ON THE MORPHOLOGY AND BIONOMICS OF *EMBIA MINOR*, SP. NOV. WITH SPECIAL REFERENCE TO ITS SPINNING ORGAN. A CONTRIBUTION TO OUR KNOWLEDGE OF THE INDIAN EMBIOPTERA.

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(Plate XXIII.)

CONTENTS.

1. INTRODUCTION.

The Embioptera or Embiidina is an isolated group of rare insects possessing peculiar structural modifications. The members of the group are more or less gregarious, living in a fairly long mesh-work of tunnels, which are generally constructed over sheltered damp spots. Although some interesting features regarding the habitat of a few Indian Embiids have been recorded by MacLachlan (1877), Wood-Mason (1885), Imms (1913) and Lefroy (1923), very little is yet known about the actual feeding habits of these insects. Most of the previously published work on these insects deals with their systematic position and our knowledge of their internal anatomy is still poor. The papers by Grassi and Sandias (1897-98) and by Melander (1905) respectively, deal with certain anatomical features of two species which do not occur in India, but some of the internal features noted by them resemble those of the present species. Sharp (1895) in the " Insecta " volume of the *Cambridge Natural History* Series and Imms (1925) in " *A general Text-book of Entomology* " have touched on a few points of the internal anatomy but their descriptions are very short and incomplete.

In the present paper I propose to deal with the external morphology and the internal anatomy, as well as with some of the peculiar habits of a species of Embiidina collected in Bihar. I have also recorded my observations on the spinning apparatus of the insect; this work was undertaken with the object of clearing up the confusion regarding the exact position of this organ.

I desire to take this opportunity of expressing my sincere thanks to Mr. T. B. Fletcher, Imperial Entomologist to the Government of India,

for the generous way in which he helped me with some of the foreign literature on the subject: he also helped me materially in determining the systematic position of the new species. My thanks are also due to Rai Bahadur C. S. Misra, First Assistant to the Imperial Entomologist, who gave me every facility for carrying out the work. I should like also to record herein my indebtedness to Lt.-Col. R. B. S. Sewell, Director of the Zoological Survey of India, for the trouble he has taken in going through the paper; his valuable criticism has also been of great help to me.

2. NOTES ON THE ORDER EMBIIDINA, ITS AFFINITIES AND GEOLOGICAL HISTORY.

The order Embiidina forms an isolated group of rather small and elongate insects with a comparatively wide distribution. They have so far been recorded from the Tropics (in which they appear to be cosmopolitan, except as regards the desert regions, where they do not occur), the sub-tropical areas and warm temperate zones (where they occur in moist coastal regions and in inland areas at high altitudes). Their structural complexities and the striking uniformity of certain other organs mark them off from other groups of insects. The peculiar features of the order are due partly to the retention of certain primitive ancestral characteristics, and partly to specialization which has gradually brought about secondary modification of some of the structures in response to altered functions. Another peculiar but constant characteristic of the group is the prevalence of sexual dimorphism in almost all the species. In a few cases the males again are dimorphic and hence a great deal of uncertainty exists with regard to the validity of the various species.

Enderlein (1912) in his monograph on the order mentions 10 genera and 61 species. Some more genera and species have recently been added to this number. According to Enderlein the structures of the two terminal abdominal segments in the case of the males furnish the most constant characters for the differentiation of the species, and I have followed Enderlein's method for the specific determination of the species discussed in this paper.

Throughout the group the body is elongate and flattened dorsoventrally. The winged members of the order have two pairs of wings, which are similar to one another both in form and structure; they are rather elongate, membranous and comparatively fragile, and are folded over the back when the insect is at rest. The venation of the wings is, in some cases, considerably reduced. The reduction of veins in the wing occurs by coalescence and atrophy of the veins, and in the forms where the venation has been reduced by atrophy, brown bands persist, indicating the positions of the veins which have disappeared. In general the males are alate and the females wingless, but in some genera the males also are without wings. The mouth-parts are adapted for biting and chewing and in the female the biting surfaces of the mandibles are specially well developed. Anal cercii are present in both sexes. The eyes are compound, and consist of numerous ommatidea of the eucone type ; ocelli are not found in any members of the order. The metamorphosis is more or less incomplete.

There has been a considerable difference of opinion regarding the systematic position of this order. Some of the earlier authorities grouped them with the Termites and the Psocids in the heterogenous order Neuroptera. Latreille (1825, 1829, 1839), and Savigny and Audouin (1826) placed the genus *Embia* close to the genus *Termes*, clearly believing in the interrelationship of the Embiids and the Isoptera ; in this they were followed by Westwood (1837), Burmeister (1839) and Rambur (1842). Burmeister, however, in another work (1839) placed the group as a family of his order Corrodentia. Brauer (1857, 1876) placed the family Embiidae in his Orthoptera-genuina, while MacLachlan (1877, 1878, 1879, 1883) remarked that the Embiids are closely allied to the Plecoptera. Wood-Mason (1883) pointed out that the interrelationship of the Embiids with the Blattids and Mantoids is shown by the asymmetry of the genital armatures, but such asymmetry is not uncommon in other ins cts, *e.g.*, (i) it occurs in all the 4 or 5 species of the genus *Glossosoma*, (ii) the terminal tergites and the cerci in the adults and nymphs of the males of *Nicrobia m culicollis* are asymmetrical. Hagen (1885) observed morphological resemblances between the Embiids and the Isoptera and grouped them together. Grassi (1889, 1894, 1897, 1898) suggested that the family Embiidae should form a separate order to be placed under a super-order of Orthoptera. Sharp (1895) grouped the Embiids with two other families, Termitidae and Psocidae, as a division of the Neuroptera and for which he suggested the name Pseudoneuroptera. He further pointed out the affinity between the Embiids and the Psocids as shown by the similarities which exist between the members of the family and those of the Cuban Psocid genus *Embidopsocus*. Enderlein (1903), following Hagen, grouped the Embiids and the Isoptera in a separate sub-order. Verhoeff (1904) again split up the old order Corrodentia of Burmeister (1839), which included a number of heterogenous groups, into a number of distinct orders. Subsequent authors have kept the Embiids and the Isoptera separate. Finally in 1909 and 1912 Enderlein again united them together in his super-order Aetioptera, which includes the orders Embiidina Enderl. and Isoptera Brullé.

According to Crampton (1917), the insects which are most closely related to the Embiids are the Plecoptera. He thus agrees with MacLachlan and suggests that the Plecopterans are probably the nearest living representatives of the ancestral Pterygota.

The Embiids are probably specialized representatives of the primitive group of insects known as Protorthoptera, which existed in the Palaeozoic age. In the Upper Carboniferous stratum the representatives of the Embiids were of a large or moderate size and possessed a complex venation. In the Lower Permian these insects became reduced and simplified, probably owing to adverse climatic conditions. The ancestors of th Embiids and Dermaptera are found in the Lower Permian strata, but no further links in the ancestral chain have been discovered. The absence of all fossil records, is due probably to the extreme delicacy of the late and more specialized forms. They, however, appear again in the Baltic amber of the Oligocene period as the direct ancestors of the modern Embiids; these resemble the later modified forms of the order to a considerable extent.

3. DESCRIPTION OF *EMBIA MINOR*, SP. NOV., FROM BIHAR.

(*a*) *The Male Imago.*

(Pl. XXIII, fig. 2.)

The general colouration of the body is brownish black. The body is clothed with dark-brown or blackish hairs. The antennae consist of 21-25 joints (text-fig. 1A) and are longer than the thorax. The proportionate lengths of the head, thorax and abdomen are as 7 : 13 : 18. The total length of the body with cerci is 9·5—12·5 mm.; the average length of the cerci being 1 mm. The first joint of the hind tarsus is provided with two arolia. The 10th tergum is completely divided by a suture into two plates, the right being distinctly larger than the left. The left plate is produced into a stout moderately curved process, while that of the right plate is represented by a thick, short, pointed spine. Mesially the 10th tergum is provided with a process,[1] the median process, which is distally rounded and curved. The basal joint of the left cercus is large and somewhat conical; its inner basal surface is provided with minute denticles (text-fig. 5B). Fore-wing 6·75 mm. long and 2 mm. broad; hind-wing 6·3 mm. long and 2 mm. broad.

Detailed description of the Male Imago.

Colouration.—Dorsally the head with the appendages, except the area between the eyes, the legs, the terminal and penultimate segments of the abdomen and the cerci (except their apices) vary in colour from deep brown to brownish black. In the prothorax the colour varies from chestnut brown to brownish black. The remaining thoracic and abdominal segments, except the two terminals, are light brown to brownish black. The claws of the feet vary in colour from light to deep brown. The articulations between the joints of the legs, the tarsi, the antennae, the maxillary palpi and the area around the bases of the eyes are of a lighter colour than the rest of the body. The ante-clypeus is light brown to deep brown, the rest of the labium and clypeus are comparatively darker. The dorsal portion of the head between the eyes is brownish yellow and conspicuous. The intersegmental regions between the head and the prothorax and the pro- and the mesothorax are distinctly membranous and are yellowish white. The pleurae are similarly membranous and form a yellowish white sinuous line along each side of the body and are more conspicuous than in the female. The apices of the cerci are fuscous.

The colour of the ventral surface is nearly the same as that of the dorsal.

