, as has been pointed out by Poppe and Mrázek (1895) in the case of *M. (Th.) schmeili* and by Smirnov (1929) in *M. (Th.) rylovi*; in the present examples I was only able to distinguish the transverse bow-like anterior part of the



TEXT-FIG. 2.—The genital segment of various species of the subgenus *Thermocyclops*. A. *rylovi* (after Sewell). B. *rylovi* (after Smirnov). C. *operculatus aberrans* (after Lindberg). D. *schmeili hastatus* (after Kiefer). E. *schmeili schmeili* (after Kiefer). H. *conspicuus* (after Lindberg). G. *trichophorus* (after Kiefer). H. *microspinulosus* (after Lindberg). I. *mongolicus* (after Kiefer). J. *decipiens* (after Kiefer). K. *inopinus* (after Kiefer).

organ but this exhibited a strong resemblance to the corresponding part of the organ in several of the so-called species, especially those of the group that is characterised by a short and broad genital segment. In Text-fig. 2 I have reproduced from several authors their diagrams of the genital segment and the shape of the receptaculum seminis in

M. (Th.) rylovi Smirnov

" „ *operculatus aberrans* Lindberg

" „ *schmeili hastatus* Kiefer

M. (Th.) schmeili schmeili (s. str.) P. and M.

„ „ *conspicuus* Lindberg

„ „ *microspinulosus* Lindberg

„ „ *trichophorus* Kiefer

„ „ *mongolicus* Kiefer

„ „ *decipiens* Kiefer

and „ „ *inopinus* Kiefer.

It seems to me that the degree of similarity between this organ in all these species is so marked and the differences so slight that it provides no adequate basis for specific discrimination.

Lindberg (1938, p. 215, Pl. IV figs. a-f and Pl. V, figs. a-p) in his comparison of *M. (Th.) vermifer* and *hyalinus* remarks, "Les différences entre les deux espèces ne sont pas très considérables" and in the figures that he gives shows that in both species there is a quite considerable range of variation and so can hardly be considered a reliable specific character.

III—SYSTEMATICS

Genus *Mesocyclops* Sars

Subgenus *Thermocyclops* Kiefer

***Mesocyclops* (*Thermocyclops*) *schmeili* Poppe and Mrazek forma *marmagoensis* nov.**

Cyclops schmeili, Poppe and Mrázek, 1895 : Lindberg, 1951

Mesocyclops (*Thermocyclops*) *schmeili schmeili* (s. str.) P. and M.

„ „ „ *hastatus* Kiefer, 1952

„ „ *tinctus* Lindberg, 1936, 1941

„ „ *inopinus* Kiefer, 1952

„ „ *trichophorus* Kiefer, 1930

„ „ *operculifer* Kiefer, 1929

„ „ *conspicuus* Lindberg, 1947

A small collection of a species of a cyclopid, belonging to the family Cyclopidae, subfamily Cyclopinae, was entrusted to me for examination and report by the Bombay Natural History Society, through the Zoological Survey of India, and I give here a description of these specimens, and have taken advantage of this opportunity of reviewing the subgenus *Thermocyclops* Kiefer.

The collection was made by Mr. Humayun Abdulali, of the Bombay Natural History Society "in a pool of fresh water, measuring 18"×18"×12" (or approximately so), on a small island about a mile off the coast of Marmagoa. The pool was a few yards from the high-tide watermark and was fed by a spring. The water appeared to be perennial" It was well known as the only fresh water available on the island and was situated on the land-ward side. The collection was made in the first week of June, 1953 : usually the south-west monsoon commences early in June in this area, but Mr. Humayun Abdulali informs me in a letter that he did not experience any rain.

The collection includes the last three stages of development, Copepodid Stages IV and V and the adult, all the specimens being females.

♀ Stage VI, Adult (Text-fig. 3).

The total length, from the forehead to the tip of the furcal ramus measures from 0.95 to 1.05 mm.

The proportional lengths of the anterior and posterior regions of the body are as 1.47 : 1.0 in larger examples and 1.52 : 1.0 in smaller ones. The length and breadth of the cephalothorax are about equal and the proportional lengths of the anterior, *i.e.*, the cephalothorax¹ and thoracic segments II to IV, and the posterior region of the body, *i.e.*, the VI thoracic segment and the abdominal segments and furca, are as 1.474 : 1.0. The proportional lengths of the various segments of the body are as follows :—

Ceph.-Th.	Th. II	Th. III	Th. IV	Th. V	Abd. 1-2	3	4	5	Furca	Total
359	83	81	81	55	124	58	50	27	82	=1,000
352	87	85	76	48	118	59	59	28	87	=1,000
343	88	84	80	47	131	58	55	26	88	=1,000
Average	351	86	83	79	124	58	55	27	86	= 999

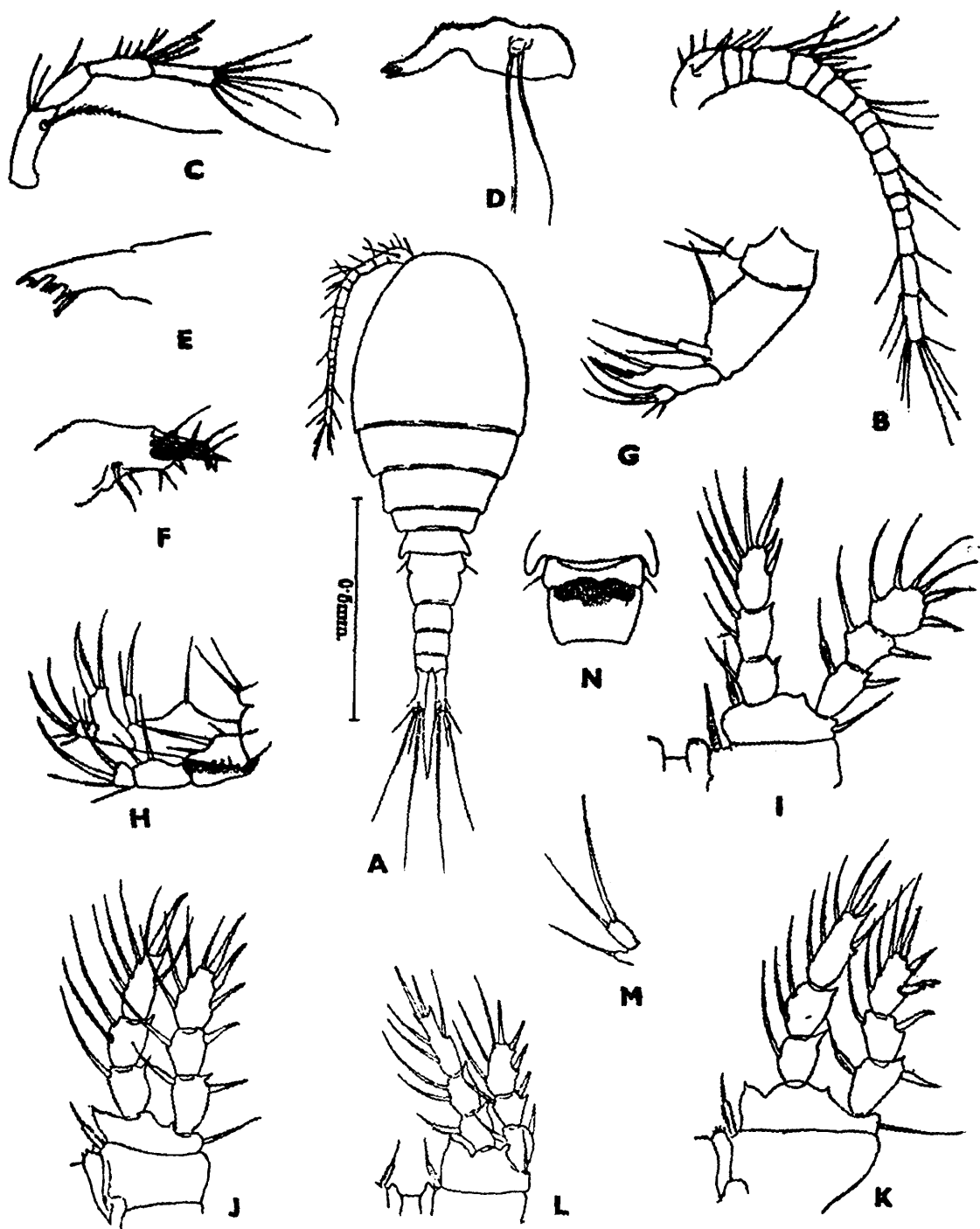
The postero-lateral borders of the 5th thoracic segment are devoid of any hairs and are produced backwards so as to overlap the anterior region of the genital segment of the abdomen. The genital segment (Text-fig. 3, N.) is slightly broader than long in the proportion of 100 : 94.2 and the posterior border is smooth and without any serrations, such as have been recorded by Lindberg (1951) in his examples of *schmeili* from Lake Tanganyika, while the whole surface of the segment is smooth and without either minute spinules or small pits, such as have been recorded in *Thermocyclops operculifer* Kiefer, *microspinulosus* Lindberg and in certain examples of *rylovi* Smirnov. Lindberg has recorded the same type of ornamentation in examples of *Mesocyclops leuckarti* (Claus) : and Lowndes (1934, p. 108) has also recorded that in some examples of *Mesocyclops meridianus* Kiefer the genital segment was “quite short and the integument may bear a series of ring-like markings” Thus the presence of such markings in *M. (Th.) conspicuus* and *microspinulosus* can hardly be regarded as a possible specific character.

The furcal rami are only slightly divergent and their inner borders are smooth, thus differing from the examples of *M. (Th.) schmeili* reported from Lake Tanganyika by Lindberg (1951), in which the inner border is hairy. The proportions of the length and breadth of the furcal rami in the present specimens are as follows :—

Length	Breadth
23 (15.5 7.5) :	6.0 or 3.83 : 1.0
24 (16.0 6.5) :	6.5 or 3.69 : 1.0
22.0 :	6.5 or 3.38 : 1.0
Average	3.633 : 1.0

¹In the following account I have used the term cephalothorax to indicate the anterior division of the body, which is formed by the fused head and 1st thoracic segment.

The 5th seta arises from the outer border of the ramus at approximately two-thirds of its length. I have given the lengths of the proximal and distal portions of the ramus in the table above.



TEXT-FIG. 3.—*Mesocyclops (Thermocyclops) schmeili* Poppe and Mrazek forma *marma-goensis*, nov.

A. Adult female, dorsal aspect. B. Antennule. C. Antenna. D. Mandible. E. Biting ramus of Mandible. F. Maxillula. G. Maxilla. H. Maxilla and Maxilliped. I. 1st swimming foot. J. 2nd swimming foot. K. 3rd swimming foot. L. 4th swimming foot. M. 5th leg. N. Genital segment of the abdomen.

Poppe and Mrazek (1895) in their original account of the species stated that the ramus was twice as long as the last abdominal segment ; but Kiefer (1952, figs. 75 and 78) indicates that in his examples of the subspecies *schmeili* and *hastatus* the furcal ramus is much more nearly three times its length. In the present specimens the rami are equal to or slightly longer than the combined lengths of the last two abdominal

segments, the proportions being 1.0-1.074 : 1.0 : in the two related subspecies, *schmeili* and *hastatus* from Africa, Kiefer (1952, figs. 75 and 78) figures the rami as having, so far as I can judge, the following proportional lengths :—

	Furcal ramus	Abd. segs. 4 and 5	Proportions
<i>M. (Th.) schmeili hastatus</i> . . .	14.5	12	1.22 : 1.0
<i>M. (Th.) schmeili schmeili</i> . . .	16	13	1.23 : 1.0

In the various species and subspecies of the subgenus *Thermocyclops* the average proportions of length to breadth of the ramus exhibit a gradually progressive change, as shown below :—

Species or subspecies	Proportions of Length to Breadth	Data from
<i>M. (Th.) pachysetosus</i>	1.74-2.0 : 1.0	Lindberg, 1951
„ „ <i>hyalinus</i> . . .	1.90-3.0 : 1.0	Lindberg, 1938
	2.50 : 1.0	Kiefer, 1936
	2.125-2.48 : 1.0	Mann, 1940
	or 2.17-2.28 : 1.0	Kiefer, 1937
„ „ <i>vermifer</i> . . .	2.15-3.25 : 1.0	Lindberg, 1938
	2.476-3.00 : 1.0	Lindberg, 1935
„ „ <i>hyalinus consimilis</i>	1.83-2.39 : 1.0	Kiefer, 1952
„ „ <i>neglectus</i> . . .	2.0 : 1.0	Sars, 1909
	2.17-2.50 : 1.0	Lindberg, 1951
„ „ <i>dybowskii</i>	2.32-3.5 : 1.0	Gurney, 1933
„ „ <i>decipiens</i>	} 2.5 : 1.0	Kiefer, 1929
„ „ <i>infrequens</i>		
„ „ <i>mongolicus</i>	2.65-2.73 : 1.0	Kiefer, 1937
„ „ <i>macracanthus</i> . . .	2.75-2.75 : 1.0	Kiefer, 1929
„ „ <i>oithonoides</i>	2.85 : 1.0	Gurney, 1933
„ „ <i>retroversus</i>	2.86-3.15 : 1.0	Lindberg, 1951
„ „ <i>schuurmanae</i>	2.86-3.19 : 1.0	Kiefer
„ „ <i>schmeili hastatus</i>	2.97-3.19 : 1.0	Kiefer, 1952
„ „ <i>trichophorus</i> . . .	barely 3.0 : 1.0	Kiefer, 1930
„ „ <i>operculifer</i>	3.0 : 1.0	Kiefer, 1929
„ „ <i>oblongatus</i>	3.1 : 1.0	Sars, 1927
„ „ <i>rylovi</i>	3.04-3.60 : 1.0	Lindberg, 1942

Species or subspecies		Proportions of Length to Breadth	Data from
M. (Th.)	Present examples	3.38-3.83 : 1.0	—
.. ..	<i>mahéensis</i>	3.39-3.90 : 1.0	Lindberg, 1941
.. ..	<i>tinctus</i>	3.42-4.75 : 1.0	Lindberg, 1941
.. ..	<i>analogus</i>	3.5 -3.75 : 1.0	Kiefer, 1936
.. ..	<i>inopinus</i>	3.5 -3.83 : 1.0	Kiefer, 1952
.. ..	<i>conspicuus</i>	3.67-3.86 : 1.0	Lindberg, 1947
.. ..	<i>operculatus aberrans</i>	3.75 : 1.0	Lindberg, 1951
.. ..	<i>schmeili schmeili</i>	3.95-4.20 : 1.0	Kiefer, 1952
.. ..	<i>brehmi</i>	3.50-4.33 : 1.0	Lindberg, 1951
.. ..	<i>brehmi</i>	4.0 : 1.0	Kiefer, 1929

Thus the present specimens fall between *schmeili hastatus* and *schmeili schmeili*, the three forms forming an almost continuous series of 2.97-3.19, 3.38-3.83 and 3.50-4.33. If, as I believe, all three forms belong to the same species, this gives a possible range of variation in the proportion of the furcal ramus from 2.97 : 1.0 to 4.33 : 1.0, with a mean of 3.65 : 1.0 and a range of variation of 45 per cent : this may seem to be a very high degree of variation but in *Mesocyclops (Mesocyclops) serrulatus* (Fischer) which is a wide ranging species, the recorded extreme range is as great as from 3.68 : 1.0 to 6.58 : 1.0, with a mean of 5.13 : 1.0 and a range of variation of 76 per cent.

The furcal setae appear to be smooth and without marginal hairs ; they are of normal length, the longest (seta 2) being only very slightly shorter than the whole abdomen and only very slightly curved. Lindberg (1939) has given this curvature of the 2nd seta as an important diagnostic character between *hyalinus* and *vermifer*, this seta being almost always recurved in a semicircle in the former and only slightly curved or straight in the latter species : but Kiefer (1952) in a series of figures has shown (figs. 1-20) that this seta may in some cases in the various subspecies of *hyalinus*, namely *macrolacius*, *consimilis* and *kivuensis* be either straight or nearly straight, and further (*loc. cit.* figs. 61 and 62) that similar strongly curved setae may occur in *infrequens infrequens* and in *schmeili schmeili*. It thus seems clear that no reliance can be placed on this character as a diagnostic feature.

The proportional lengths of the furcal setae are as follows :—

Seta	1	2	3	4	5	6
	23.6	100	78.4	15.9	6.6	15.9
	24.4	100	78.9	15.6	6.7	13.3
	25.5	100	72.4	14.3	7.1	18.3
	26.1	100	78.3	16.3	6.5	18.4
	26.1	100	75.0	14.8	5.7	14.8
Average	25.14	100	76.6	15.38	6.52	16.4

The 4th seta, arising from the outer distal corner of the ramus is spine-like and the 5th seta arising from the outer border is situated almost exactly at the junction of the middle and distal thirds of the length of the ramus. Reference to the Table given above (*vide supra*, p. 79) of the proportional lengths of the setae in other species of *Thermocyclops* shows that the present specimens fall into line between *M. (Th.) tinctus* and *operculatus aberrans*.

Previous observers have attributed considerable importance to the relative proportions of the various setae to each other as an aid to the identification of a species. Smirnov (1929) in his account of *Thermocyclops rylovi* remarks, "For the species described here the proportions of the innermost seta to the median seta is very characteristic 1 : 1.43 or 1 : 1.75, average 1 : 1.55" Between the lower and the higher figure there is a range of 22 per cent.

I give below the average proportional lengths of seta 1 to the other apical setae and of seta 4 to the dorsal seta (seta 6):—

Species	Data from	Average proportional lengths of setae			
		1—2	1—3	1—4	4—6
<i>M. (Th.) operculatus aberrans</i>	Lindberg	1.0 : 5.927	4.05	0.935	1.049
" " <i>tinctus</i>	Lindberg	1.0 : 3.817	2.696	0.777	0.954
" " Present examples		1.0 : 3.788	3.029	0.592	1.079
" " <i>schmeili hastatus</i>	Kiefer	1.0 : 2.836	2.591	0.916	0.665
" " <i>dybowskii</i>	Guiney	1.0 : 2.717	2.046	0.565	0.744
" " <i>inopinus</i>	Kiefer	1.0 : 2.6	2.220	0.597	..
" " <i>schmeili schmeili</i>	Kiefer	1.0 : 2.5 2	2.060	0.565	0.744
	Lindberg	1.0 : 2.40	1.977	0.60	0.665
" " <i>schuurmanae</i>	Kiefer	1.0 : 2.33	1.611	0.445	1.314
" " <i>pachysetosus</i>	Lindberg	1.0 : 2.83	2.14	0.674	1.039
" " <i>neglectus neglectus</i>	Kiefer	1.0 : 2.178	1.714	0.552	1.035
" " <i>hyalinus hyalinus</i>	Lindberg	1.0 : 1.783	1.510	0.471	1.720
	Mann	1.0 : 1.54	1.164	0.334	..
" " <i>consimilis</i>	Kiefer	1.0 : 2.186	1.760	0.52	1.140
" " <i>trichophorus</i>	Kiefer	1.0 : 2.155	1.539	0.369	..
" " <i>iwoyiensis</i>	Onabamiro	1.0 : 2.078	1.417	0.421	1.039
" " <i>mahéensis</i>	Lindberg	1.0 : 2.008	1.259	0.361	2.067
" " <i>rylovi</i>	Lindberg	1.0 : 1.897	1.378	0.385	0.963
" " <i>vermifer</i>	Lindberg	1.0 : 1.701	1.335	0.360	1.212
" " <i>mongolicus</i>	Kiefer	1.0 : 1.626	1.176	0.376	1.597
" " <i>retroversus</i>	Kiefer	1.0 : 1.473	1.312	0.389	1.721
" " <i>microspinulosus</i>	Lindberg	1.0 : 1.497	1.260	0.401	1.304

It is clear from the above that there is a progressive lengthening of seta 1 in proportion to seta 2 and not quite so regular a lengthening in respect to seta 3.

The present examples come near to *tinctus* and *schmeili hastatus* as regards the proportions of seta 1 to setae 2 and 3, and as regards the proportions of seta 1 and 4 they come near to *inopinus* and of seta 4 to 6 near to *iwoyiensis* and *pachysetosus*.

In a number of species the proportions of seta 1 to seta 3 fall into a progressive series, as follows :—

Species	Seta 1 : seta 3
<i>M. (Th.) operculatus aberrans</i> . . .	1·0 : 4·05
„ „ Present examples . . .	1·0 : 3·029
„ „ <i>tinctus</i> . . .	1·0 : 2·696
„ „ <i>schmeili, hastatus</i> . . .	1·0 : 2·591
„ „ <i>inopinus</i> . . .	1·0 : 2·220
„ „ <i>pachysetosus</i> . . .	1·0 : 2·14
„ „ <i>schmeili schmeili</i> . . .	1·0 : 2·066 or 1·977 (Lindberg)
„ „ <i>dybowski</i> . . .	1·0 : 2·046
„ „ <i>trichophorus</i> . . .	1·0 : 1·539
„ „ <i>iwoyiensis</i> . . .	1·0 : 1·417
„ „ <i>vermifer</i> . . .	1·0 : 1·345
„ „ <i>rylovi</i> . . .	1·0 : 1·331-1·482
„ „ <i>hyalinus</i> . . .	1·0 : 1·297 or 1·431 (Gurney)
„ „ <i>microspinulosus</i> . . .	1·0 : 1·291
„ „ <i>maheensis</i> . . .	1·0 : 1·269
„ „ <i>mongolicus</i> . . .	1·0 : 1·175
„ „ <i>hyalinus</i> . . .	1·0 : 1·159 (Mann)

Here we seem to have an indication of a break in the series between *dybowski* and *trichophorus* : in the top part of the series we have the present examples and the two subspecies of *schmeili* together with *operculatus aberrans*, *tinctus*, *inopinus*, *pachysetosus*, and *dybowski*.

If we take the proportions of seta 1 to 4 in different species we get the following series in an ascending scale :

<i>M. (Th.) hyalinus</i>	1·0 : 0·309—0·503
„ „ <i>oithonoides</i>	1·0 : 0·335
„ „ <i>rylovi</i>	1·0 : 0·350
„ „ <i>decipiens</i>	1·0 : 0·353
„ „ <i>vermifer</i>	1·0 : 0·348—0·519
„ „ <i>maheensis</i>	1·0 : 0·361
„ „ <i>trichophorus</i>	1·0 : 0·369

<i>M. (Th.) microspinulosus</i>	1·0 : 0·418
„ „ <i>iwoyiensis</i>	1·0 : 0·421
„ „ <i>neglectus prolatus</i>	1·0 : 0·429
„ „ <i>schmeili schmeili</i>	1·0 : 0·523—0·589 or 0·60
„ „ <i>dybowski</i>	1·0 : 0·569
„ „ Present examples	1·0 : 0·592
„ „ <i>inopinus</i>	1·0 : 0·596
„ „ <i>conspicuus</i>	1·0 : 0·735—0·870
„ „ <i>tinctus</i>	1·0 : 0·777
„ „ <i>schmeili hastatus</i>	1·0 : 0·87—0·962

Here again we get a progressive series ; but the most interesting point is the great range of the proportions between the two subspecies of the species *schmeili*, in which the range extends from 0·523 to 0·962 and between the two subspecies fall the present examples and the species *dybowski*, *inopinus*, *conspicuus*, and *tinctus*. Clearly no distinction, so far as the proportions of these two setae are concerned, can be drawn between these species.

In the proportions of setae 4 and 6 we again get a progressive sequence as follows :—

<i>M. (Th.) mahéensis</i>	1·0 : 2·067
„ „ <i>retroversus</i>	1·0 : 1·721
„ „ <i>hyalinus consimilis</i>	1·0 : 1·720—1·14
„ „ <i>mongolicus</i>	1·0 : 1·597
„ „ <i>schuurmanae</i>	1·0 : 1·314
„ „ <i>microspinulosus</i>	1·0 : 1·304
„ „ <i>vermifer</i>	1·0 : 1·212
„ „ Present examples	1·0 : 1·079
„ „ <i>operculatus aberrans</i>	1·0 : 1·049
„ „ <i>pachysetosus</i>	} 1·0 : 1·039
„ „ <i>iwoyiensis</i>	
„ „ <i>neglectus neglectus</i>	1·0 : 1·035
„ „ <i>rylovi</i>	1·0 : 0·963
„ „ <i>tinctus</i>	1·0 : 0·950
„ „ <i>dybowski</i>	} 1·0 : 0·744
„ „ <i>schmeili schmeili</i>	
„ „ <i>schmeili hastatus</i>	1·0 : 0·665

and here again the species fall into two groups, the group with the lower proportions extending from the present examples with a proportion of 1.0 : 1.079 to the subspecies of *schmeili*, *schmeili* and *hastatus*, with proportions of 1.0 : 0.665 and 0.744, and between these two extremes fall *operculatus aberrans*, *pachysetosus*, *iwoyiensis*, *neglectus neglectus*, *rylovi*, *tinctus* and *dybowski*.

The antennule (Text-fig. 3 B.), as in other members of the genus is composed of seventeen segments : it reaches back only as far as the posterior margin of the cephalothorax (Th. I). I have been unable to detect any trace of a hyaline membrane on the border of either of the two terminal segments : such a membrane has been recorded in *M. (Th.) oithonoides*, *hyalinus* and *dybowski* (Gurney, 1933) and in *inopinus* (Kiefer, 1926) and in the last two joints in *tenuis* (Marsh) and the last joint in *minutus* by Lowndes (1934) ; and Lindberg (1935, p. 413) has recorded such a membrane in *vermifer*, but it seems probable that these examples which he was describing were actually examples of *hyalinus*. I have been unable to find any mention of such a structure in any other member of the subgenus.

Lindberg (1947, p. 130) has recorded that in *conspicuus* the proximal 6 segments are ornamented with small pits. It seems probable that this ornamentation is of the same type as that seen in the abdominal segments of some species (*vide supra*, p. 90), namely, *conspicuus* and *microspinulosus*. Gurney (1933, fig. 1904) has shown a short spine at the distal anterior angle of the 6th segment in *dybowski*. In the present examples there is a somewhat similar one, not on the 6th segment, however, but on the anterior margin about the middle of the length of the 7th segment. In a Table on p. 59 Gurney (1933) has given a comparison of the segmentation of the antennules of *Diaptomus* and *Cyclops*, but in the present examples there seem to be differences from Gurney's arrangement for *Cyclops*.