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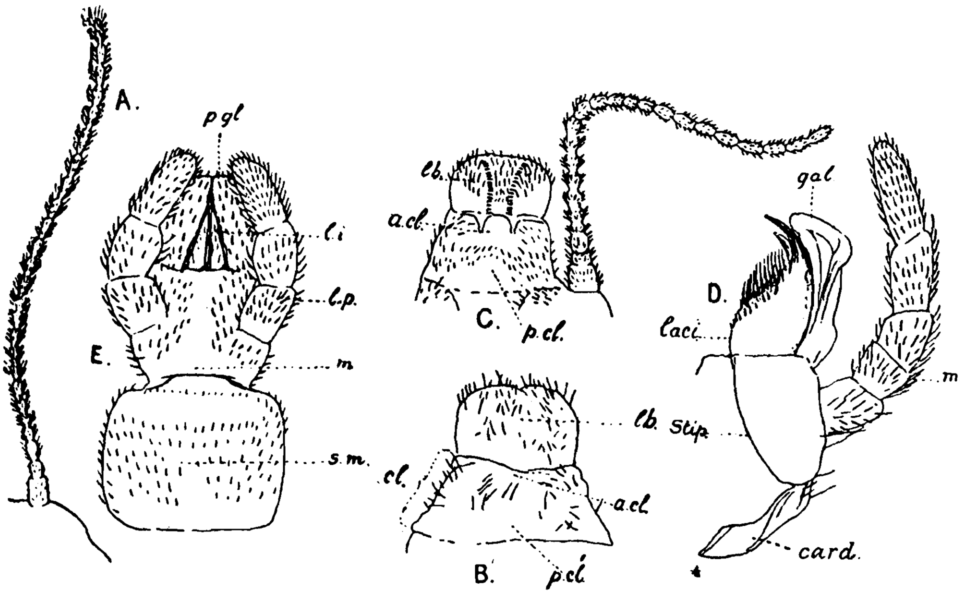
[1] This process, which is dorsal in position, is quite distinct from the ventral process or "anhang" of the 9th sternum, which is pointed and curved.

The head is covered with fine yellowish hairs. The eyes are reniform in shape and nearly half of them are visible from above (pl. XXIII, fig. 3).

The labrum is sparingly clothed with fine hairs and its distal margin is slightly depressed in the middle. The distal free-margin of the labrum (text-fig. 1 B) is more rounded than that of *Embia major* Imms.



TEXT-FIG. 1.

Embia minor, sp. nov.

A. Antennae of the ♂, × 10.
B. Labrum and clypeus of ♂, × 20.
C. Labrum, clypeus and antenna of the ♀ as seen from below, × 12·5.
D. First pair of maxillae of the ♀, × 25.
E. Second pair of maxillae of the ♀, × 25.

a. cl. = ante-clypeus ; *card.* = cardo ; *cl.* = clypeus ; *gal.* = galea ; *laci.* = lacinia ; *lb.* = labrum ; *l. i.* = inner lobes of the second maxillae ; *l. p.* = labial palp ; *m.* = mentum ; *mx. p.* = maxillary palp ; *p. cl.* = post-clypeus ; *p. gl.* = outer lobes of the second maxillae or paraglossae ; *s. m.* = submentum ; *stip.* = stipes.

The antennae (text fig. 1 A) vary in length from 5·5 to 6 mm. and the number of joints of the antennae varies between 21—25.[1] In one specimen the total length of the 4th, 5th and 6th joints was 0·50 mm., while that of the 1st and 2nd joints was 0·41 mm.

The mandibles are furnished with rudimentary apical denticles (text-fig. 2 A, B). A more or less broad and distally rounded denticle is situated on the outer margin of the mandibles and has an irregular, incomplete, median longitudinal suture which probably indicates its paired origin. A second rather small denticle lies behind the apical one ; its pointed apex appears to be bifid. On the inner surface of each mandible behind the denticles, the sides are produced into sharp straight cutting edges, which are provided with irregular, wavy serrations. The point of attachment of the adductor muscle (text-fig. 2 A, B ; *add. m.*), the ginglymus (*ging.*), the condyle (*cond.*) and the point of attachment of the abductor muscle (*abd. m.*) do not differ from those of *Embia major.*

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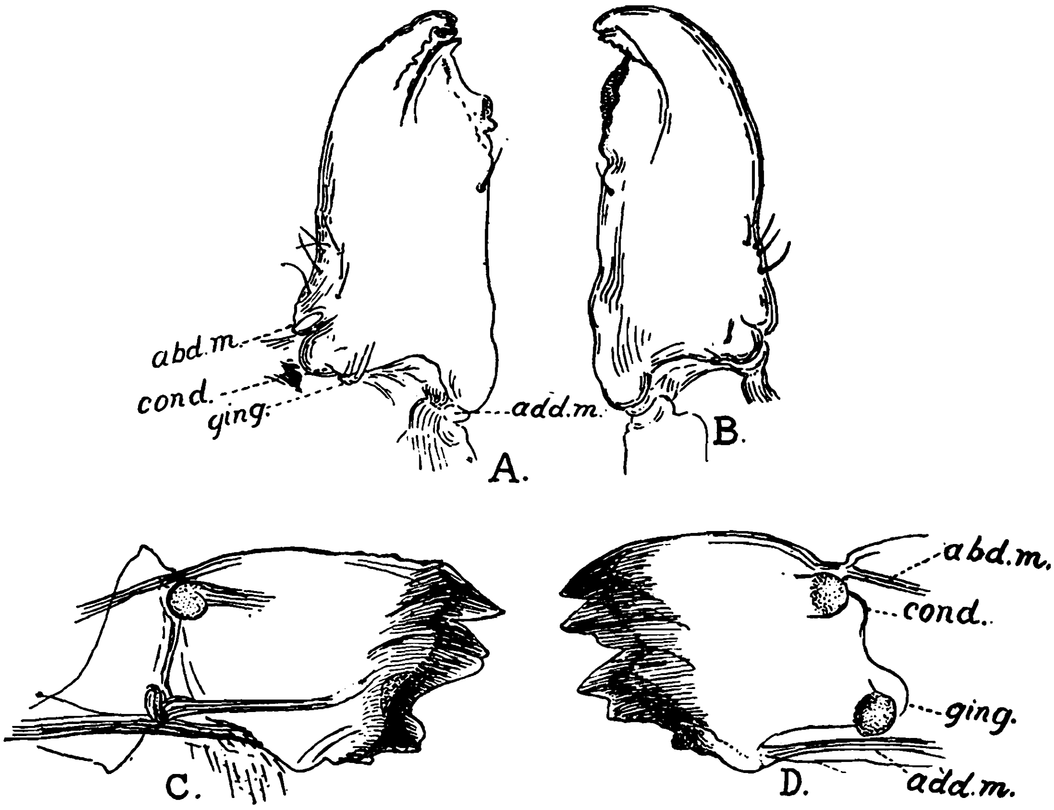
[1] Owing to the fragile nature of the antennae it is not possible to be quite certain as to the exact number of the antennal joints.

Each mandible bears inwardly an elongate hair at the posterior end of the serrations on the cutting surface.

The first and second maxillae are similar in structure to those of the female (*vide infra*, p. 263).

The hypopharynx[1] is rounded at the distal corners, and the rounded corners bear a group of longish hairs, most probably sensory in function. The dorsal surface of the lingua has a covering of minute scales. These scales were noted by Enderlein (1909, p. 168, fig. 3) and by Imms (1913); the former author designated them as the " Geschmacks-Schuppen " or taste-scales. The lingua is sharply marked off from the hypopharynx by a constriction and at its origin is about half the breadth of the hypopharynx. Ventrally a longitudinal groove runs throughout the length of the tongue and is continued a little on the dorsal surface.



TEXT-FIG. 2.

Embia minor, sp. nov.

A. Left mandible of the ♂, ×40. C. Left mandible of the ♀, ×40.
B. Right mandible of the ♂, ×40. D. Right mandible of the ♀, ×40.

abd. m.=point of attachment of abductor muscle; *add. m.*=point of attachment of adductor muscle; *cond.*=condyle; *ging.*=ginglymus.

The anterior third of the prothorax is marked off from the rest of the tergum by a moderately deep transverse sulcus. The posterior third of the tergum bears another shallow transverse sulcus. At right angles to both these transverse lines, crossing the deeper sulcus and reaching the margin anteriorly, there is a shallow median longitudinal groove. The tergum is sparsely covered with fine light brown hairs. The mesothorax has its proximal region sparsely clothed with fine

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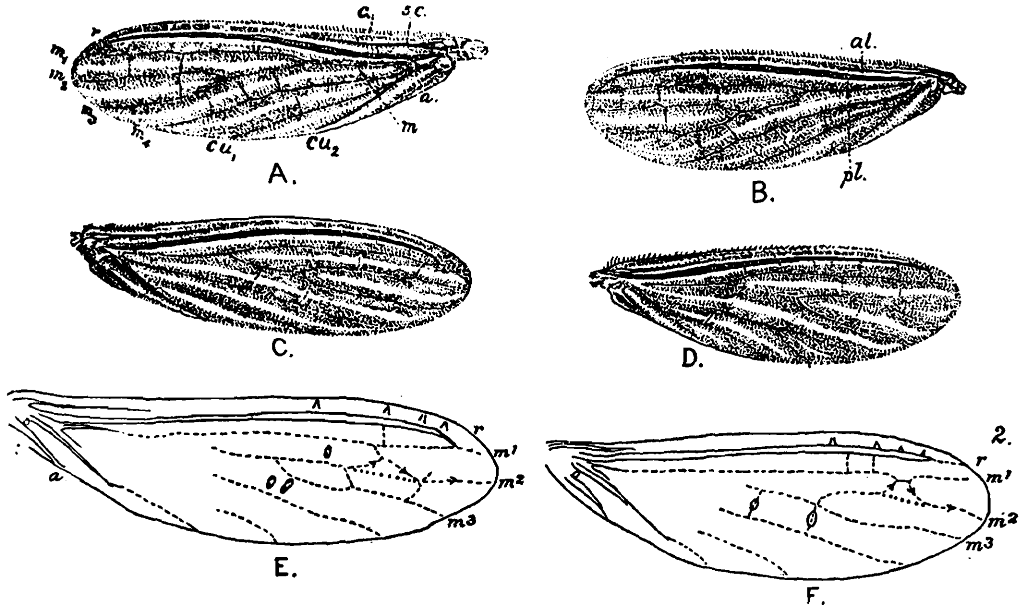
[1] I have adopted Huxley's terminology, according to which the attached base of the tongue is the hypopharynx and the free tip the lingua.

brownish hairs. The metathorax is shorter than the mesothorax, and its proximal region is sparsely clothed with fine brownish hairs.