Antennal segments of female :—														
<i>Diaptomus</i>	1	2	3	4	5	6	7	8	9	10	11	12	13	14
(from Gurney) 1933														
<i>Cyclops</i>	1			2		3	4			5		sp	6	7
Present examples	1			2		3	4		5		6		7	8
							sp.						sp.	
<i>Diaptomus</i>	15	16	17	18	19	20	21	22	23	24	25			
(from Gurney) 1933														
<i>Cyclops</i>	8	9	10	11	12	13	14	15	16	17				
Present examples	9	10	11	12	13	14	15	16		17				

In the present specimens the 4th segment appears to correspond to 7th and 8th of *Diaptomus*, not 7th, 8th and 9th as indicated by Gurney ; the 5th corresponds to the 9th and 10th, the 6th to the 11th, the 7th to the 12th and 13th, the 8th to the 14th, and the 16th to the 22nd and 23rd, and the 17th to the 24th and 25th segments. Thus the spine on the middle of the anterior margin of the 7th segment corresponds with the spine on the 12th segment in *Diaptomus*, and that on the 6th segment in *M. (Th.) dybowski*.

The proportional lengths of the various antennular segments, taking the total length of the appendage as 1000, are as follows :—

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
186		49	24	64	49	25	62	39	36	39	40	47	45	46	63	88	98	=1000
188		46	23	64	50	27	64	32	37	37	46	50	41	46	64	83	100	=1000
192		45	27	64	50	27	64	32	36	36	45	50	41	45	64	82	100	=1000
Average	189	47	25	64	50	26	63	34	36	37	44	49	42	46	64	83	99	=999

Unfortunately in their descriptions of most species in this subgenus the authors have omitted giving any measurements of the individual segments. I give below a few such measurements and I have added an estimate of the lengths in the subspecies *schmeili hastatus* based on Kiefer's illustration (1952, fig. 77).

Segment	1	2	3	4	5	6	7	8	
<i>vermifer</i>	164	41.5	25.5	67	43.5	25.5	75.5	33	41.5
<i>rylovi</i>	174	44	25	75	44	34	75	25	42
<i>schmeili hastatus</i>	183	35	22	74	46	38	67	34	34
Present examples	189	47	25	64	50	26	66	34	36
<i>stinctus</i>	175	30	65	55	38	44	44	38	33
<i>iwoyiensis</i>	210	34	29	38	38	29	38	38	34
Segment	10	11	12	13	14	15	16	17	
<i>vermifer</i>	43	52	49.5	44	55	57	98.5	83.0	1,000
<i>rylov</i>	42	48	48	44	52	52	80	94	1,000
<i>schmeili hastatus</i>	32	49	53	40	45	53	96	99	1,000
Present examples	37	44	49	42	46	64	83	99	1,000
<i>stinctus</i>	38	44	44	33	49	60	93	109	1,000
<i>iwoyiensis</i>	42	55	42	50	46	71	97	109	1,000

The present examples thus appear to come between *rylovi* and *iwoyiensis* and close to *schmeili hastatus*. It appears that in the above series there is a tendency towards a gradual increase in the length of the 1st segment and of the 17th. The species *vermifer* differs from the others in that the terminal segment (17th) is considerably shorter than the previous one (16th).

The antenna (Text-fig. 3C.) is composed of the usual four segments, of which the 1st is slightly longer than the 2nd and 3rd and the 4th a little shorter : the segments in two specimens have the following average lengths :—

Segment	1	2	3	4
	29	24	24	23
	= 100			

The 3rd segment bears six or seven setae on its anterior border and the 4th segment bears seven terminally. Most authors give no account of this appendage in their description of the species but Sars (1909) states that in *M. (Th.) neglectus* the 3rd joint bears 9 setae and Gurney (1933, fig. 1907) shows 6 only in *dybowskii*.

The mandible (Text-fig. 3 D, E) is strongly built and consists of a stout basal segment that is produced internally into a long curved gnathobase that terminates in a somewhat oblique biting edge, armed from the upper margin downwards with a strong tooth with three terminal pointed projections ; this is followed after a gap by a similar but less strongly-formed tooth, then comes a simple spine-like tooth and finally there are two setae at the lower end of the biting margin.

The maxillula (Text-fig. 3 F) is strongly built and exhibits the usual form.

The Maxilla (Text-fig. 3 G) has the usual shape and armature but exhibits an interesting variation : in some examples the posterior border of the 2nd basal segment is perfectly straight and without any protuberances : but in other specimens (Text-fig. 3 H) it exhibits a quite distinct corrugation near the proximal end, thus resembling the condition found in *M. (M.) leuckarti* (Claus). A similar variation appears to be occasionally present in *M. (Th.) hyalinus* (Rehberg) for, according to Gurney (1933, p. 298) this segment is "not ribbed" ; but Andreae (1955, p. 287) found that in this species there are "a few minor protuberances" Gurney (1933, fig. 1908) figures a single protuberance in this position in *M. (Th.) dybowskii* (Lande).

In the four pairs of Swimming legs the two rami are composed of three segments and the spine formula is, as in all other species in the subgenus, 2,3,3,3. The setae arising from the various parts of these limbs usually appear to be smooth and devoid of the usual fringing lateral hairs ; but in each leg, certain setae are slightly modified ; they are somewhat stouter than those arising from the more distal segments and have an appearance of being fringed along the more proximal part by rows of small thickenings of the cuticle. In the 1st leg (Text-fig. 3 I) the 1st basal segment bears a modified seta at its distal inner angle ; basal 2 bears a simple seta on its outer margin and a modified seta at the distal end of its curved inner border. In the possession of this last seta these examples resemble specimens of *M. (Th.) hyalinus* (Rehb.) (*vide* Gurney, 1933, fig. 1886) and *dybowskii* (Lande) (*vide* Gurney, 1933, fig. 1910) and also what I took to be *M. (Th.) rylovi* Smirnov (*vide* Sewell, 1934, p. 93) and differ from *oithonoides*, in which this inner seta is wanting (*vide* Sars 1913-1918, Pl. XXXVI, fig. p1). The inner seta on the 1st segment of the exopod is also modified.

In the 2nd leg (Text-fig. 3 J) the inner seta of basal 1 is modified : basal 2 bears an outer seta and at its distal inner angle it is produced into a conical prominence that is tipped with a short spine-like projection ; there is also a short spinous process on the distal margin of the segment between the articulations of the rami : the 1st segment of the exopod bears a modified inner seta.

The 3rd leg (Text-fig. 3 K) resembles the 2nd in all respects.

In the 4th leg (Text-fig. 3 L) basal 1 bears a modified inner seta : basal 2 bears an outer seta that instead of projecting outwards runs along the face of exopod 1 almost as far as its distal margin, thus resembling *M. (Th.) hyalinus*, *dybowskii* and *rylovi*. There is a spine-like projection on the distal margin between the attachments of the rami, and the inner distal angle is produced into a spine-tipped conical process, as in the 2nd and 3rd legs. The 1st segment of the exopod bears a modified seta. The proportions of the 3rd segment of the endopod

have been utilised by previous observers as a specific character ; in the present specimens this segment is of moderate length and the proportions of length to maximum breadth are as follows :—

Length :	Breadth
2.82 :	1.0
2.80 :	1.0 average 2.65 : 1.0
2.73 :	1.0
2.25 :	1.0

In this character we again find a gradual change in the proportions in the different species and in many of them there is a wide range of variation. I give below the proportional measurements as recorded in a series of species by various observers :—

Species	Data from	Range of variation Length : breadth	Average
<i>M. (Th.) macracanthus</i>	Kiefer, 1929, p. 314	....	3.50 : 1.0
„ „ <i>hyalinus persicus</i>	Lindberg,	....	3.50 : 1.0
„ „ <i>neglectus</i>	Kiefer, 1952, Table X	3.22—3.4 : 1.0	3.31 : 1.0
„ „ <i>vermifer</i>	Lindberg, 1942, p. 185	2.32—4.0 : 1.0	3.248 : 1.0
„ „ <i>mahéensis</i>	Lindberg, 1941, p. 263	3.05—3.4 : 1.0	3.152 : 1.0
„ „ <i>hyalinus</i>	Gurney, 1933, p. 299	2.34—3.52 : 1.0	3.102 : 1.0
	Mann, 1940	2.88—3.07 : 1.0	2.94 : 1.0
	Kiefer, 1952, Table XI	2.06—3.03 : 1.0	2.68 : 1.0
„ „ <i>tenuis</i>	Lowndes, 1934, p. 111	....	3.2 : 1.0
„ „ <i>asiaticus</i>	Kiefer, 1932	....	3.0 : 1.0
„ „ <i>dybowski</i>	Gurney, 1933, p. 305	2.90—3.16 : 1.0	3.06 : 1.0
„ „ <i>decipiens</i>	Kiefer, 1952	....	3.0 : 1.0
„ „ <i>analogus</i>	Kiefer, 1936, p. 230	....	3.0 : 1.0
„ „ <i>infrequens</i>	Kiefer, 1929, p. 316	....	3.0 : 1.0
	Kiefer, 1952, Table X	2.79—3.02 : 1.0	2.895 : 1.0
„ „ <i>pachysetosus</i>	Lindberg, 1951	2.5—3.0 : 1.0	2.75 : 1.0
„ „ <i>rylovi</i>	Lindberg, 1942, p. 181	2.33—3.09 : 1.0	2.75 : 1.0
„ „ <i>inopinus</i>	Kiefer, 1926	....	2.72 : 1.0
	Present specimens	2.25—2.82 : 1.0	2.65 : 1.0
„ „ <i>microspinulosus</i>	Lindberg, 1942, p. 187	2.22—3.04 : 1.0	2.55 : 1.0
„ „ <i>schmeili hastatus</i>	Kiefer, 1952, Table X	2.33—2.50 : 1.0	2.55 : 1.0
„ „ <i>schmeili schmeili</i>	Kiefer, 1952, Table X	2.08—2.65 : 1.0	2.40 : 1.0
„ „ <i>operculatus aberrans</i>	Lindberg, 1952	....	2.29 : 1.0
„ „ <i>tinctus</i>	Lindberg, 1941, p. 264	1.40—1.951 : 1.0	1.594 : 1.0

Thus the present specimens come near to *inopinus* and *rylovi* on the one hand and *microspinulosus* and *schmeili* on the other in the lower part of the table. In some species there is a wide range of variation, as for instance, in *vermifer* and *hyalinus*, especially in the former with a range 2.32—4.0, covering all the other species in the Table with the exception of the last two, *operculatus aberrans* and *tinctus*.

Another character used by previous observers to assist in discriminating between species has been the proportional lengths of the distal segment of the endopod of the 4th leg and of the inner terminal spine on the distal extremity of the joint. I give below the various proportions that have been recorded :—

Species	Data from	Proportional lengths Inner spine : endopod 3	Average
<i>M. (Th.) oithonoides</i>	Gurney, 1933, p. 299	....	1.56 : 1.0
„ „ <i>rylovi</i>	Lindberg, 1942, p. 121	1.0—1.27 : 1.0	1.24 : 1.0
„ „ <i>inctus</i>	Lindberg, 1941, p. 264	1.11—1.33 : 1.0	1.221 : 1.0
„ „ <i>asiaticus</i>	Kiefer, 1932	....	1.22 : 1.0
„ „ <i>mongolicus</i>	Kiefer, 1937, p. 297	....	1.159 : 1.0
„ „ <i>operculatus aberrans</i>	Lindberg, 1952	....	1.103 : 1.0
„ „ <i>schmeili hastatus</i>	Kiefer, 1952, Table XII	1.04—1.20 : 1.0	1.12 : 1.0
„ „ <i>iwoyiensis</i>	Onabamiro, 1952	1.0—1.1 : 1.0	1.083 : 1.0
„ „ <i>mahéensis</i>	Lindberg, 1941, p. 263	1.05—1.09 : 1.0	1.072 : 1.0
„ „ <i>vermifer</i>	Lindberg, 1942, p. 182	0.813—1.124 : 1.0	0.990 : 1.0
	Lindberg, 1938, p. 235	0.714—1.137 : 1.0	0.975 : 1.0
„ „ <i>microspinulosus</i>	Lindberg, 1942, p. 182	0.855—1.124 : 1.0	0.947 : 1.0
„ „ <i>inopinus</i>	Kiefer, 1926	....	0.941 : 1.0
„ „ <i>tenuis</i>	Lowndes, 1934, p. 111	....	0.941 : 1.0
„ „ <i>decepiens</i>	Kiefer, 1952, Table VI	....	0.915 : 1.0
„ „ <i>trichophorus</i>	Kiefer, 1930, p. 82	....	0.885 : 1.0
„ „ <i>hyalinus</i>	Gurney, 1933, p. 299	0.73—1.04 : 1.0	0.795 : 1.0
	Lindberg, 1938, p. 235	0.699—1.042 : 1.0	0.870 : 1.0
	Kiefer, 1952, Table XI	0.750—0.915 : 1.0	0.847 : 1.0
Present specimens	....	0.786—0.891 : 1.0	0.855 : 1.0
„ „ <i>infrequens</i>	Kiefer, 1929, p. 315	....	0.50 : 1.0
	Kiefer, 1952, Table VI	0.818—0.905 : 1.0	0.849 : 1.0
„ „ <i>schmeili schmeili</i>	Kiefer, 1952, Table XII	0.808—0.990 : 1.0	0.895 : 1.0
„ „ <i>dybowskii</i>	Gurney, 1933, p. 305	....	0.74 : 1.0

In this series we again find a gradual reduction in the proportional lengths of the inner spine and the endopod 3 of the 4th leg, ranging from 1.56 in *oithonoides* to 0.74 in *dybowskii*. If, as I believe, the present specimens are examples of the species *M. (Th.) schmeili* Poppe and Mrázek then the extreme range of variation in these proportional lengths extends from 0.786 : 1.0 in the present form through 0.808—0.990 : 1.0 in the subspecies *schmeili* (s. str.) to 1.20 : 1.0 in *hastatus* Kiefer, and such a

range covers the proportions found in all the other species with the exception of *oithonoides*, at the head of the Table and *dybowskii* at the bottom. Another character that has been used in the discrimination of species in this subgenus is the proportional lengths of the two end-spines on the terminal segment of the endopod of the 4th leg. In the Table below I give the average proportions of these in most of the species and subspecies, and, where the data have been given by previous authors, the extremes of variation :—

Species	Data from	Proportional lengths of terminal spines of endopod 3 of P4 Inner : Outer.	Average
<i>M. (Th.) oithonoides</i>	Gurney, 1933, p. 299	....	4.100 : 1.0
„ „ <i>retroversus</i>	Lindberg, 1951	3.32—4.01 : 1.0	3.86 : 1.0
„ „ <i>twoyiensis</i>	Onabamiro, 1952, p. 257	2.4—3.1 : 1.0	2.60 : 1.0
„ „ <i>hyalinus</i>	Kiefer, 1937, p. 296	2.20—2.22 : 1.0	2.21 : 1.0
	Lindberg, 1937, p. 235	2.80—3.33 : 1.0	2.51 : 1.0
	Gurney, 1933, p. 299	1.60—2.70 : 1.0	2.207 : 1.0
„ „ <i>persicas</i>	Lindberg	2.8—2.9 : 1.0	2.85 : 1.0
„ „ <i>ndalaganus</i>	....	2.12—2.17 : 1.0	2.145 : 1.0
„ „ <i>hivucnsis</i>	....	....	2.08 : 1.0
„ „ <i>hyalinus</i>	Kiefer, 1952	1.81—2.16 : 1.0	2.10 : 1.0
„ „ <i>byzantinus</i>	....	2.03—2.11 : 1.0	2.058 : 1.0
„ „ <i>macrolasius</i>	....	1.93—2.14 : 1.0	2.055 : 1.0
	Mann, 1940	1.92—2.44 : 1.0	2.18 : 1.0
„ „ <i>neglectus</i>	Sars, 1909	3.5—4.0 : 1.0	3.75 : 1.0
<i>bcipiens</i>	Kiefer, 1952 ....	....	2.67 : 1.0
<i>neglectus</i>		2.0—2.78 : 1.0	2.39 : 1.0
<i>prolatus</i>	...	....	1.79 : 1.0
„ „ <i>infrequens</i>			
<i>nigerianus</i>	....	....	2.33 : 1.0
<i>eduardensis</i>	Kiefer 1952	....	2.20 : 1.0
<i>infrequens</i>	....	1.76—2.07 : 1.0	1.864 : 1.0
„ „ <i>mongolicus</i>	Kiefer, 1937, p. 297	....	2.353 : 1.0
„ „ <i>mahéensis</i>	Lindberg, 1941, p. 261	2.14—2.48 : 1.0	2.324 : 1.0
„ „ <i>vermifer</i>	Lindberg, 1942	1.89—2.83 : 1.0	2.28 : 1.0
„ „ <i>pachyestusus</i>	Lindberg, 1951	....	2.12 : 1.0
„ „ <i>tinctus</i>	Lindberg, 1942, p. 22	....	1.96 : 1.0
	Lindberg, 1941, p. 264	1.57—1.89 : 1.0	1.779 : 1.0
„ „ <i>rylovi</i>	Lindberg, 1942	1.45—2.18	1.89 : 1.0
„ „ <i>tenuis</i>	Lowndes, 1934, p. 111	....	1.889 : 1.0
„ „ <i>inoptnus</i>	Kiefer, 1926	....	1.882 : 1.0
„ „ <i>operculatus aberrans</i>	Lindberg, 1952	....	1.50 : 1.0
Present examples	....	1.158—1.545 : 1.0	1.426 : 1.0
„ „ <i>conspicuns</i>	Lindberg, 1947, p. 130	1.05—1.10 : 1.0	1.075 : 1.0
„ „ <i>schmeili schmeili</i>	Kiefer, 1952	1.01—1.125 : 1.0	1.06 : 1.0
„ „ <i>schmeili hastatus</i>	Kiefer, 1952	0.83—0.96 : 1.0	0.895 : 1.0
„ „ <i>dybowsaii</i>	Gurney, 1933, p. 305	0.80—0.895 : 1.0	0.842 : 1.0

Here again we get a gradual sequence without any clear break in the series except at the very top with *oithonoides* and *retroversus*, and, according to Sars, *neglectus*, exceeding a proportion of 3.5: 1.0. In all the other species the average proportion falls within a range of 0.842 to 2.60; an almost equally wide range appears from the data given by different observers to be present in *hyalinus* (s. lat.), in which it extends from 1.60 to 3.33 and in *vermifer* with a range of from 1.89 to 2.83. In the present examples the range of variation from 1.158 to 1.545 overlaps the range found in *rylovi*, and if linked with the proportions in the subspecies of *schmeili*, the combined range 0.83—1.545, overlaps that of *dybowskii*.

Kiefer (1952) has laid considerable emphasis on the character of the connecting plate between the 4th pair of swimming legs and I have already (*vide supra*, p. 84) pointed out that Lindberg is less dogmatic about this point and has shown that in a given species there may be a very considerable range of difference and even in rare instances the plate may not be symmetrical, one side conforming to the condition in one species, e.g., *rylovi*, and on the other to a different species, such as *vermifer*; and later (1951) he pointed out that his examples of *M. (Th.) schmeili* taken in Lake Tanganyika differed from those recorded by Kiefer from the Belgian Congo in that the rounded prominences at the sides of the distal border of the plate were wanting and their place was taken by 2 or 3 spinules on the margin and scattered hairs on the surface.

In the present specimens the connecting plate of the 1st swimming legs has a well rounded prominence, each surmounted by some 5 or 6 small spines and between these prominences the interval is equal in width to the prominence itself. In the 2nd and 3rd legs the prominences are equally well rounded but are narrower than those of the 1st leg and bear only 3 or 4 spinules. In the 4th leg the prominences are narrow but project well beyond the margin of the plate and are separated by a space about twice the width of the prominence; their margins are devoid of any spinules and in their general appearance resemble those of *M. (Th.) trichophorus* Kiefer (1930) and *M. (Th.) oithonoides* Sars, as figured by him (1913-18 Pl. XXXVI, p. 4).

The 5th leg (Text-fig. 3 M) consists of the usual two segments; the proximal segment bears a single seta at its distal outer angle and the free segment is of moderate length and bears an outer seta on the distal margin and an inner spine near the inner distal angle either on the distal border or on the inner margin. In the present examples in some instances both seta and spine arise from the distal border but in others the spine springs either from the distal inner angle of the segment or from the inner margin close to the distal angle. The spine appears to be denticulate as in both *schmeili schmeili* and *schmeili hastatus* in which it is, according to Kiefer, fringed with minute spinules along the distal two-thirds of its length. In other species it seems that this spine may be either denticulate or smooth. In *hyalinus* Gurney (1933, fig. 1955) has shown the spine as smooth in a specimen from India, but Lindberg (1938, Pl. V, fig. 11) shows it as being denticulate along the distal two-thirds of its outer border; and Lowndes (1934, p. 111) states that in specimens of *M. (M.) meridianus* Kiefer from South America this limb was variable, "the inner seta of the second joint," he states, "may be quite stout and bear coarse teeth or it may be quite fine and smooth" The relative lengths of the terminal seta and spine on the free segment have been used as a diagnostic feature between members of the subgenus: but here again there seems to be a great range of variation in certain

species and in the Table following I give the relative lengths* of the inner spine to the outer seta as recorded by previous observers :—

Species	Data from	Proportional lengths Inner spine : outer seta	Average
<i>M. (Th.) neglectus</i>	Sars, 1909	....	about 1·0 : 1·0
„ „ <i>oithonoides</i>	Gurney, 1933, fig. 1897	....	1·0 : 1·0
„ „ <i>hyalinus</i>	Gurney, 1933, p. 298 Gurney, 1933, fig. 1895	....	1·0 : 1·0 1·56 : 1·0
	Gurney, 1938	0·80—1·5 : 1·0	1·07 : 1·0
	Gurney, 1951	1·10—1·49 : 1·0	1·29 : 1·0
	Lindberg, 1935	1·15—1·46 : 1·0	1·33 : 1·0
„ „ <i>infrequens</i>	Kiefer, 1938, fig. 31	....	1·07 : 1·0
„ „ <i>vermifer</i>	Lindberg, 1942	0·96—1·56 : 1·0	1·10 : 1·0
	Lindberg, 1938	1·0—2·03 : 1·0	1·28 : 1·0
	Lindberg, 1935	1·15—1·46 : 1·0	1·33 : 1·0
„ „ <i>dybowskii</i>	Gurney, 1933, fig. 1914	....	1·12 : 1·0
„ „ <i>retroversus</i>	Lindberg, 1951	1·09—1·23 : 1·0	1·16 : 1·0
„ „ <i>emini</i>	Kiefer, 1938, fig. 49	....	1·20 : 1·0
„ „ <i>schuurmanae</i>	Lindberg, 1951	1·08—1·26 : 1·0	1·20 : 1·0
„ „ <i>rylovi</i>	Lindberg, 1942, p. 181	1·0—1·76 : 1·0	1·26 : 1·0
	Sewell, 1934, fig. 7 b.	....	1·67 : 1·0
„ „ <i>mahéensis</i>	Lindberg, 1941, fig. 1a	1·20—1·33 : 1·0	1·27 : 1·0
„ „ <i>pachysetosus</i>	Lindberg, 1951	1·26—1·34 : 1·0	1·30 : 1·0
„ „ <i>operculatus aberrans</i>	Lindberg, 1952	....	1·31 : 1·0
„ „ <i>macracanthus</i>	Kiefer, 1938, fig. 42	....	1·36 : 1·0
„ „ <i>tinctus</i>	Lindberg, 1941, fig. 1a	1·3—1·5 : 1·0	1·4 : 1·0
„ „ <i>analogus</i>	Kiefer, 1936, p. 229	....	1·40 : 1·0
„ „ <i>neglectus decipiens</i>	Kiefer, 1952, fig. 55	....	1·40 : 1·0
„ „ Present examples	....	1·36—1·50 : 1·0	1·43 : 1·0
„ „ <i>mongolicus</i>	Kiefer, 1937	....	1·44 : 1·0
„ „ <i>schmeili schmeili</i>	Lindberg, 1951	1·46—1·50 : 1·0	1·48 : 1·0
	Kiefer, 1952 fig. 30	....	1·78 : 1·0
„ „ <i>trichophorus</i>	Kiefer, 1930	....	1·91 : 1·0
„ „ <i>schmeili hastatus</i>	Kiefer, 1952, fig. 73	....	1·91 : 1·0

Here again we find that the species fall into a gradual series in which the outer seta becomes relatively shorter in comparison with the inner spine, and in those species of which we have sufficient data the proportional lengths of these two structures to each other show a wide range, as for instance in *hyalinus*, from a number of different localities, where the extreme range extends from 0·80 to 1·56, thus covering almost the whole series of proportions in all the species in the list. The present examples come near to *tinctus*, *analogus* and *neglectus decipiens*, in all of

* In those species such as *mahéensis* and *tinctus*, in which no actual measurements have been given I have attempted to calculate the proportions of the two appendages from the figures, where such have been given : but these estimates can only be regarded as approximate.

which the average proportion is 1.140 : 1.0 and *macracanthus*, in which the estimated proportion is 1.36 : 1.0 ; on the other hand they are close to *mongolicus*, with a proportion of 1.44 : 1.0 and *schmeili schmeili* which according to Lindberg has an average of 1.48 : 1.0.

♀ *Copepodid Stage V* (Text-fig. 4)

The total length of the animal in this stage is 0.9 mm. The proportional lengths of the anterior and posterior regions of the body are as 1.80 or 1.67 : 1.0 ; average 1.735 : 1.0. The proportional lengths of the various segments of the body are as follows :—

Ceph.—Th. I	Th. II	III	IV	V	Abd. 1	2	3	4-5	Furca
368	99	94	58	45	63	58	49	71	95 =100
369	100	95	60	50	60	56	50	65	95 =1000
Average 368.5	99.5	94.5	59	47.5	61.5	57	49.5	68	95 =1000

The furcal rami are parallel and the proportional dimensions of length to breadth are :—

22 (14.5+7.5) :	6.5 or 3.38 : 1.0
23 (15.0+8.0) :	6.5 or 3.54 : 1.0
Average	3.46 : 1.0

In the above table I have given the lengths of the proximal and distal portions of the length of the ramus from the point of origin of the 5th seta.