The wings are tawny brown. The hyaline areas have a very definite arrangement with reference to the longitudinal veins, and almost always are devoid of the longer setae which are found over the rest of the wings. The hyaline areas in *Embia minor* are distributed as follows : (i) A rather broad but short strip above the sub-costal vein (text-fig. 3A ; *s. c.*), (ii) a pair of extremely narrow strips bordering the " two thin pink areas mentioned on p. 260 which represent the " Radiussaumlinien of Enderlein (text-fig. 3B ; *al*, *pl.*), (iii) a prominent area situated between the two branches m_1 and m_2 of the median vein, (iv) a short area between the branches m_2 and m_3, (v) a long and conspicuous space between the two veins m and m_1 and extending outwards to the outer margin of the wing, (vi) a rather short area between m_4 and the upper branch of the cubital vein cu_1, (vii) a short area between the forks of the cubital vein, *i.e.*, between cu_1 and cu_2, and (viii) a short, rather indistinct area between the thickened stem of the cubital vein and the less distinct one of the anal vein *a.* In some specimens where m_3 is bifurcated an additional very small hyaline area is present between its branches, and this joins with the main hyaline area between m and m_4. Sometimes at the points where the cross-veins traverse the hyaline areas, the cross-veins become surrounded by small transverse hyaline strips which appear as small cross-pieces. The existence of rudimentary cross-veins in a few species points either to the retention of primitive characters in the wing-venation or to a reduction of the veins. The different individuals of the



TEXT-FIG. 3.

Embia minor, sp nov.

A. Left anterior wing of the ♂, ×6.
B. Left posterior wing of the ♂, ×6.
C. Right anterior wing of the ♂, ×6.
D. Right posterior wing of the ♂, ×6.
E. Abnormality in the venation of right anterior wing of ♂, ×7·5.
F. Abnormality in the venation of right posterior wing of ♂, ×7·5.

al. = anterior pseudoradial line ; *pl.* = posterior pseudoradial line.

species *Embia minor* exhibit considerable variation both in the length and the breadth of their wings. The length of the fore-wing varies from 7 to 7·5 mm. and the breadth from 2·0 to 2·33 mm. In the hind-wing the length varies from 6·5 to 6·75 mm. and its breadth from 1·75 to 2·25 mm. The venation also presents a great deal of individual variation especially as regards the number and position of the cross-veins and this variation is to be found even in the wings of the two sides of the same specimen (text-fig. 3A-F).

The costal (*c*), the sub-costal (*s. c.*), and the radial (*r*) veins do not present any special features and their courses are more or less similar to those of *Embia major.*

The thin dull pink areas which enclose the anterior and posterior margins of the radial vein represent the " Radiussaumlinien " or " Radiolimbolarien " of Enderlein (1912, p. 10), the " Radius-nebenlinien " of Krauss (1911, p. 7), or the " anterior and posterior radial lines " of Imms (1913, p. 171).[1] The courses of the media and its different branches (m, m_1—m_4), of the cubitals (cu_1, cu_2), and of the anal (a) are similar to those of *E. major*. The number of cross-veins in the anterior and posterior wings of a specimen is shown in text-fig. 3 A-D.

A peculiar case of abnormal venation was observed in the wings of the right side of a specimen of *Embia minor.* The wings of the left side, though apparently more normal than those of the right side, differed greatly in the number and position of the cross-veins and the distribution of the hyaline areas. The following were the outstanding features of this specimen. The anterior $\frac{2}{3}$rd of m_2 (text-fig. 3 E), after emergence from m_1, is more or less normal and when it reaches the portion marked by dots in the figure it suddenly turns upwards and meets a cross-vein which descends down from m_1 at an angle, the vein m_2 then descends and takes the normal course; at the point where it resumes the normal course it sends upwards a small incomplete cross-vein. The vein m_1 in this case is normal. In the case of the right hind-wing the abnormality in the venation is most marked. Here the anterior $\frac{4}{5}$th of m_1 (text-fig. 3F) is normal, it then abruptly bends downwards a little and proceeds horizontally a short distance, then rises up and follows the normal course and terminates without meeting the radial vein *r*, as was the case in the fore-wing. At about its middle, m_2 suddenly rises up and unites with the horizontal portion of m_1 and then descending down follows the normal course. The abnormal course of the veins in the figures of the wings is shown by arrows and the normal course by dots (text-fig. 3 F, F). The position and number of cross-veins and of the hyaline areas also exhibited considerable variation, but these are not of sufficient interest to be described here in detail.

The legs.—The arolia or ventral pads of the tarsi or " Sohlenbläschen " of Verhoeff (text-fig. 4 B; ar_1, ar_2, ar_3) are of great use to these insects for rapid locomotion inside their tunnels. The number and position of the arolia on the tarsi are similar to those of *Embia major.* The arolia on the metatarsus are furnished with a few elongate spines. The area around the arolia of the metatarsus is beset with numerous short,

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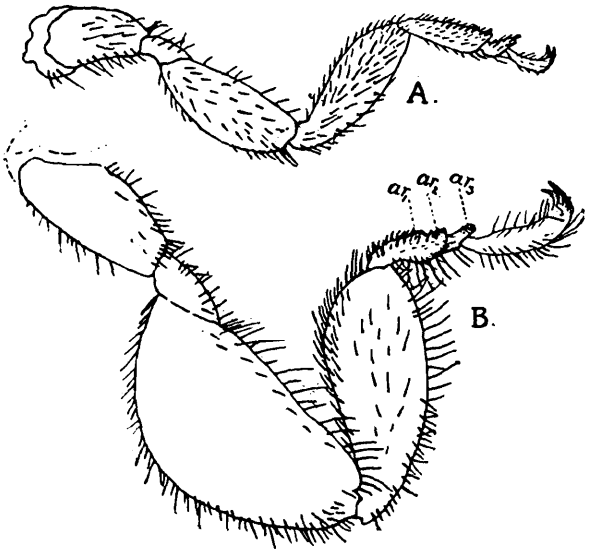
[1] I suggest the non-committal name of " pseudoradial lines " for these areas.

thick and pointed spines besides the usual elongate setae which cover them. Beneath the thin transparent cuticle the arolia appear to be spongy in character and are slightly darker in colour than the rest of the metatarsus. The arolium of the second tarsal joint bears on its inner aspect very short, thick, pointed, yellowish spines situated on an oval area. The arolium of the second tarsal joint is also spongy in character.



Text-fig. 4.
Embia minor, sp. nov.
A. Hind leg, ×20. B. Second leg, ×20.
ar_1 ; *ar_2*=arolia of the first tarsal joint; *ar_3*=arolium of the second tarsal joint.

The abdomen.—The structures of the abdominal tergites and the sternites, except those of the 9th and 10th abdominal segments in this species, differ very little from those of *Embia major*. The following differences may, however, be especially noted; (i) The 9th tergum is more compressed in *E. minor* than that of *E. major* and this compression is clearly visible towards the left side of the tergum, (ii) in *E. minor* the right plate of the 10th tergite bears on its apex a small acuminate process (text-fig. 5 A, B ; *sp.*), (iii) the left plate of the 10th tergite (ltg_{10}) is comparatively well developed in *E. minor* and the process ($prtg_{10}$) of the left plate of the 10th tergite is less curved and less acuminate apically than that of *E. major*, (iv) the median process is a well developed structure in *E. minor* and is of the same thickness throughout, (v) the ventral process (*v. pr.*) or " anhang " of the 9th sternite is somewhat triangular in shape and pointed apically[1]; it is firmly hinged to the distal end of the 9th sternite which forms the sub-genital plate.