The furcal setae have the following proportional lengths :—

Seta 1	2	3	4	5	6
24.0	100	73.3	16.0	6.7	..
24.3	100	78.3	22.9	8.6	21.4
Average 24.15	100	75.8	19.45	7.65	21.4

The proportional lengths of the various setae to each other in this stage are as follows :—

Proportional lengths of furcal setae				
	1—2	1—3	1—4	4—6
Present examples, Stage V	1.0 : 4.14	3.139	0.805	1.10

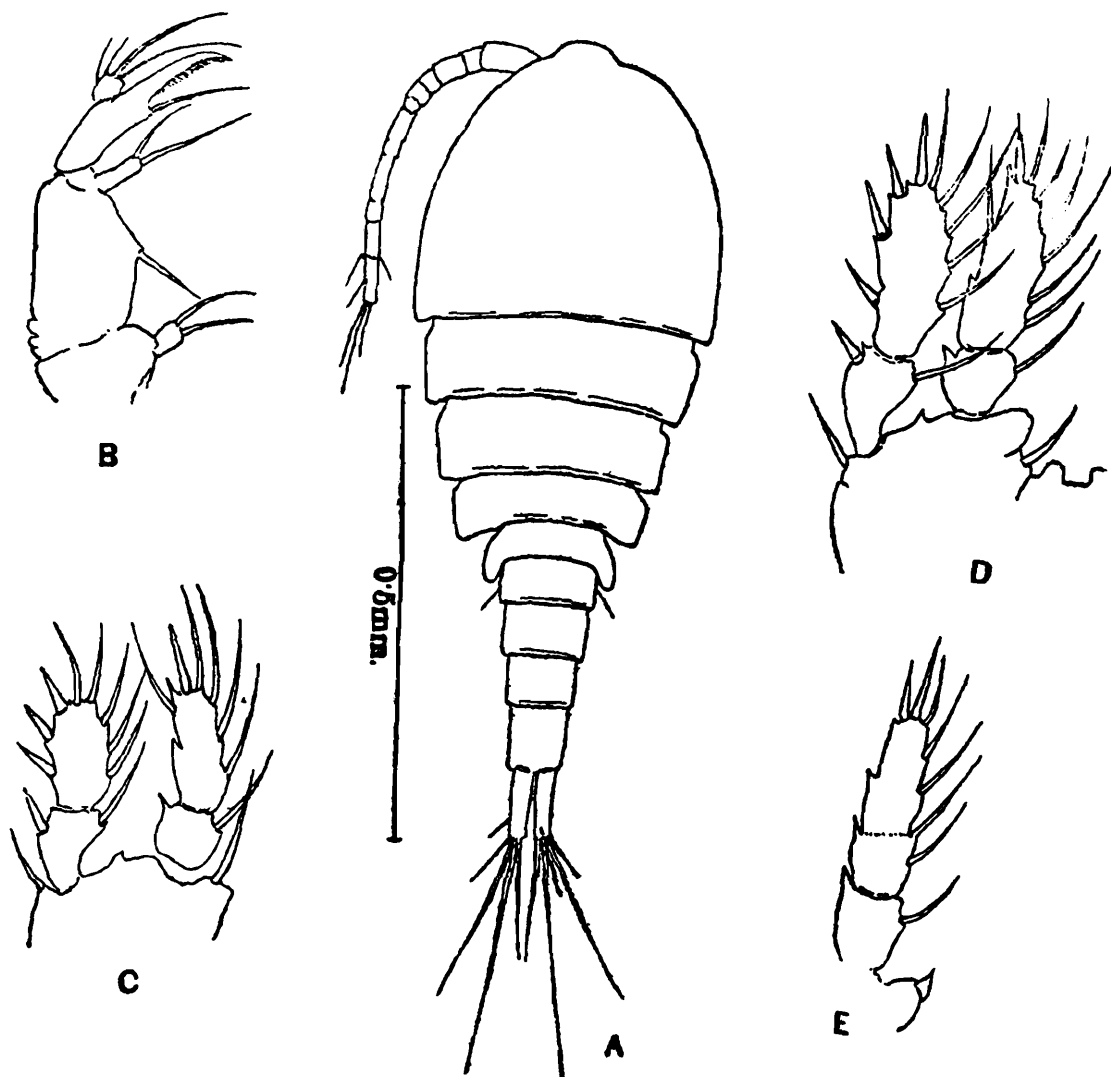
The antennule in this stage is composed of only eleven free segments that have the following proportional lengths :—

Segment	1	2	3-4	5	6	7	8-9-10-11	12-13-14	15	16	17
	195	43	76	49	27	59	146	124	59	92	130
	172	40	75	46	23	63	161	128	69	98	125
Average	183.5	41.5	75.5	47.5	25.0	61.0	153.5	126.0	64	95	127.5

The antenna and the mouth-parts are already fully developed and resemble those of the adult.

In the maxilla (Text-fig. 4 B) the same corrugation in the posterior margin of the 2nd basal segment, as has been noted in certain of the adults (*vide supra*, p. 99, Text-fig. 3, H), may be present at this stage also.

In the swimming legs (Text-fig. 4 C and E) the rami are composed of only two free segments, the 2nd and 3rd not having as yet separated, though the line along which separation will take place at the next moult can clearly be seen in the endopod running across the face of the undivided segment to terminate in a notch on the outer margin. None of



TEXT-FIG. 4.—*M. (Th.) schmeili* f. *marmagoensis*, Stage V.
A. Whole animal dorsal view. B. Maxilla. C. 1st swimming leg. D. 2nd swimming leg. E. Endopod of 4th swimming leg.

the setae arising from the basal segments or the proximal segment of the rami of any of the limbs is modified in the manner found in the adult. In the 4th leg the inner of the two spines on the distal margin of the terminal segment of the endopod is, as in the adult, considerably shorter than the length, as estimated, of that portion of the still fused 2nd and 3rd segments that at the next moult will separate off as segment 3; the tactual proportions are as 0.84 to 1.0. The two end-spines have between them selves the following proportional lengths :—

Inner spine : outer spine.

1.545 : 1.0

In the 5th leg the inner spine is about one-and-a-third times the length of the outer seta on segment 2, the proportions being 13 : 10 or 1.3 : 1.0.

♀ *Copepodid Stage IV* (Text-fig. 5)

Total length 0.717 mm. The proportional lengths of the anterior and posterior regions of the body in this stage are as 64 to 36 or 1.78 : 1.0 ; and the proportional lengths of the various segments are as follows :—

Ceph.—Th.	Th. II	III	IV	V	Abd. 1	2	3—5	Furca:	
375	100	95	75	50	65	55	90	95	1000

The furcal rami are long and narrow, having the proportion of length to breadth as 3.2 : 1.0, thus closely resembling the adult *schmeili hastatus*. In this stage the 5th furcal seta appears to arise somewhat nearer the base of the ramus, the lengths of the proximal and distal parts of the ramus being in the proportions of 7.5 : 12.5. The furcal setae have the following proportional lengths :—

Seta	1	2	3	4	5	6
	24	100	77	16	7	16
	24	100	73	16	7	..
Average	24	100	75	16	7	(16)

The proportional lengths of the setae in this stage are as follows :—

	Proportional lengths of setae			
	1—2	1—3	1—4	4—6
Present specimens, Stage IV	1.0 : 4.167	3.125	0.667	1.0

The antennule is, as in the adult, short and barely reaches to the level of the posterior margin of the cephalothorax. In this stage there are only eight separate joints in the appendage, though indications of future separation can be detected in the 2nd joint. The proportional lengths of the segments are as follows :—

Segments	1—2	3-4-5	6-7	8-9-10-11	12-13-14	15	16	17
	176	120 (80, 40)	80	160	160	64	104	136 = 1,000

The antenna and mouth-parts are very similar to those of the adult.

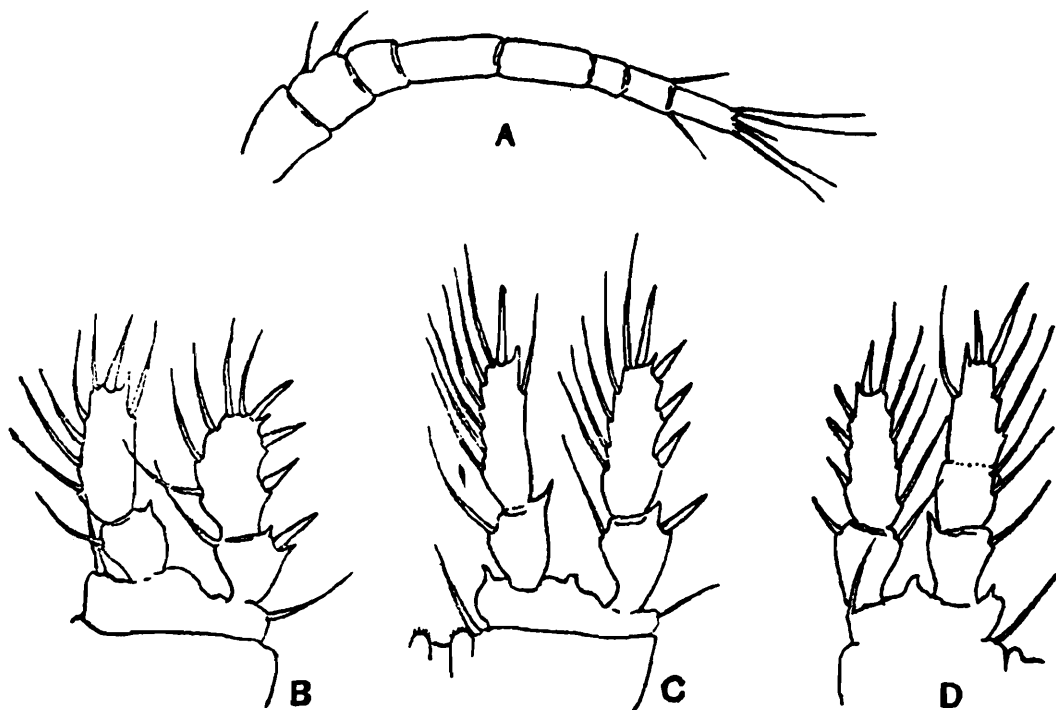
In the 4th swimming legs (Text-fig. 5 D) the proportional lengths of the inner and outer spines on the distal end of the endopod are as 9 to 5 or 1.80 : 1.0.

In the 5th leg the main structure was already similar to that of the adult and the inner spine at the distal end of the free segment was longer than the outer seta, but I was unable to get an exact measurement of either.

IV—DEVELOPMENTAL CHANGES

Although the total number of specimens was small, it seemed to be worth while to study the various changes that had taken place during the course of development in the final three stages of the life-history. During the successive moults both the body as a whole and the various parts undergo changes that result in an alteration in the proportions

of the various parts. The whole body increases in size at each moult but individual segments may increase at a higher rate than others. In



TEXT-FIG. 5.—*M. (Th.) schmeili* f. *marmagoensis*, Stage IV.
A. Antennule. B. 1st swimming leg. C. 2nd swimming leg. D. 4th swimming leg.

the present individuals the proportional lengths of the anterior and posterior regions change as follows :—

	Anterior region Ceph.-Th. I-IV		Posterior region Th. V, Abd. 1-5, furca
	mm.		
Stage IV	1.79	:	1.0
V	1.67	:	1.0
VI	1.47—1.52	:	1.0

It is thus clear that at each moult the posterior region increases in length at a greater rate than the anterior region ; but individual segments may also increase at a higher rate than others so that the proportional lengths of the segments of the body alter at each moult, as follows :—

	Ceph.-Th. I	Th. II	III	IV	V	Abd. 1	2	3	4	5	Furca
Stage IV	375	100	95	75	50	65	55		90		95 = 1000
Stage V	368.5	99.5	94.5	59	47.5	61.5	57	49.5	68		95 = 1000
Stage VI	351	86	85	79	50	124		58	55	27	86 = 1000

In the cephalothorax and the first two free thoracic segments there is a reduction in the proportional lengths of the region which is most marked in the moult from stage V to VI and in segments Th. IV and V the proportional lengths appear to decrease in the first moult from Stage IV to V and then increases again in the next moult from Stage V to VI. In the abdomen alterations in the length of the segments are complicated by the fusion of the two anterior segments at Stage VI to form the adult genital segment, and the separation of the combined posterior three segments, 3, 4 and 5, into two at Stage V and finally into 3 at Stage VI. The furcal rami do not appear to change between Stages IV and V but are

reduced in length at Stage VI : as in the Calanoida, when a segment divides at a moult into two daughter-segments the combined lengths of these is greater than the length of the parent, so that at the moult from Stage IV to V the three fused abdominal segments 3, 4, and 5 increase in length from 90 to two segments having the lengths of 49.5 and 68 (=117.5). At the anterior end of the abdomen the two segments 1 and 2 remain separate between Stages IV and V, having a combined length of 65+55(=120) in Stage IV and 61.5 and 57(=118.5) in Stage V and at Stage VI these fuse to form the genital segment which has a total length of 124. Andreac (1955, p. 292) has observed a similar change in length of abdominal segments 1 and 2 in the moult from Stage IV to V in *M. (Th.) hyalinus* (Rehberg) : in this species examples of Stage IV can be divided into two groups according to the number of segments in the antennule, one group having 10 segments and the other only 9, the difference being apparently a sexual one, the 10 segment group being females and the 9 segment group males. In the females the proportional lengths of the first 2 segments of the abdomen are given as follows :—

	Length in μ		Combined length 1-2	Proportions of segment 2 to 1	
	Segment 1	2			
Stage IV	48.3	43.4	91.7	1.0 :	1.113
Stage V	50.1	52.5	102.6	1.0 :	0.954

In the males with only 9 segments in the antennule the proportions are as follows :—

	Length in μ		Combined length 1-2	Proportions of segment 2 to 1	
	Segment 1	2			
Stage IV	49.7	41.3	91.0	1.0 :	1.203
Stage V	53.2	47.3	100.5	1.0 :	1.125

In the present collection I have only females and in these the measurements are as follows :—

	Length in μ		Combined length 1-2	Proportions of Segment 2 to 1	
	Segment 1	2			
Stage IV	46.6	39.4	86.0	1.0 :	1.193
Stage V	55.4	51.3	106.7	1.0 :	1.080

The proportions found in the present examples are thus of much the same order as in *hyalinus* and cannot be regarded as having any specific significance ; such slight differences may well be due to different environmental conditions.