The basal joint (*ba. j.*) of the left cercus is sub-conical in shape and bears on its broadest basal surface a prominent concavity (*co.*). The inner margin of the sub-conical basal joint bears several minute cone-shaped spines. The distal joints of the cerci are normal. Both the cerci are covered externally with hairs which are of three different types, numerous long setose hairs, interspersed with rather shorter and finer

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[1] In the absence of a true " aedeagus " or intromittant organ, the complex appendages of the terminal abdominal segment serve to keep the aperture of the vas deferens closely applied to that of the oviduct during copulation.

spinous hairs, cover both the cerci uniformly (pl. XXIII, figs. 7, 8). In specimens cleared in caustic potash, the interspaces between these setose hairs were seen to be occupied by fine sensory hairs (pl. XXIII, fig. 6). The sensory pits (*s. pt.*) are situated at the bases of these hairs and it is only by means of these pits that sensory hairs can be distinguished from other types of hairs.[1]

The sensory hairs of the cercus are sparsely distributed over the dorsal and ventral surfaces of the basal joint of each cercus. The hairs are more numerous on the dorsal than on the ventral surface of the basal joints, and are arranged in a single row at the distal region of the joints. This arrangement of the sensory hairs is more distinct in the case of the basal joint of the left cercus. The second or distal joint of the right cercus does not appear to bear any sensory hairs, but the inner edge of the terminal joint of the left cercus bears a single sensory hair on the dorso-median region. The measurements of the different parts of the sensory hairs are as follows : diameter of the outer rim of the sensory pit 0·018 mm. ; diameter of the inner rim of the pit 0·0072 mm. ; length of a sensory hair 0·0288 mm.

(*b*) *The Female Imago.*

(Pl. XXIII, fig. 1.)

The general colouration of the body is light to deep brown. The body is clothed with light brown elongated hairs, and the hairs on the body are more numerous than in the case of the male.

The antennae are 22-23 segmented and are shorter than the thorax. The relative lengths of the head, the thorax and the abdomen are 2 : 4 : 5. The first tarsal joint of the hind-legs, as in the male, is furnished with two arolia. The 8th abdominal tergum is distinctly larger than the 9th, but both are shorter than any of the preceding segments. The 10th tergum is larger than the 9th, which is the smallest of all. The 10th tergum narrows terminally with its hind-margin distinctly rounded. Total length 14·5 to 15·75 mm.

Detailed description of the Female Imago.

Colouration.—Dorsally the colouration varies from light to dark brown, but the general colouration is always lighter than that of the male. The intersegmental regions between the head and the prothorax, between the pro- and the mesothorax, and between the meso- and the metathorax are yellowish white in colour and are more membranous than those of the male. The pleural region begins from the basal half of the metathorax and extends backwards to the distal extremity of the

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[1] Verhoeff (1908) noticed these sensory hairs and termed them " Hörhaare " or the auditory hairs. Berlese (1909) termed them " Sensilli tattili ", and believed them to have auditory and tactile functions. The sensory hairs of the cercus are not of rare occurrence in insects. The cerci of *Mantis religiosa* and *Decticus albifrons* bear such sensory hairs and the sensory hairs of *Embia minor* (pl. XXIII, fig. 6) greatly resemble those of the latter species. According to Packard, Folsom and some other authors, the main function of sensory sacs, pits and other sensory structures of the cerci is olfactory, while the cerci themselves are tactile. The ability of the Embiids to run backwards with equal facility inside their tunnels and their being positively thigmotactic adds further support to the suggested tactile function of the sensory hairs of the cerci.

8th abdominal segment. The pleural region is membranous and yellowish white. Seen from the dorsal surface the pleural region appears as two lateral lines running longitudinally one on each side of the body (Pl. XXIII, fig. 1). The antennae are of the same colour as the head, but the articulations of the joints are paler. The ante-clypeus, the maxillary and the labial palpi, the area around the articulations between the joints of the legs, the apical joints of the tarsi, the tibiae and the tarsi of the two hind pairs of legs are somewhat paler in colour than the rest of the body. The claws are pale yellow with brown apices. The basal joints of the cerci are of the same colour as the body, while the apical joints are somewhat paler.

The ventral surface is lighter than it is dorsally, while the lateral margins of the sterna are slightly darker. The three terminal sterna are, with the exception of the middle portion of the 8th, darker in colour than the preceding abdominal sterna. In specimens which are of a lighter colour, a brownish line starts from the base of each antenna, meeting a third line of the same colour, which is produced a little backwards towards the posterior margin of the head in the middle line. The area bounded anteriorly by these lines contains 8 brownish longitudinal lines, which run backwards to the neck.

The head attains its maximum width behind the insertion of the eyes. The eyes are distinctly less reniform in shape than those of the male and are comparatively smaller in size. The antennae are 4 mm. in length, and consist of 22-23 joints when intact. The hairs on the labrum are more numerous and more uniformly distributed than in the male. The labrum of the female bears two rows of setose hairs, one on either side of the median region (text-fig. 1 c). Each of the mandibles bears 4 prominent teeth (text-fig. 2 c, d). The right and the left jaws differ to a certain extent so far as the dentition is concerned. The right jaw near its outer angle has four teeth. Of the first two, which are situated close to each other, the first is simple and sub-triangular, while the second is bilobed and is larger than the first. The third is a large bilobed tooth, and is situated behind the first two, while the rudimentary fourth is somewhat rounded in shape and lies on the inner angle of the biting surface. The process for the attachment of the abductor muscle (*abd. m.*) is moderately distinct. The condyle (*cond.*) is represented by a short distally rounded process. The ginglymus (*ging.*) is represented by a well developed distally rounded process which is larger than the condyle. The process for the attachment of the adductor muscle (*add. m.*) is small and less distinct. The first maxilla (text-fig. 1 d) consists of a 5-jointed palp (*mx. p.*), a membranous unarmed galea (*gal.*) and a well developed lacinia (*lac.*) attached to the cardo (*card.*) and the stipes (*stip.*).[1]

The labium formed by the fused second maxilla (text-fig. 1 e) consists of a quadrangular sub-mentum (*s. m.*) and a well developed mentum (*m.*). It differs from that of *Embia major* in the following points : (*a*) the triangular space at the distal end of the mentum, which encloses

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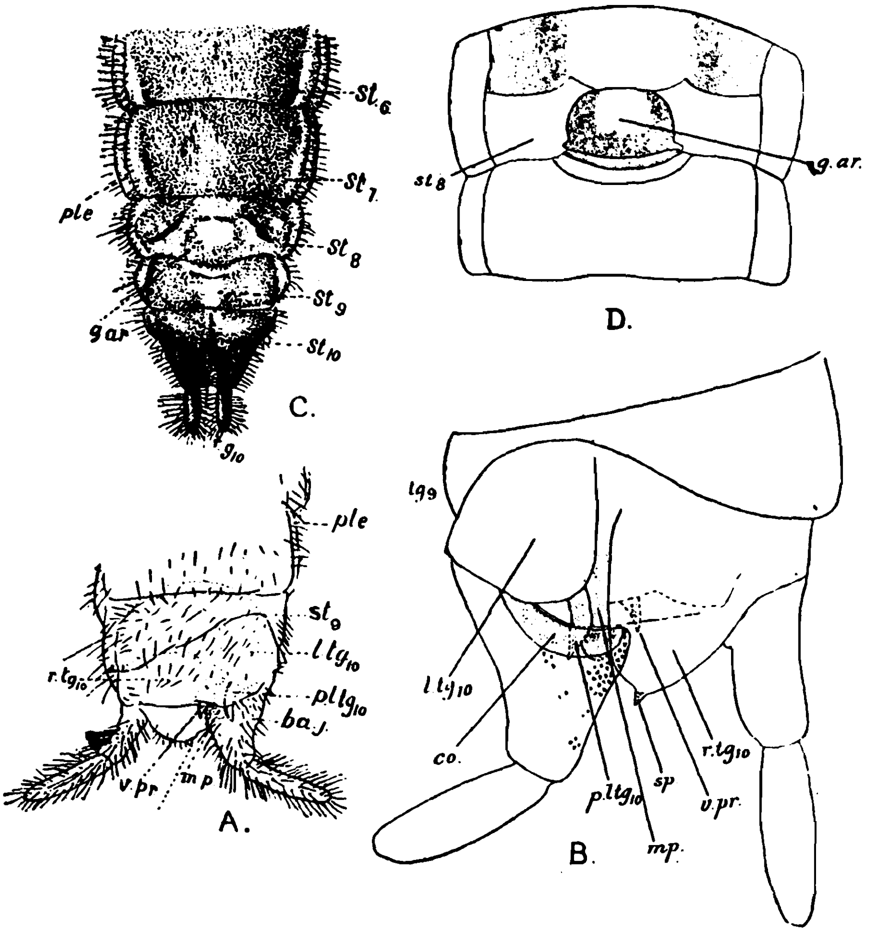
[1] The lettering as well as the explanation of the figures of the cardo and stipes by Imms (1913) for *Embia major* are misleading. In his figure he calls the basal portion as the stipes, and the portion bearing the galea the maxillary palp, and the lacinia as the cardo. The correct name for the basal portion is the cardo and for the distal the stipes.

the inner lobes of the second maxillae, is more prominent in the case of *E. major* than it is in *E. minor*; (*b*) in *E. minor* the paired inner lobes (*l. i.*) of the second maxilla are apically acuminate and distinctly triangular in shape[1]; they occupy the entire space between the paraglossae (*p. gl.*), whereas in *E. major* they cover only a portion of the space; (*c*). the portion of the mentum bearing the inner lobes is not concave in *E. minor*. The labial palpi (*l. p.*) are three-jointed. The relative lengths of the joints are as 10 : 11 : 20.



TEXT-FIG. 5.

Embia minor, sp. nov.

A. External genetalia of the ♂ with the 10th abdominal segment as seen from below ×12·5.

B. External genetalia of the ♂ with the 10th abdominal segment as seen from above, ×27·5.

C. Last five abdominal sternites of a female showing the symmetrical arrangement of the 10th sternite, the normally developed cerci and the female genital aperture, ×13·5.

D. 8th abdominal sternum (sub-genital plate) of female showing the area of the female genital aperture, ×27·5.

ba. j.=modified basal joint of the left cercus; *co.*=concavity of the basal joint of the left cercus; *g. ar.*=area of the female genital aperture; *l. tg.*=left plate of the 10th tergite; *m. p.*=median plate; *ple.*=pleuron; *p. l. tg* $_{10}$.=process of the left 10th tergal plate; *r. tg* $_{10}$=right plate of the 10th tergite; *sp.*=process of the right 10th tergal plate; st_1, st_2 etc.=sternites; tg_1, tg_2, etc.=tergites; *v. pr.*=ventral process of the 9th sternum.

The prothorax is sub-quadrate, being slightly narrower anteriorly, and has a deep transverse suture running across its breadth at the junc-

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[1] These are the "Lobi-interni" of Enderlein, and according to him are the organs on which the external openings of the spinning glands are situated. On this subject, however, see *infra*, p. 271.

tion of the anterior and middle ⅓rd; the posterior ⅔rds bears a similar incomplete longitudinal groove running backwards to the distal margin. This groove is sometimes produced forwards in front of the transverse sulcus to meet the anterior margin of the pro-thoracic tergum. The mesothorax is also sub-quadrate and presents no special features. The metathorax is considerably broader than long; it is distinctly smaller than the mesothorax. The thoracic terga bear long brownish hairs especially at the margins.

The legs are similar to those of the male. The abdominal terga differ from those of *Embia major* only in size and present no special features. The 8th sternum forms the sub-genital plate. The posterior half of the 8th sternite contains a semicircular brownish area enclosing a small pale area, which bears a median transverse incision marking the position of the female genital aperture (text-fig. 5 C, D; *g. ar.*).[1] In the specimen examined the relative lengths of the 8th and 9th sterna were as 19 : 22. The anterior half of the 8th sternum bears laterally a pair of brownish longitudinal areas which gradually merge into their respective pleurae. The 9th sternum contains anteriorly a thin crescentic brownish area which runs anteriorly into the brownish area of the 8th sternum. The 10th sternum is divided longitudinally into two symmetrical halves (st_{10}). The cerci exhibit no asymmetry and are similar to each other.

In the case of the female, the distal thirds of the basal joints of the cerci bear on the dorsal surface more sensory hairs than on their proximal portions, while on the ventral surfaces of the basal joints the condition is reversed. Each of the distal joints of the cerci bears on the dorso-median region towards the inner edge a single sensory hair, but its position does not appear to be constant.[2] The presence of a single sensory hair on the distal joints of the cerci appears to be characteristic of the genera *Oligotoma* and *Embia*.

Table showing the differentiating characters of allied species of the genus Embia.

	Embia major Imms.	*Embia minor*, sp. nov.
1.	Length of the male 12·75—18 mm.	Length of the male 9·5—12·5 mm.
2.	Length of the female 14·75—20·75 mm.	Length of the female 14·5—15·75 mm.
3.	Number of antennal joints varies from 20—29.	Number of antennal joints varies from 18—25.
4.	9th tergum less compressed than that of *E. minor*.	9th tergum more compressed towards the left side than that of *E. major*.
5.	Process of the left plate short and very much curved.	Process of the left plate comparatively long, less curved and less pointed.
6.	Ventral process curved and appears to be larger than the process of the left 10th tergal plate.	Ventral process not curved, pointed and distinctly smaller than the process of the left 10th tergal plate.
7.	Median process smaller than the process of the left 10th tergal plate.	Median process nearly of the same length as the process of the left 10th tergal plate.
8.	Inner surface of the concavity of the thickened basal joint of the left cercus denticulate.	Inner surface of the concavity of the thickened basal joint of the left cercus does not bear any denticles.
9.	Arolia on the tarsal joints of the hind pair of legs glabrous.	Arolium on the second tarsal joint armed with minute yellowish spines.

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[1] In young specimens the pale area containing the genital aperture was found to be situated more anteriorly than in adults.

[2] Okajima (1926) has described these hairs on the cerci of *Oligotoma japonica*.

4. Internal Anatomy.

Alimentary Canal.

The alimentary canal is extremely simple and in general structure resembles that of the primitive insects. It is almost straight without any diverticula, and is nearly of the same length as the actual length of the insect. Specialization of the different parts of the alimentary canal for separate digestive functions is a more or less constant characteristic of all insects, but in the case of the Embiids this specialization is not so marked. The relative sizes of the different parts of the alimentary canal as far as they can be distinguished are as follows :—

	mm.
Oesophagus	6
Gizzard	0·95
Chylific stomach	4·50
Small intestine	1·25
Colon	1·95
Rectum	1·55
Total length	16·20

The mouth, the oesophagus and the crop form the stomodaeum, while the mesenteron of the Embiids, as in other insects, is very short and includes only the chylific stomach. The proctodaeum begins with the malpighian tubules and extends thence to the anus. Both the stomodaeum and proctodaeum have a chitinous lining which is absent in the mesenteron.

The mouth of the Embiids is enclosed by the labrum on top and the labium below, while it is bounded laterally by the mandibles and by the first pair of maxillae. The lingua or the tongue hangs like a flap from the posterior wall of the buccal cavity and covers about ¾ths of its depth. The hypopharyngeal part of the lingua is sub-quadrate with its posterior angles rounded. Each of the rounded ends is covered by a group of fairly long hairs, about 12 in number. At the posterior end of the hypopharynx there is a constriction which marks the beginning of the lingua. At the point of its origin from the hypopharynx the lingua is half as broad as the hypopharynx ; its breadth, however, increases as it runs posteriorly until it becomes almost as broad as the hypopharynx. Distally the lingua again diminishes in breadth and its posterior extremity becomes narrow and round. There is apparently a small groove at the posterior ⅔rds of the lingua, while a longitudinal groove runs throughout the length of the tongue ventrally.[1] The chitinous sides of the lingua are furnished with very minute hairs.

The mouth leads into a narrow oesophagus, the anterior portion of which is beset with thick, short and pointed denticles (pl. XXIII, fig. 4, *dt.*). It passes through the neck into the thorax, where it gradually dilates into a bag-like crop, the dilated end of which extends into the

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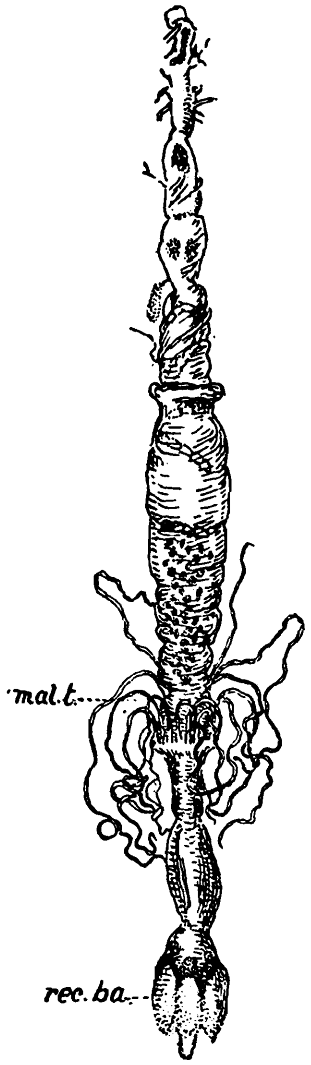
[1] Superficially the tongue is invested with taste-scales or " Geschmacks-Schuppen " of German authors.

fore-part of the abdomen. Numerous tracheal tubes are found all over its outer surface. The gizzard is like a blunt slightly curved cone. Its wall is thicker than that of the crop, and it is attached by its broader base to the hinder end of the crop. Along its distal end it appears like a rather narrower blunt tube which protrudes into the chylific stomach. The chylific stomach is a simple cylindrical tube without any caecal tubes. Posteriorly the chylific stomach opens into the intestine. At the hinder end of the chylific stomach there is a very short tube, the small intestine, which is broadest at its point of origin from the chylific stomach. It gradually narrows down till at its posterior end its diameter is roughly half that of the chylific stomach. At its junction with the chylific stomach about 20-30 malpighian tubules are attached.



TEXT-FIG. 6.

Embia minor, sp. nov.

Alimentary canal, ×6.

mal. t.=malpighian tubules ; *rec. ba.*=rectal bands.

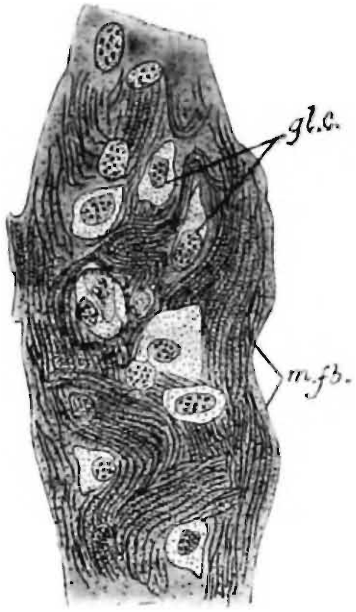
The junction of the small intestine with the colon is marked by a strong constriction, which is muscular and appears to function as a circular valve. The colon extends for about 2 mm. and its diameter is slightly greater than that of the small intestine, but is smaller than that of the chylific stomach. The colon is constricted both anteriorly and posteriorly at its junction with the small intestine and the rectum respectively. The middle portion of the colon is slightly dilated and its wall presents a striated structure.