Similar changes are to be seen in the successive stages in the proportions of length to breadth in the furcal ramus ; these are as follows :—

	Length	:	Breadth	Mean
Stage IV	3.20	:	1.0	
Stage V	3.38—3.54	:	1.0	3.46 : 1.0
Stage VI	3.38—3.83	:	1.0	3.633 : 1.0

Thus at Stage IV the proportions fall within the range found in the adults of *vermifer*, *dybowskii* and *rylovi* and only extremely little above the upper limit found in *schuurmanae* and *schmeili hastatus* : in Stage V it falls within or overlaps the range found in *rylovi*, *mahéensis*, *tinctus*, *analogus* and *inopinus* : and in Stage VI it lies between the ranges found in *schmeili schmeili* and *schmeili hastatus* in a group of species that includes the species in Stage V and also *conspicuus* and *operculatus aberrans*.

The position of origin of the 5th furcal seta appears to change at each moult, the proportions of the distal and proximal parts of the ramus being as follows :—

	distal	proximal
Stage IV	1·0	1·667
Stage V	1·0	1·904
Stage VI	1·0	2·007

The relative proportions of the various furcal setae to each other in the last three stages of development are as follows :—

	Stage IV	Stage V	Stage VI
Seta 1 to seta 2	1·0 : 4·167	4·1475	3·788
Seta 1 to seta 3	1·0 : 3·125	3·1275	3·049
Seta 1 to seta 4	1·0 : 0·667	0·596	0·592
Seta 1 to seta 6	1·0 : 0·667	0·564	0·639
Seta 3 to seta 4	1·01 : 0·213	0·191	0·203
Seta 3 to seta 6	1·0 : 0·213	0·180	0·218
Seta 4 to seta 6	1·0 : 1·0	0·945	1·079

Thus at the moult between Stages IV and V there is a fall in the proportions of seta 1 to setae 2, 3 and 4 and this is continued at the next moult between Stages V and VI : but in the proportions of seta 1 to seta 6, seta 3 to 4 and 6, and seta 4 to 6 there is a drop at the moult from Stage IV to V but this is followed by rise at the moult between Stages V and VI.

In the present form the antennule is composed of 8 segments in Stage IV and 11 in Stage V, increasing to 17 in the adult. Gurney (1933, p. 48) has shown what he terms the normal development of the antennule in *Cyclops*, in which there are 9 segments in Stage III, 10 segments in Stage IV, 11 in Stage V and the usual 17 in Stage VI. In the Table below

I give the actual measurements of these various segments in the three last Stages of the life-history :—

Segment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17			
Stage IV	175	120			80			160				160		64		104	126			
„ V	183·5	41·5		75·5		47·5		25·60		153·5			126		64		95	127·5		
„ VI	189	47	25		63	50	26	66	34		36	37	44	49		42	45	64	83	99

Andreae (1955, p. 292) has confirmed the statement made by Gelmini that in *hyalinus* in Stage V there are 10 segments in the antennule of the females and 9 in the males : in the present examples the number at this stage was 11 and the mode of separation of the segments appears to be as follows :—

Segment		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17					
Nauplius			1				2																
Copepodid Stage	III		1				2			3				4			5	6	7				
	IV		1		2		3				4			5			6	7	8				
	V		1	2	3		4		5	6		7			8			9	10	11			
Adult	VI		1	2	3		4	5	6	7	8		9	10		11	12		13	14	15	16	17

It would thus appear that in this species the condition at Stage III must correspond with that at Stage II in the normal method of development as given by Gurney : at the moult from Stage III to IV the proximal segment is the only one that undergoes division, thus raising the number of segments from 7 to 8. In the moult from Stage IV to V, segment 2 divides into segments 2 and 3 and segment 3 divides into segments 4, 5 and 6 ; and in the final moult from Stage V to the adult, segment 3 divides into segments 3 and 4, segment 7 into 8, 9, 10 and 11 and segment 8 into segments 12, 13, and 14. The distal three segments remain unchanged throughout these last stages.

Minor changes in the proportions of various parts of the legs can also be detected at each moult. The terminal segment of the endopod of the 4th leg becomes somewhat narrower in proportion to its length and the inner terminal spine becomes slightly shorter in proportion to the end-joint at each moult : the inner spine also becomes progressively shorter in respect to the outer spine. The changes noted are as follows :

Proportions of :	Stage IV	V	VI
Length to breadth of endopod 3 of P ₄	2·11 : 1·0*	2·53 : 1·0*	2·65 : 1·0
Inner spine to endopod 3 of P ₄	0·79 : 1·0	0·84 : 1·0	0·855 : 1·0
Inner spine to outer spine of endopod 3 of P ₄	1·80 : 1·0	1·545 : 1·0	1·426 : 1·0

* As in these stages the endopod is composed of only two segments, 2 and 3 not having separated, the length of the distal portion that will ultimately separate off as segment 3 has been estimated by the length of that part of the combined segments between the extreme distal end and the notch on the outer margin which marks the point where the line of separation will be formed in the final moult.

Thus the proportions of the terminal segment of endopod 3 of the 4th leg fall at all three stages within the limits of variation found in the adult of *schmeili schmeili* namely, 2.08—2.65 : 1.0. The proportions of the inner and outer spines of the distal segment fall within the limits of variation found in the species *rylovi* and *tinctus*, namely, 1.45—2.18 : 1.0 ; and in the proportions of the inner spine to the length of endopod 3 the observed proportions fall within the limits of variation found in the species *vermifer*, *hyalinus*, *infrequens* and *schmeili schmeili*.

In the 5th leg the inner spine arising from the neighbourhood of the inner distal angle of the 2nd segment appears to get longer in proportion to the outer seta at the last moult, but I was unable to get an accurate measurement of the seta in Stage IV.

	Stage V	Stage VI
Proportional lengths of inner spine to outer seta of distal segment of P ₅	1.30 : 1.0	1.43 : 1.0

At both Stages the proportions fall within the limits of the proportions found in *hyalinus*, *vermifer*, *rylovi* and *tinctus* and at Stage VI come near to the average in *analogus*, *pachysetosus*, *macracanthus*, *neglectus decipiens* and *mongolicus*. The proportions as given in *macracanthus* lie exactly between the proportions in Stages V and VI.

V—DISCUSSION

From the foregoing pages it must be obvious to anyone that in the subgenus *Thermocyclops*, with the increase in our knowledge of the finer details of structure and of the degree of variation that may be found to occur between one specimen and another, it becomes, as Lowndes pointed out, more and more difficult to lay down any definite characters by which we can separate one set of examples from another and so draw a hard and fast line of demarcation between one species and another. In the following pages I have taken a number of the points listed above (*vide* p. 73) which have been taken by previous authors as indicative of specific difference and have commented on the resemblance of the present specimens to those belonging to other closely related, or at least very similar 'species' :—

1. *The total length of the adult and the proportions of length to breadth of the genital segment.*—In the present examples the total length of the adult is from 0.95 to 1.05 mm. Reference to the Table given on p. 74 reveals that these specimens fall within the range of variation exhibited in the following species :—

<i>rylovi</i>	<i>tinctus</i>	<i>trichophorus</i>
<i>hyalinus</i>	<i>mahéensis</i>	<i>emini</i>
<i>schuurmanae</i>	<i>decipiens</i>	<i>vermifer</i>
<i>schmeili</i> (s. lat.)	<i>brehmi</i>	

and it seems clear that if more examples had been measured this list would have been extended even further to include :—

<i>dybowskii</i>	<i>pachysetosus</i>	and <i>infrequens</i> .
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In the proportions of the length to breadth of the genital segment the present examples have a range of 0.816—1.03 : 1.0, and so fall into line with the following species :—

<i>tinctus</i>	<i>schmeili</i> (s. lat.)
<i>operculifer</i>	<i>operculatus aberrans</i>
	and <i>trichophorus</i> .

The observed variation in *tinctus* covers the range in all the above species, and also in *conspicuus* and *inopinus*.

2. *The proportions of length to breadth of the furcal rami.*—The present examples (*vide supra*, p. 92) come nearest to the following species :—

<i>rylovi</i>	<i>inopinus</i>
<i>mahéensis</i>	<i>conspicuus</i>
<i>tinctus</i>	<i>operculifer</i>
<i>analogus</i>	and <i>operculatus aberrans</i> .

Here again the range recorded by Lindberg in *tinctus* covers the proportions in all the above species.

3. *The proportional lengths of the furcal setae.*—The present examples come nearest to *tinctus* in the proportions of seta 1 to 2 ; in the proportions of seta 1 to 3 near to—

<i>tinctus</i>	<i>inopinus</i>
<i>operculatus aberrans</i>	<i>pachysetosus</i>
<i>schmeili hastatus</i>	and <i>schmeili schmeili</i> .

In the proportions of seta 1 to 4 they are near to—

<i>dybowski</i>	<i>schmeili schmeili</i>
<i>inopinus</i>	and <i>neglectus prolatus</i>

and come between these and—

pachysetosus and *tinctus*.

As regards the proportions of seta 4 to 6 the present examples fall close to the following species :—

<i>operculatus aberrans</i>	<i>rylovi</i>
<i>pachysetosus</i>	<i>tinctus</i>
<i>iwoyiensis</i>	and <i>dybowski</i> ,
<i>neglectus neglectus</i>	

the proportions of all the above and the present examples lying between 1.0 : 0.64—1.11.

4. *The proportions of the 3rd segment of the endopod of the 4th swimming leg.*—The average proportions of length to breadth of this segment in the present examples come nearest to that of—

<i>pachysetosus</i>	<i>schmeili hastatus</i>
<i>rylovi</i>	<i>schmeili schmeili</i>
<i>inopinus</i>	<i>operculatus aberrans</i> .
<i>microspinulosus</i>	

The proportions fall in all these species between 2.55 : 1.0 and 2.75 : 1.0 but the range of variation in the present specimens also falls within or at least overlaps the range found in *vermifer*, *hyalinus*, *infrequens* and *operculatus aberrans*.

5. *The proportional lengths of the inner spine and the distal segment of the endopod of the 4th leg.*—The present examples come near the bottom of the list (*vide*, p. 101) with *decipiens*, *trichophorus* and *hyalinus* just above and *infrequens*, *schmeili schmeili* and *dybowskii* immediately below.

6. *The proportional lengths of the inner and outer spines on the distal end of the 3rd segment of endopod 4.*—Here the present examples (*vide supra*, p. 102) overlap with *rylovi* and come very near to *tinctus* and the two subspecies of *schmeili*, forming with these latter an almost continuous range from 0.83-0.96, 1.01-1.125 and 1.158-1.545.

7. *The proportional lengths of the inner spine and outer seta on the free segment of the 5th leg.*—Here the present examples (*vide supra*, p. 104) agree closely with—

<i>tinctus</i>		<i>mongolicus</i>
<i>analogus</i>	and	<i>schmeili schmeili</i> ,
<i>neglectus decipiens</i>		

and also overlap with the range in *vermifer*, *rylovi*, *macracanthus* and *hyalinus*.

Between *schmeili schmeili* and *s. hastatus* there is a wide gap, the proportions in this latter form being as great as 1.91 : 1.0, and between these two subspecies lies *trichophorus*.

In the subgenus *Thermocyclops* there is, as we have now seen, in most of the morphological characters of the body, such as the relative proportions of the length and breadth of the parts, a gradual change, without any very definite break, as we pass from one species or subspecies to another. Gurney (1933, p. 306) commented on the similarity that exists between *M. (Th.) rylovi* Smirnov, *dybowskii* (Lande) and *schmeili* Poppe and Mrázek and remarks that *schmeili* Poppe and Mrázek and *rylovi* Smirnov might be regarded as subspecies of *dybowskii* (Lande). How great is the difficulty in distinguishing one species from another with any degree of certainty is clearly seen in accounts that have been given us by previous workers and especially by Kiefer and Lindberg. Lindberg (1935) when he first described *vermifer* regarded it as a subspecies of *rylovi*, but he later separated it as a new species : he admits, however, that none of the characters enumerated by him served for the absolute discrimination of these forms and claims that it is only the existence of several of these characters that permits of their separation. Kiefer (1937, p. 298) considered that the shape of the receptaculum seminis in the female is one of the main characters that serve for the discrimination between species and subspecies in this subgenus : but Lindberg (1938, p. 212) in a paper in which he compares *M. (Th.) vermifer* with *hyalinus* comes to the conclusion that the shape of the receptaculum seminis is not always a reliable character, for in certain specimens he found that the shape of this organ was intermediate between those characteristic of the two species and in these examples other characters were also found to be intermediate : he concluded that these specimens

must be hybrids produced by the crossing of the two species. Lindberg (1942) came to the conclusion that there are distinct differences between *decipiens* Kiefer and certain other species but admits that in *vermifer*, *rylovi*, *analogus* and *mongolicus* the receptaculum seminis is very similar and he suggests that *analogus* Kiefer is manifestly a *vermifer* with a longer furcal ramus, while *mongolicus* Kiefer seems to represent a form of passage between *vermifer* and *rylovi*.

Lindberg (1942, p. 153) has commented on the resemblances that exist between *rylovi* and *microspinulosus* in the character of the receptaculum seminis but claims that they differ in the character of the connecting plate between the fourth pair of legs : in *rylovi* the spines on the rounded prominences at the two sides of the plate are strong, whereas in *microspinulosus* they are small ; but he concludes that though these two forms represent distinct species they are closely related. The present examples also closely resemble *rylovi* in the shape of the receptaculum seminis but differ in that there are no spines on the connecting plate : so that in this respect *rylovi*, *microspinulosus* and the present specimens appear to form a gradual series, in which these spines are reduced and finally abolished.

Kiefer (1937b) in his earlier account of the various forms from the Belgian Congo created several new species and subspecies among which were *M. (Th.) consimilis* and *decipiens* ; but in his later work (1952) he concludes that these are to be regarded as subspecies of other species, the former being a subspecies of *hyalinus* and the latter of *neglectus*. In this review he admits that in Southern and Eastern Asia there are not a few *Thermocyclops* species, which in the shape of the receptaculum seminis, as well as in other characters, so strongly resemble one another that they are not easy to separate and as examples of this he mentions *Thermocyclops rylovi* Smirnov, *vermifer* Lindberg and *analogus* Kiefer and he remarks that these also show a resemblance to *decipiens* Kiefer. As characteristics of this group he enumerates the form of the seminal vesicle, the long dorsal furcal seta (seta 6), the prominences on the free margin of the connecting lamella between the 4th pair of legs, the long inner spine on the distal border of the terminal segment of the endopod of the 4th leg and the longer inner spine on the free segment of the 5th leg : but, as we have already seen, throughout the whole subgenus there is a gradual change in the proportions of these spines and setae to each other or to the dimensions of the segment that bears them, while Lindberg himself (1938, p. 213) remarks, " les auteurs, tel que Kiefer, qui attachent une importance fondamentale à des aspects même légèrement différents du réceptacle séminal en vue de la distinction d'espèces, seront peut-être enclins à considérer que les divers types de réceptacle séminal que j'ai donnés, correspondent à autant d'espèces distinctes "

It thus appears that we have very nearly reached the stage, foreshadowed by Lowndes (*vide supra*, p. 70) that the inclusion of more and more detail in the description of any of the known forms has rendered it almost impossible to discriminate between a number of forms as distinct species. In quite a number of so-called species the published descriptions are anything but full. Very few authors have given, for instance, the relative lengths of the various segments of the antennule or the characters of the mouth-parts, or any descriptions of the various stages during the course of development.

Mann (1940, p. 80) pointed out in his account of his work on the fauna of the Turkish Lakes that both *Mesocyclops leuckarti* and *Eucyclops serrulatus* exhibited variation in the proportions of several parts of the body in different lakes in the same year and in the same lake in different years ; and he concludes that his data certainly show that the present scheme for the determination of the species of the Cyclopoids is not yet finally established, and that it is probable that they will have to be arranged in larger groups. Charles Darwin (1897, p. 294) himself pointed out that, "It should be constantly borne in mind that any linking variety between two forms which might be found, would be ranked unless the whole chain could be perfectly restored, as a new and distinct species ; for it is not pretended that we have any sure criterion by which species and varieties can be discriminated"

Kiefer (1952) has arranged a number of species and subspecies into groups, namely :

I. The 'Hyalinus' group, which includes—

<i>M.</i>	(<i>Th.</i>)	<i>hyalinus</i>	<i>hyalinus</i> (s. str.)
"	"	"	<i>ndalaganus</i>
"	"	"	<i>consimilis</i>
"	"	"	<i>kivuensis</i>
"	"	"	<i>macrolasius</i>
"	"	"	<i>byzantinus</i>

II. The 'Infrequens' group, which includes—

<i>M.</i>	(<i>Th.</i>)	<i>infrequens</i>	<i>infrequens</i> (s. str.)
"	"	"	<i>nigerianus</i>
"	"	"	<i>eduardensis</i>

III. The 'Neglectus' group, including—

<i>M.</i>	(<i>Th.</i>)	<i>neglectus</i>	<i>neglectus</i> (s. str.)
"	"	"	<i>decipiens</i>
"	"	"	<i>prolatus</i>

and IV. The 'Schmeili' group, including.—

<i>M.</i>	(<i>Th.</i>)	<i>schmeili</i>	<i>schmeili</i> (s. str.)
"	"	"	<i>hastatus</i> .

All that it seems possible to say is that the present examples appear to come so near to *M. (Th.) schmeili* Poppe and Mrázek, that they may well be a local variety of that species for which I propose the name of *marmagoensis* and I regard the two forms of this species described by Kiefer (1952) under the names *schmeili schmeili* and *schmeili hastatus* as representing local races, rather than subspecies of the same species : the close resemblance between the present form and such other forms as those described under the names *tinctus* Lindberg, *operculifer* Kiefer, *operculatus aberrans* Lindberg, *conspicuus* Lindberg, *trichophorus* Kiefer and *inopinus* Kiefer suggests that they are all members of a group, the ramifications of which extend through India and Africa and to this group the name *schmeili* may be given.

VI—SUMMARY

The paper deals with a review of the subgenus *Thermocyclops* Kiefer of the genus *Mesocyclops* Sars, and includes the description of a new form *marmagoensis* of the species *Mesocyclops (Thermocyclops) schmeili* Poppe and Mrázek based on the material collected from a fresh water pool on a small island about a mile off the coast of Marmagoa.

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FOOD AND FEEDING HABITS OF SOME MADRAS FISHES

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(With 4 Tables)

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I—INTRODUCTION

The feeding habits of four common adult fishes occurring in Madras (*Upeneus indicus*, *Polydactylus indicus*, *Polynemus sextarius* and *Leiognathus ruconius*) were studied some time ago by the author (1955a) who also reviewed then the work done on other Indian species. In the present account the results of the analysis of the stomach contents of *Caranx affinis*, *Sciaena albida* and *Engraulis purava* are presented.

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II—MATERIAL AND METHODS

The material for the study was collected in the inshore waters of Chepauk, Royapuram and Santhome areas of the Madras coast. The fishes for study were collected only from the fishermens' nets. Collections were made three times daily—at 8 A. M., 1 P.M. and 5-30 P.M. to note the difference of diet during different parts of the day. They were immediately brought to the laboratory, identified and their stomachs were removed and the contents of the stomachs were examined under high power. The methods followed in the analysis of the stomach contents were those described by the author earlier (1955a).

A considerable number of specimens examined had their stomachs empty. Affalo and Martson (1904) had observed that many fishes have the habit of throwing up their last meal when captured. Ogilvie (1927) found that the shock of capture did not induce post-larval herrings to

throw out food. The present author also, like Job (1940) and Pillay (1953), found no direct evidence in support of the observations of Affalo and Martson.

III—RESULTS OF OBSERVATIONS

The results of the analysis of the stomach contents of *Caranx affinis* showed that it is an omnivorous feeder, feeding almost on all prey available in the Madras inshore area. From Table 1, it is clear that Crustacea formed the main bulk of food of which Copepods seemed to be the commonest item of diet. The latter were identified as *Oithona* sp., *Acartia* sp., *Paracalanus* sp., *Calanoid* sp., *Euterpina* sp. Apart from these, the Crustaceans were represented by *Penaeus carinatus*, *P. indicus* and *Squilla mantis*. The examination of the stomach contents also revealed the presence of sand particles, Polychaetes and Foraminifera. The Foraminifera were identified as *Biloculina* and *Rotalia*, and the Polychaetes as *Axiiothella*, *Diopatra* and *Ammotrypane* which are bottom-dwelling forms. The presence of bottom-dwelling Polychaetes, Gastropods and Foraminifera along with planktonic Crustacea such as Copepods, etc., as well as nectonic Crustacea like *Penaeus*, *Acetes*, etc., in the stomachs of *Caranx affinis*, on the other hand, indicates considerable vertical feeding in the case of these fishes. It may be presumed from the above inference that the fishes migrated from the upper layer of the sea to the benthic region. Being rovers into all layers of the sea, they can obtain the most and the best of food.

Sciaena albida is called "kathalai" in Tamil and is distributed in Indian seas up to the Malay Archipelago. From Table 2 it will be seen that Teleostei (*Engraulis grayi*, *E. indicus*, *E. dussumieri*, *E. hamiltonii*, *Mugil crenilabis*, *M. dussumieri*, *Stolephorous tri*, *Decapterus russelli*) form the main bulk of the food. The predaceous propensities on the part of these "Jew Fishes" are responsible for considerable damage to many food fishes especially to their spawn and young stages. The damage, however, does not seem to be so great as in the case of some of the freshwater perches described by Gunther (1880). Crustacea were represented by *Acetes* sp., *Penaeus* sp., *Squilla* sp., and Copepods. Polychaetes also were identified in the stomachs in the months of August, September and December. This fish arrives in Madras inshore waters in the month of August. All the fishes examined were in a well-fed condition. Their well-fed condition and the immature condition of gonads indicate that their visit in this area is probably for the purpose of feeding. By the end of February, when food became scarce in this area, not a single species of fish was landed in the Madras area. Even prior to their departure, the examination of the gonads revealed their immaturity. It is inferred from the above observations and the data collected that *Sciaena albida* migrated from elsewhere to the Madras waters in August. When food becomes scarce in that area, they leave the Madras inshore waters by the end of February for other places in search of fresh feeding grounds.

The Tamil name for *Engraulis purava* is "Poruva". It is distributed in seas of India up to the Malay Archipelago and beyond. The results of the analysis of the stomach contents showed that Crustacea dominated in the food (*vide* Table 3). The Copepods present were identified as *Acartia* sp., *Oithona* sp., etc. Other Crustacea were *Penaeus* sp., *Acetes* sp., *Squilla* sp., and *Lucifer* sp. In July, insect larvae

and minute appendages of insects were found in the stomachs of these fishes. It is possible that these fishes are estuarine in habit. *Engraulis purava* visits the Madras inshore waters in the month of July. Almost all the fishes examined were in a well-fed state with immature gonads. A remarkable feature is that when the gonads were well developed, feeding of these fishes was observed to be less, as is seen from Table 4. Just prior to the shedding of the germ cells *i.e.*, by the end of February, not even a single fish was landed on the whole of the Madras coast. An examination of the inshore plankton revealed no eggs of the species and hence it is probable that these fishes migrated from the Madras inshore waters to other areas in search of fresh spawning and nursery grounds.

IV—SUMMARY

558 specimens belonging to three genera of fishes from the Madras coast were examined and their stomach contents studied with a view to determine the type of food and also the migratory movements of these fishes. The results in brief are :

(i) *Caranx affinis* : Being capable of considerable degree of vertical feeding, often browsing on the bottom, they are less affected by the changes in the pelagic fauna. They are vertically migratory in their feeding habits and feed on all the prey that comes within reach.

(ii) *Sciaena albida* : The presence of this immature "Jew-Fish" in August clearly showed that they immigrated to the Madras inshore waters for the purpose of feeding. By the end of February, as the food becomes scarce in this area, they migrate to the off-shore areas in search of fresh feeding grounds. Prior to their departure, the examination of the gonads revealed an immature condition.

(iii) *Engraulis purava* : They visit the Madras inshore waters in July and feed well till October. When the gonads become mature they feed less and by the end of February none was to be seen. It is inferred that they migrated elsewhere in search of spawning grounds.

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TABLE 1.—*Showing the average total volume of food, number of fishes examined each month and also the percentage average of the various food items of Caranx affinis.*

Particulars	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.
Volume of stomach contents in c.c.	0·8	1·1	1·2	0·8	1·2	1·3	1·3	0·9	0·8	0·6	0·7
Number of fishes examined	28	22	24	18	21	20	20	18	22	19	18
Copepods	18·2	8·6	11·2	19·4	10·7	8·6	7·8	11·9	12·4	10·2	9·0
Cancer larva .. .	2·4	3·8	..	..	2·4	..	5·8	..	6·6	8·2	9·7
<i>Mysis</i> sp. .. .	6·4	2·8	5·0	1·1	5·4	..	12·8	..	7·3	6·4	4·3
<i>Lucifer</i> sp.	2·8	..	8·8	..	4·8	9·3	8·9	12·9	..	9·4	6·9
Entomostraca	8·6	12·4	4·8	..	..	..	7·6	14·6	..	8·6	7·1
Brachyura	..	10·8	..	8·3	14·3	12·6	13·4	10·1	8·2	10·2	12·8
Vegetable matter	8·6	4·0	18·2	10·0	11·6	14·4	..	17·0	10·0	11·6	10·2
<i>Squilla</i> sp.	18·6	8·2	12·6	9·3	..	15·6	17·8	..	12·5	..	14·2
<i>Penaeus</i> sp.	10·6	16·7	13·3	20·3	12·3	..	20·3	18·5	26·4	18·6	14·8
Mollusca	6·8	10·4	4·6	8·6	10·4	6·8	..	2·5	2·6	8·4	..
Foraminifera	4·4	6·8	11·6	10·2	3·8	14·2	..	3·6	6·7	..	2·4
Broken shell pieces	4·0	8·2	..	2·5	4·6	4·1	..	2·4	..	..	..
Polychaetes .. .	6·8	5·3	8·8	10·7	12·6	12·8	4·6	5·5	7·2	8·0	7·6
Sand particles .. .	..	2·0	1·1	1·6	1·1	1·6	1·0	1·0	1·1	1·4	1·0

TABLE 2.—*Showing the average total volume of food, number of fishes examined each month and also the percentage average of the various food items of Sciaena albida.*

Particulars	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Volume of stomach contents in c.c.	1.3	1.4	1.9	2.4	1.4	1.0	0.8
Total number of fishes examined	22	28	21	28	21	19	18
Crustaceans	27.3	23.4	28.4	22.6	18.4	28.6	21.8
<i>Penaeus</i> sp.	16.6	19.6	28.2	14.6	17.6	20.2	18.8
<i>Acetes</i> sp.	12.4	10.0	..	8.4	10.4	..	8.2
Teleosteans	33.7	27.6	34.6	22.6	32.6	42.4	39.2
Polychaetes	4.4	8.4	..	..	1.0	..	..
Decapods	1.6	6.4	6.8	8.6	12.8	1.6	12.0
Copepods	4.0	4.6	2.0	7.4	7.2	..	..