The rectum is about 1·5 mm. long and when distended is dilated in the middle. The rectal bands are fairly well developed in these insects (text-fig. 6, *rec. ba.*) and are 6 in number. They are more or less crescentic in shape and are closely apposed, covering nearly $\frac{3}{4}$ths of the external wall of the rectal chamber, over which they are meridionally arranged.

In longitudinal sections of the rectal band the muscle fibrillae are found to run throughout the entire length of the bands ; only at certain places they are curved and leave a more or less clear space occupied by epithelial or glandular cells. The nuclei of these cells are granular and show up in the clear spaces between the fibrills (text-fig. 7).

No anal glands are found in the pygidial region of these insects. The rectum opens ventrally below the 10th tergum.

The salivary glands are paired, rather small, irregularly elongated structures, situated in the prothoracic region. The malpighian tubules (text-fig. 6, *mal. t.*) are elongate, slender tubules and are of nearly the same thickness throughout. As mentioned above, they vary in number



TEXT-FIG. 7.
Embia minor, sp. nov.
Longitudinal section of a rectal band, showing the development of muscle fibrils and the presence of glandular (epithelial) cells, ×232·5.
gl. c.=glandular cells; *m. fb.*= muscle fibrils of the rectal band.

in different individuals and are situated at the junction of the chylific stomach and the small intestine.

Nervous System.

The nervous system, composed of ganglia and connectives, extends throughout almost the entire length of the body. In the Embiids there are 12 ganglia in all, 2 cephalic, 3 thoracic and 7 abdominal. Grassi (1897-1898) noted that there is no ganglion in the 5th abdominal segment, but in *E. minor* I found a distinct ganglion in this segment, but there was no trace of a ganglion in the 4th segment. The seven abdominal ganglia are connected with one another by a double chain, the component elements of which are very closely apposed. The last ganglion is larger than the others and probably represents several coalesced posterior ganglia. It supplies nerves to the reproductive organs, the rectum and the cerci.

In addition to the above a well-developed visceral part of the nervous system has been demonstrated by Melander (1903).

The Female Reproductive Organs.

As in other insects, the ovaries of the two sides are distinct and on each side consist of 4—5 fairly long tubes (text-figs. 8 B; *ov. t.*),[1] which open at intervals into a straight oviduct (*ov. d.*). The oviducts of the two sides meet posteriorly, forming a short vestibule or the vagina, which is slightly constricted anteriorly. Tracheae and fat cells permeate the ovarian tubules of each side, but the ends of the tubes appear to be quite free. Each tube is about 5·51 mm. long and is moniliform in appearance. The slender ends of the tubules gradually diminish in diameter anteriorly and passing upwards lose themselves in the fat body. The wall of the ovarian tubule is externally invested with a peritoneal layer of connective tissue, and is internally composed of a transparent elastic membrane lined by epithelium. Posteriorly the vagina (*vag.*) opens by a median transverse slit in the posterior half of the 8th sternum. The vaginal area can be distinguished from the outside as a brownish somewhat semi-circular area in the posterior half of the 8th sternum or the sub-genital plate (text-fig. 5 C, D; *g. ar.*). It encloses anteriorly a somewhat irregularly ellipsoidal rather translucent portion of the 8th sternum which acts as a flap for the vaginal slit.

The spermatheca is comparatively large and elongated, its distal free end is somewhat narrower and rounded and the free tip reaches the

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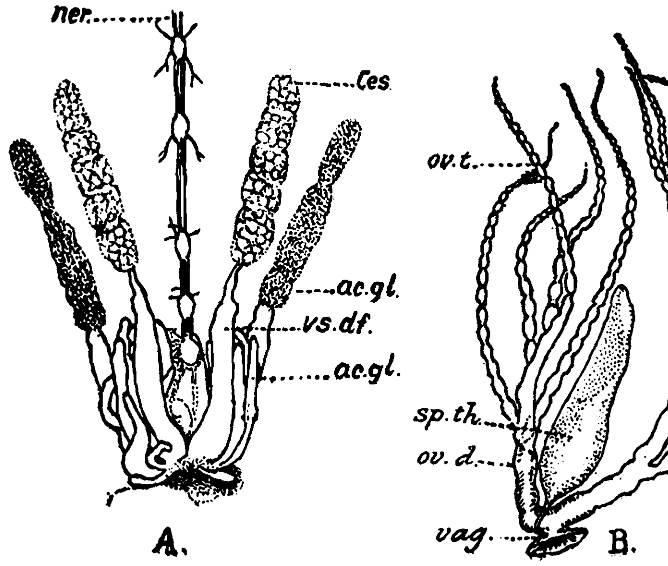
[1] The ovarioles are of the panoistic or holoistic type.

3rd or even the 2nd abdominal segment. Its basal portion suddenly narrows to a thin tube (text-fig. 8 B ; *sp. th.*). The orifice of the spermatheca is situated on the dorsal wall of the genital pouch.



TEXT-FIG. 8.

Embia minor, sp. nov.

A. Internal genital organs of the ♂, ×12.
B. Internal genital organs of the ♀, ×10.

ac. gl.=accessory glands ; *ner.*=a portion of nerve chain of the abdominal region with ganglia ; *ov. d.*=oviduct ; *ov. t.*=ovarian tubules ; *sp. th.*=spermatheca ; *tes.*= testis ; *vag.*=vagina ; *vs. df.*=vas-deferens.

The oviduct is devoid of a chitinous lining. The vagina and the spermatheca, as also its short tubular duct, have a cuticular covering. The ovarian tubes contain ova in different stages of development encased in follicles. A ripe egg is somewhat oval in shape with a distinct micropylar area.

The Male Reproductive Organs.

The two testes lie one on each side. Each testis is a flattened, elongated structure and occupies a considerable portion of the terminal part of the abdomen, lying laterally to the alimentary canal (text-fig. 8 A ; *tes.*). The testes are concealed in the fat body from which they cannot be easily separated. Each testis consists of 5 lobes elongated and subcylindrical in shape arranged in a single row ; each lobe in its turn is composed of a large number of small rounded vesicles. The testis of each side is connected to the vas-deferens, which starts as a narrow tube from the posterior end of the testis ; it gradually increases in thickness until it becomes markedly thick, about 8 times as thick as its anterior portion. It is about 2·40 mm. in length (*vs. df.*). The dilated rounded ends of the vasa deferentia form the vesiculae seminales. The vasa deferentia of the two sides unite posteriorly to form a short, muscular, ejaculatory duct occupying a space between the 9th and the 10th sterna. The ejaculatory duct opens between the external chitinous parts of the genitalia and not, as is generally believed, through the median plate (text-fig. 5 A, B ; *m. p.*) or the aedeagus in other insects, In adults the duct is distended with spermatozoa. The external genitalia have already been dealt with in the description of the external characters of the male.

The Respiratory System.

The respiratory system of the Embiids consists of ramified tracheal tubes which communicate externally through stigmata or spiracles. Of these spiracles the Embiids have ten pairs, two thoracic and eight abdominal, connected by longitudinal and transverse tracheae and forming a single connected system.

The first thoracic spiracle is the largest, being about 0·21 mm. in diameter. Its position is in front of the mesothorax between the bases of the first and the second pairs of legs, a little beneath the edge of the tergum. It is placed in an inclined position, the spiracular slit being oblique and pointing somewhat downwards and backwards.

The second thoracic spiracle lies in front of the metathorax between the bases of the second and the third pairs of legs. It is smaller than the first, its length being 0·15 mm. The free borders of both the thoracic spiracles are strengthened on their deep surfaces by chitinous rims.

The abdominal spiracles (plate XXIII, fig. 5) are smaller than the thoracic ones and occupy the anterior regions of the first eight abdominal pleura. Each lies in the anterior portion of the pleuron, *i.e.*, in the interspace between the tergum and the sternum. The external portion of the orifice of the stigmata shows no valvular structure. The orifice leads to a shallow ellipsoidal chamber which communicates with the tracheal trunk by a slit or an aperture situated inside the spiracular chamber. All the abdominal spiracles are funnel-shaped and the first, which is rather larger, is situated a little more dorsally than the others.[1]

The transverse connections are single and occupy a ventral position. The branches of the two sides unite and form transverse commissures between the trunks which originate from the spiracles. The dorsal longitudinal branches are formed by the union of the dorsal transverse branches, while the ventral branches form a transverse network. In the thoracic region two large tracheae run longitudinally on either side to the head. The ultimate endings of all the tracheal branches form a complicated mesh-work of very fine tubes which permeate all the tissues.

The spiracles of the Embiids, owing to their very minute size and differences in structure and position, are often difficult to locate.

5. (*a*) THE SPINNING APPARATUS.