TABLE 3.—*Showing the average total volume of food, number of fishes examined each month and also the percentage average of the various food items of Engraulis purava.*

Particulars	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Volume of stomach contents in c.c.	3.1	3.3	3.4	3.5	2.2	0.8	0.6	0.4
Number of fishes examined.	24	22	28	21	20	18	18	19
Crustaceans	29.1	40.4	30.2	29.8	30.9	28.2	31.9	38.2
<i>Aceles</i> sp.	11.4	..	8.6	11.2	..	18.4	23.1	11.1
<i>Lucifer</i> sp.	14.2	11.6	..	10.2	10.1	..	11.3	10.7
Copepods	16.2	20.6	18.2	12.2	22.0	28.4	24.6	20.8
Decapods	2.1	..	12.8	8.6	7.0	4.0	..	8.2
Macrura	6.0	..	8.2	8.0	10.3	8.2	6.4	6.8
Amphipods	7.2	10.4	12.4	6.4	19.7	12.8	..	4.2
Vegetable matter	..	12.8	7.4	7.6	4.6	..	2.7	..
Insect larvae and appendages.	8.8	..	..	..	..	..	..	..
Miscellaneous animal matter.	5.0	4.2	2.2	6.0	5.4	..	..	2.3

TABLE 4.—*Showing the condition of feed and also the length of the fishes examined during mature and immature stages.*

Condition of feed				Length of fishes					
				7 cms. mature	11 cms. immature	12 cms. mature	17 cms. immature	17 cms. mature	21 cms immature
Empty	.	.		12	..	8	1	8	1
little	.			13	1	12	..	9	2
$\frac{1}{2}$ full	.	.	.	6	2	3	2	3	1
$\frac{3}{4}$ full			.	..	9	1	6	1	12
$\frac{1}{2}$ full	.			1	6	2	11	..	6
full	.	.		..	12	1	8	2	8

FIRST RECORD OF *OS CINELLA FRIT* (LINN.) (CHLOROPIDAE, DIPTERA) AND *HYLEMYIA CILICRURA* (ROND.) (ANTHOMYIDAE, DIPTERA) FROM INDIA

By

A. P. KAPUR

Zoological Survey of India, Calcutta

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I—INTRODUCTION

In May and June 1955, during the course of a faunistic survey of the Kulu and Lahaul-Spiti Valleys in the Punjab, India, the writer collected over fifty species of dipterous flies from snow over the Rohtang Pass (32° 22.5' N. 77° 15.0' E.) and adjacent mountains, at altitudes between 13,800 ft. and 14,500 ft. Of the species collected, the following four are well known pests of a variety of crops in different parts of the world. While the first two have been recently reported from India, the last two do not appear to have been recorded from the country previously.

1. *Phytomyza atricornis* (Meigen) (Agromyzidae)
2. *Acanthiophilus helianthi* (Rossi) (Trypanidae)
3. *Oscinella frit* (Linnaeus) (Oscinellinae ; Chloropidae)
4. *Hylemyia cilicrura* (Rondani) (Anthomyidae)

P. atricornis, the Pea Leaf Miner, which is wide spread in central Asia, Europe, North America, Australia, New Zealand, etc., was for the first time recorded, under that name, from India in 1937 by Ahmad and Gupta, who subsequently in 1943, gave a fuller account of it and concluded that the species, though not properly identified earlier, had been reported upon in India a few decades before their own record.

A. helianthi, the Safflower Fruit Fly, which is also widely distributed in central Asia, southern Europe, and North Africa, was first recorded from Delhi, India, in 1939, by Bhatia and Singh and subsequently reported upon in greater detail by Pruthi (1941, 1942) and more recently by the present writer (1956) from the Rohtang Pass.

The present account deals with the remaining two species, namely, *O. frit*, often called the European Frit Fly, and *H. cilicrura*, the Seed Corn Maggot of America or the Shallot Fly. Pruthi (1950) included these two species in his list of "some of the more important pests found in various countries but not recorded so far in India", under their older names, i.e., *Oscinis frit* Linnaeus and *Chortophila cilicrura* Rondani. Since both the species were collected alive in fairly large numbers from the Rohtang Pass, it is probable that their source of origin was not very far. Further investigations on the species are desirable in view of their notoriety as pests of cereals, such as wheat, barley and maize which constitute some of the principal crops grown in the valleys on either side of the Pass. Their record is also of interest from the point of quarantine against insect pests.

The material of the Frit Fly was kindly identified by Dr. G. W. Sabrosky of the U. S. National Museum, Washington, and of *H. cilicrura* by Dr. F. van Emden, of the Commonwealth Institute of Entomology, London, to both of whom the writer is highly indebted for their help.

II—NOTES ON *Oscinella frit* (Linnaeus)

1758. *Musca frit* Linnaeus, *Systema naturae*, ed. 10, 1, p. 598. Holmiae.

1933. *Oscinella frit* (Linn.), Duda, *Lindner die Fliegen*, 16, p. 88 (Chloropidae).

The species has frequently appeared under the following names in the literature on economic entomology ; *Oscinis frit* (Linn.), *Chlorops frit* (Linn.) and *Oscinella frit* (Linn.). Aldrich (1920) and Duda (1933) have discussed its taxonomy in detail and to a certain extent the same has been done by Collins (1946).

When Linnaeus first described this species in 1750, he stated that in Sweden its larvae caused serious damage to barley, by attacking the immature grains which shrivelled and became worthless. Such grains are called "Frits" by the Swedes, hence the name Frit Fly.

In Europe, the larvae of the late autumn brood over winter as stem miners in winter grain, chiefly rye. The spring grain, especially rye and oats, is attacked in the same way by the spring brood. The summer brood, on the other hand attacks kernels of oats more commonly than those of barley. These differences were mostly responsible for a general belief prevailing for a long time that several species were involved (Aldrich, 1920). Similarly in North America when the infestation was first noticed on young wheat and several grasses the fly was known under various names of *Oscinis variabilis* Loew, *Oscinis carbonaria* Loew, *Oscinis soror* Macq., etc., until 1912 when Becker identified *O. frit* for the first time from North America.

The preference of the fly for certain crops as well as the degree of its attack on them appears to vary according to several ecological factors. In England, for instance, it usually attacks oats but the injury to sweet corn (*Zea mays*) may be, according to Haskell (1952 : 519), "often so devastating that a large proportion of the crop may be ruined" In North America while wheat and grasses are preferred, in most countries of Europe and in Russia, wheat, barley, rye, etc., are commonly attacked.

Distributed widely in Europe, Russia and North America, the species is being recorded for the first time from India where its hosts are still unknown.

Material examined.—27 examples of the Frit-fly were collected as follows :

Locality	Date of collection	Material collected	Collector
Rohtang Pass (ca. 13,800 ft.).	4-vi-1955	3♀♀	A. P. Kapur
Rohtang Pass (ca. 14,000-14,500 ft.).	5-vi-1955	15♀♀, 3♂♂	„
Rohtang Pass (ca. 13,800 ft.) (return journey).	19-vi-1955	4♀♀, 2♂♂	„
Total		22♀♀, 5♂♂	

Most of the flies collected were alive and were females. Those which were preserved in spirit and examined subsequently had distended abdomen containing from 8 to 24 elongate eggs in each case.

III—NOTES ON *Hylemyia cilicrura* (Rondani).

1866. *Chortophila cilicrura* Rondani, *Atti. Soc. Milano*, 9, p. 165.

1937. *Hylemyia cilicrura* (Rond.), Seguy, *Gen. Ins.*, 205, Diptera, Muscidae, p. 82.

In the literature on applied entomology this species has been generally referred to under *Phorbia cilicrura* (Rond.), *Anthomyia cilicrura* (Rond.) and *Hylemyia cilicrura* (Rond.), besides the original name under which it was described. Detailed synonymies and taxonomic notes on the species are given by Seguy (*loc. cit.*) and van Emden (1951) respectively.

The flies lay eggs usually on freshly turned soil where there is abundance of decaying vegetable matter or on the seeds and seedlings. The eggs hatch readily and the maggots burrow into the seed, often destroying the germ. Corn, beans, peas, cabbage, turnip, beet, radish, onion, seed potatoes, etc., are attacked in Europe and North America. Occasionally wheat, oats, sun-flower and cucurbit seeds are also attacked in the U.S.A. and in Argentina, South America. In the U.S.S.R. cotton seeds and cotyledons, and in Japan soya beans, wheat and a wide range of other crops are attacked.

The species is widely distributed in parts of Africa, Europe, the U.S.S.R., N. China, Korea, Japan, and the U.S.A., where it is believed to have got introduced and was first recorded in 1856.

Material examined.—(a) From the Rohtang Pass : 106 examples of the flies were collected, as follows :

Locality	Date of collection	Material collected	Collector
Rohtang Pass (ca. 13,800 ft.).	4-vi-1955	25♀♀	A.P. Kapur
Rohtang Pass (ca. 14,000-14,500 ft.).	5-vi-1955	67♀♀, 2♂♂	„
Rohtang Pass (ca. 13,800 ft.) (return journey)	19-vi-1955	12♀♀	„
Total		104♀♀, 2♂♂	

The majority of the flies were alive at the time of capture. Nearly one-third of the number of female flies had distended abdomens which were full of mature ovaries. Nearly 20 elongate eggs could be seen in each case on dissecting the abdomen of specimens preserved in spirit.

The sexes were very unevenly represented, there being only two males in a total catch of 106 examples as mentioned above. Miles (1948) and Hawley (1922) have also referred to the occurrence of uneven sex-ratio in this species. The former observed that in *bred* specimens the number of males and females produced were approximately equal but this was not so in examples collected in nature. Hawley observed that females seemed to be more numerous than males on bare soil and males seemed to predominate about herbage. It seems obvious, therefore, that differences in the habits of males and females are responsible for the uneven proportion of sexes among the captured material.

(b) *From other parts of the Himalayas*: On going through the collections of the Zoological Survey of India, Calcutta, the writer came across the following interesting material of *H. cilicrura*, which, though collected many years back, was identified by Dr. F. van Emden and incorporated into the Survey's collections in November, 1950. This collection shows that the species is probably distributed all along the Himalayas, from Simla Hills in the western to Darjiling in the eastern Himalayas.

Earlier collections of *H. cilicrura* in the Zoological Survey of India, Calcutta.

Locality	Date of collection	Material collected	Collector
Simla (7,000 ft.), N. W. Himalayas.	24-iv-1907	2 ♀♀	N. Annandale
"	5-v-1907	2 ♀♀	"
"	11-v-1908	1 ♀	"
"	7-v-1910	1 ♀	"
"	9-v-1910	10 ♀♀, 1 ♂	"
"	12-13-v-1913	2 ♀♀, 3 ♂♂	"
Phagu (9,000 ft.), Simla Hills	11-v-1909	1 ♀	"
Theog (8,000 ft.), Simla Hills.	13-v-1909	1 ♀	"
Matiana (8,000 ft.), Simla Hills.	?	1 ♂	"
Unchagoan, (Nainital Dist., U. P.), central Himalayas.	7-iv-1909	1 ♀	Museum collector
Mussoorie (6,650 ft.), U.P., central Himalayas.	?	1 ♀	Bond
Darjiling (6,000 ft.), N. Bengal; eastern Himalayas.	22-ix-1908	. 1 ♂	E. Brunetti
"	24-ix-1908	1 ♀	"
"	26-ix-1908	.. 1 ♂	"
"	30-ix-1908	2 ♀♀	"
"	2-x-1908	1 ♀	"
Total	.	26 ♀♀, 8 ♂♂	

These collections show that *H. cilicrura* is widely distributed in the higher altitude of the western, central and eastern Himalayas. Since the species is a notorious pest of a variety of crops in Europe, central Asia, North China, Japan, North America and parts of South America, it would be useful to determine its economic status in different places in India from where it has been collected. At present it is known from the hills in North India, but perhaps a more thorough survey in the neighbouring areas may also be considered desirable from the point of internal quarantine in the country.

IV—SUMMARY

The Frit Fly, *Oscinella frit* (Linn.) and the Seed Corn Maggot, *Hylemyia cilicrura* (Rond.) which are notorious pests of cereals and other crops in different parts of the world and which were hitherto not recorded from India, were collected together with many other insects from the snow-covered Rohtang Pass (13,800-14,500 ft.) in the Kulu subdivision, Punjab, India, during June 1955. Since the flies were collected in fairly large numbers and when most of these were alive, it seems probable that their source was not far away from the Pass.

Notes on the taxonomy, nature of injury and geographical distribution of the species and on the extent of the material collected are given. An examination of the insect collection in the Zoological Survey of India, showed that while *O. frit* was unrepresented, a fair number of examples of *H. cilicrura* from Simla Hills (7,000-9,000 ft.), Nainital district (exact altitude of locality unknown), Mussoorie (ca. 6,650 ft.) and Darjiling (ca. 6,000 ft.) were present. These had been collected a number of years ago but were identified and incorporated in the collections only recently. In view of the notoriety of these species as pests in several other countries, it seems desirable to determine their economic status and geographical distribution in India.

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