The way in which the Embiids spin their tunnels has attracted the attention of several entomologists, but no definite conclusions regarding

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[1] For studying the stigmata with their connectives a specimen was longitudinally divided into two and the halves were cleared in clove oil and mounted in Canada balsam. Further complete specimens mounted whole in Canada balsam were studied for determining the exact positions of the stigmata. For studying the minute structure of the spiracles on the other hand a longitudinally bisected specimen was boiled in dilute caustic potash and mounted in Canada balsam after clearing.

the position of the spinning apparatus and the mechanism of spinning have so far been published. Imms (1913) in his paper on *Embia major* remarks that the question of the mechanism of silk production in the Embiids is a much debated one, while a full discussion of the earlier literature is to be found in the works of Grassi and Sandias (1898), Melander (1903), Friedrichs (1906), Rimsky-Korsakow (1910), Krauss (1911) and Enderlein (1912).

My studies on this question have led me to the results described below. These are based on a prolonged series of observations and experiments made in the laboratory upon living specimens, and on the results of my studies of the whole organs and their sections.

Grassi and Sandias, Melander, Friedrichs and Rimsky-Korsakow are of opinion that the spinning glands are situated on the metatarsal joints of the forelegs. Enderlein (1903, 1912), on the other hand, from his studies on the mouth-parts and the metatarsus of the forelegs, came to the conclusion that the " lobi-interni " or the internal lobes of the second pair of maxillae constitute the external spinning apparatus. Imms (1913), from his work on *Embia major*, upholds the view of Grassi and Sandias, Friedrichs and Rimsky-Korsakow. These authors are unanimous in their opinion as to the situation of the spinning glands in the metatarsi of the forelegs. They, however, were unable to elucidate the complete mechanism for the extrusion of the fluid contents of the metatarsal glands, and even after the excellent histological work on the metatarsal spinning glands by Melander and Rimsky-Korsakow, the problem remained only partially solved.

From a series of experiments which I carried out to determine the function of the internal lobes of the second maxillae and the metatarsal joints of the forelegs, I am in full agreement with the authors who believe that the spinning glands are situated in the metatarsi of the forelegs.

Enderlein stated that the internal lobes of the second maxillae in the Embiids are pointed, closely apposed and characteristically shaped structures, like those of other spinning insects, especially the Copeognaths, and probably represent the site of the external spinning organ or the spinnerets. This remark of Enderlein appears to be entirely hypothetical, as sections through the head and thorax reveal no sign of the existence of any glands or ducts other than those of the salivary glands. It appears that Enderlein's analogy of the spinning organ of the Copeognaths with that of the Embiids is based only on the fact that the Copeognaths are the only adult insects allied to the Embiids which possess the spinning power. This is clear from Rimsky-Korsakow's (1910) remark, who added that Enderlein has taken the Copeognaths for comparison as in the earlier days these forms were classified with the Embiids under Corrodentia. Enderlein's figures of the " lobi-interni " or glossae of the labium show neither the position nor the shape of the spinnerets, and the ducts also are not indicated.

The " lobi-interni " or glossae of the labium are too small to contain an elaborate system of spinnerets, which would be capable of spinning a fairly long tunnel within a few minutes. Further, as I found from my observations on living specimens of *Embia minor*, the peculiar crossing and recrossing movement of the forelegs during spinning are quite different from the ordinary movements of the legs, and are not connected with the movements of the labium. When the spinning is in progress, the metatarsi of the forelegs seldom approach the labium and so could not manipulate the threads which, according to Enderlein, issue from the internal lobes or glossae of the labium. Observations on a living specimen of *E. minor* under a binocular microscope showed that the threads are emitted in fair numbers at a time from the metatarsal tubular hairs, and that these threads are laid in nearly parallel and distinct lines along the tracks of the forelegs of these insects. The rapidity with which the tunnels are built, and the fact that the threads come out in fair numbers at a time, suggests the existence of an elaborate system of glands for spinning. This presumption is further strengthened by the peculiar arrangement of the glandular vesicles in the metatarsi of the forelegs and the openings at the tips of the fine setae mentioned already.

Regarding the secretion of the gland-vesicles Enderlein was of opinion that they are of little or no importance since the secreted fluid is granular and thin. It is evidently the chemical constituents of the gland-contents which are the main factors for the manufacture of the threads, and thus the importance of the gland-contents for the formation of the silk depends principally on the chemical constituents of the fluid rather than on its consistency. The gland-contents of other silk-spinning insects, *e.g.*, the silk spinning caterpillars, are thick, but this is no argument against the view that the fluid-contents of the glandular vesicles of the metatarsi of the forelegs of Embiids are concerned in the formation of the silk threads. It is not known what causes the solidification of the secretion, but there can be no doubt that the secretion solidifies almost immediately after the emission of the fluid from the tips of the tubular hairs, and apparently is independent of any other secretion.

Enderlein assigned quite a novel function to the metatarsal glands. He suggested that their role was to cause the hardening of the silk threads which he supposed to be discharged from the labium of the Embiids and was similar to that of the gland lying below the gula in the spinning caterpillars, *e.g.*, the silk worms. This comparison, however, is of no consequence, and, further, it is difficult to believe that such an elaborate system of glands as those on the metatarsal segments and situated at such a distance from the source of the main secretion, *viz.*, the labium, should have the function of hardening assigned to them. The only pair of glands in the head and thorax of the Embiids are the salivary glands and these certainly do not secrete any silky material.

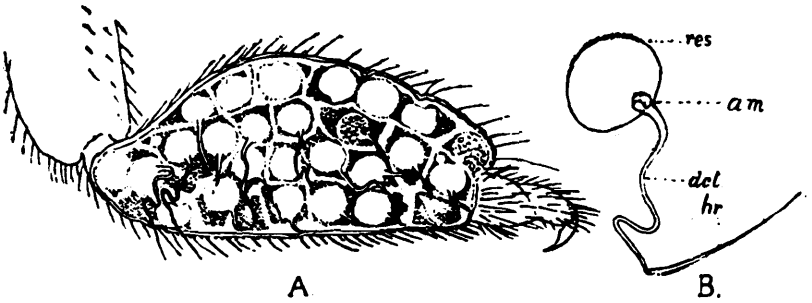
Enderlein further stated that the thin oily secretion from the metatarsal gland-vesicles prevents the hairs of the metatarsus from sticking together during the manipulation of the threads which issue, as he supposed, from the spinnerets of the labium. It is difficult to conceive how the tubular setae containing the ducts and not the ordinary setae of the metatarsus help in the manipulation of the threads, especially when all the metatarsal setae are not connected with the glands. Further, the manipulation of the threads by the setae when they are oily would, owing to capillary action, be a physiological impossibility. The thin layer of oil on the fine setae would make the extremely thin threads stick to the setae rather than spread them into bundles. The occurrence of such a type of lubricating arrangement in insects is doubtful and it is certainly not found in the web-spinners, *e.g.*, in the Araneae (spiders), where the hind legs help in the manipulation of the threads. The metatarsi of the forelegs in the Embiids alone, as has been described above, perform both the functions of secreting and manipulating the threads to form bundles.

As regards the cementing up of the excretory orifices by the passage of the secretion through a microscopically fine canal, as stated by Enderlein, I am of opinion that the passage of the fluid without choking up the orifice of the canal does not seem to be a physiological impossibility, especially when the fluid flows out at a fairly rapid rate. It is also highly probable that the extreme fineness of the canal and the passage of the fluid through it helps to some extent to solidify the fluid.

Enderlein and Rimsky-Korsakow are to some extent justified when they remark that the problem of the emission of the fluid from the metatarsal glands, in the absence of a special arrangement for the extrusion of the secreted fluid, appears incomprehensible. Rimsky-Korsakow in his later paper (1910) added that this objection is not applicable to the Embiids only, but is common to other Arthropods such as Araneae, where no contrivance for the extrusion of the fluid has been discovered. He noted that in the case of comparatively tubular spinning glands, a special contrivance for pressing out the fluid is present, but that the small dimensions of the canals from the glands in the Embiids eliminates the necessity of such a contrivance. There is some difficulty in accepting this theory of Rimsky-Korsakow since, in the absence of other factors, capillary action would set in within these extremely fine tubes and render the out-flow of the secreted fluid well nigh impossible.

5. (*b*) THE GLANDULAR RESERVOIRS.

The glandular reservoirs containing the secretion lie in the swollen metatarsi of the forelegs. Each of the reservoirs opens separately to the exterior by means of a curved hollow seta situated on the plantar surface of the metatarsus. In *E. minor* these reservoirs are arranged longitudinally in 4 to 5 rows and vertically there are 3 to 4 layers of them (text-fig. 9 A), while each row contains on an average 6 to 7 reservoirs. The reservoirs are ovoid in shape, their largest diameter being 0·066 mm., and the shortest 0·02 mm. The portion from which the duct arises and the portion just opposite to it are slightly depressed. The length of the duct which leads to the seta is from the point of its origin to the root of the seta 0·16 mm. (text-fig. 9 B ; *dct, hr, res.*). The duct originates from a peculiar structure—the ampulla of Rimsky-Korsakow (text-fig. 9 B ; *am.*), which is a thin-walled ovoid sac with the proximal and distal regions slightly thickened. This ovoid sac is in continuation with the duct and the thickened mass at its proximal pole is continued laterally into 4 to 5 radiating arms equidistant from each other, and passing as meridional lines to the opposite pole, where they meet again. In a section of the ampulla the opening of the duct is seen as a minute centrally situated lumen, while the ampulla is provided with 4-5 ellipsoidal or semilunar lateral lacunae. The function of the ampulla and the lateral openings are perhaps to prevent too sudden a flow of the fluid through the thin lumen of the fine canal.



TEXT-FIG. 9.

Embia minor, sp. nov.

A. Metatarsus of the foreleg showing the gland-vesicles and their ducts (*in situ*), ×50.

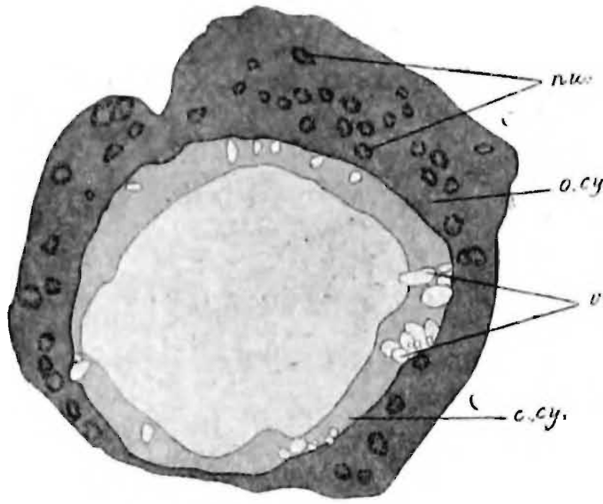
B. Individual gland-vesicle with its duct, ×150.

am. = ampulla; *dct.* = duct of the glandular reservoir; *hr.* = spinning seta; *res.* = reservoir of the metatarsal gland vesicle.

Histology.—In *Embia minor* the thickness of the wall of a vesicle varies at different parts. The external contours of the walls of different vesicles in a section are so variable that no two glands appeared to be similar. In a section of the metatarsal gland two distinct layers of cytoplasm are visible in the wall of a vesicle, *viz.*, (*a*) an inner rather thin rim of clear vacuolated cytoplasm (text-fig. 10, *c. cy.*) devoid of any nucleus. The vacuoles (*vac.*) are of different sizes and their number in each vesicle is extremely variable, 1-29 vacuoles being present in a gland. The vacuoles are unevenly distributed in the clear cytoplasm, but in some places were found to be collected in groups; (*b*) an outer rather thick layer of reticulated cytoplasm (*o. cy.*) over which the nuclei (*nu.*) are scattered. The nuclei are more or less rounded and are almost uniform in size. Their number in a gland-vesicle varies considerably; as many as 43 were counted in a single vesicle. The chromatin granules of the nuclei are distinct and lie more or less towards the periphery of the nuclear membrane. No cell boundaries could be distinguished. The secretion appears to be finely granular in sections and occupies the central lumen of the glandular reservoirs.

The minute structure of the metatarsal gland of *Embia minor* described above resembles that of *Embia texana* and *Embia ramburi*, described and figured by Melander (1903) and Rimsky-Korsakow (1905) respectively, in that the individual cell-walls of the gland-vesicle are indistinct, but differs in (*a*) a comparatively more variable thickness of the wall of the gland-vesicle; (*b*) the presence of a clear inner layer of vacuolated cytoplasm and (*c*) the nuclei distributed along the periphery on the reticulated cytoplasm.

Rimsky-Korsakow (1905) is of opinion that the glandular reservoirs are not multicellular since the cell boundaries are not distinct, and that no multicellular secretory glands are known to occur in the legs of insects. I am, however, of opinion that the glands are multicellular in origin. The individual cell-walls have disappeared owing probably to the peculiar function of the glands and only the numerous nuclei remain to demonstrate the original multicellular nature of the glands.



TEXT-FIG. 10.
Embia minor, sp. nov.
Section of a metatarsal gland-vesicle, × 400.
nu. = nucleus ; *c. cy.* = inner layer of clear cytoplasm ; *o. cy.* = outer layer of reticulated cytoplasm ; *vac.* = vacuoles on the clear cytoplasm.

The spinning glands of the Embiids are probably to be compared with the isolated glands which are present in the feet of various insects. In the Embiids these glands are, however, more evolved in that they are united together to form a group and do not occur separately. The presence of the spinning apparatus in the metatarsi of the forelegs of the Embiids is not very extraordinary, as it is only a specialization of certain hypodermal glands for a special function in response to their peculiar habits. The interspaces between the glandular reservoirs in the swollen metatarsi are filled with a somewhat granular secretion, which apparently is extruded through minute openings situated at the base of the hollow setae lying in the second metatarsal joint. I have, however, failed to distinguish any cellular elements in the interspaces which could produce the secretion described above.

Numerous fine muscle-fibrils are present at the proximal end of the metatarsus. They originate from the dorsal surface of the main tendon of the foot as it runs through the constricted proximal end of the first joint of the metatarsus and are attached distally to the dorsal wall of the metatarsus. I believe them to be specially connected with the control of the expulsion of the fluid-contents of the metatarsal glands. By the simultaneous contraction of the muscles mentioned above a reduction of the space in the metatarsus takes place and the pressure so exerted causes the fluid-contents of the gland-vesicles to be forced out through the tubular setae.

6. SOME NOTES ON THE NATURE AND THE HABITAT OF *EMBIA MINOR*, SP. NOV.

On the 17th September 1924 I found both the male and female forms of *E. minor* in several complicated mesh-works of tunnels spun under pieces of damp wooden planks in a godown of stored pulses at the Pusa farm (Bihar). The godown was badly lighted and very damp. The mesh-work of silken tunnels were 9-11 inches long and nearly as much in breadth, and were constructed under the sacks containing stored grains, or under piles of sacks and ropes. A large number of tunnels were examined, and it was found that the number of male insects in them was much smaller than that of the females.

All stages of the insect were found inside the tunnels. The males are usually smaller in size than the females and are winged. Some immature forms were also found, but it was impossible to determine their sex at that early stage. A few male nymphs, however, were found with the wings not fully developed and containing only a few nervures. In confinement individuals were seen to spin a rather flimsy tunnel within 15-20 minutes. When confined in a corked tube, they were found to nibble the cork, and the bits of cork thus chewed were found on the webbing along with the pellets of excreta of a greenish grey colour. A completed tunnel is fairly thick and is sometimes furnished with a few lateral branches which arise from the original tunnel and meet it again further on. In spite of their thickness, the tunnels are more or less translucent. The time taken to finish a tunnel depends upon the size of the tunnel and the number of individuals present in the colony. Under laboratory conditions it was seen that several insects lived comfortably in one and the same tunnel when plenty of food of the right kind was available.

A single fibre from the wall of a tunnel is extremely fine and a tunnel is composed of innumerable such threads irregularly gummed and webbed together to form bundles. These bundles are not of a uniform thickness and Melander (1902) attributes this to a selective action in the secretion of some or all the glands at different times. From my observations, however, I am of opinion that the difference in the thickness of the bundles is due to the manipulation of the forelegs while the secretion is being laid, and is in no way dependent on the secretion by the glands themselves. The colour of the threads is milky white.

In addition to the lateral branches there are a few openings along the sides of the tunnels and the insects use them for ingress and egress from the tunnels when disturbed. The insects can move backwards and forwards with equal facility and in their backward movement the cerci appear to serve as feelers for finding the lateral openings.[1]

During spinning the anterior pair of legs move sharply in their acetabula. From the openings at the tips of the metatarsal setae numerous white threads are secreted and these threads are laid down into bundles by the rapid movements of the legs mentioned above.

Irregular rhombohedral crystals of a chalky white substance were also found in the tunnels, but their exact nature could not be determined.

Scolytid and Bruchid beetles with a few species of Microlepidoptera were also found in association with *Embia minor*.

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[1] This may explain the presence of the sensory hairs on the cerci of the Embiids.

Various kinds of food material, as for example wheat flour, dead insects, dry leaves, dry wood shavings, bits of cork, green vegetables, were supplied to the insects and it was found that the wheat flour was preferred to all other kinds. Adult females kept together without food were found to have lost some of their appendages wholly or in part. No appendages were, however, found in the breeding jars, and it is, therefore, possible that under extreme conditions of starvation the insects begin to feed on each other.

Males of this species when frightened can fly short distances, otherwise they behave like apterous insects and their wings are not functional in the usual sense of the term. This loss of the function of flight may be due to the sedentary habits of the insects or the disuse of the wings over a very long period of their existence.

From my observations on the nature of the silken tunnels I am of opinion that, though the tunnels of the Embiids serve to some extent as a protection against the attacks of small insects, they are not so perfect in their function as has been stated by Imms (1913). The following observations were made in the Entomological laboratory at Pusa to investigate the efficiency or otherwise of the tunnels as protective recesses. On the 7th October nymphs of several Reduviid bugs were collected by the Imperial Entomologist as the suspected carriers of Leishmania bodies (kala-azar). These were kept in glass crucibles for observation and were fed with the Embiids, both nymphs and adults. The Embiids supplied as food to the bugs rushed about for a few minutes but afterwards settled down and began to spin tunnels. Within 10-15 minutes a fairly long (about 2-3 inches) zig-zag tunnel was spun. The tunnel was more or less thick but semi-transparent, and the movements of the Embiids could be clearly observed through it. The Reduviid nymphs walked sluggishly over the tunnels several times but, as mentioned by Imms (1913), they were never seen to become entangled in the webbings of the tunnel. Some of them were observed to pierce the meshes of the webbings with their strong proboscis and suck the juices from the bodies of the Embiids.

Grassi and Sandias (1897) consider that these tunnels serve to protect the body from excessive transpiration and help in maintaining a sufficiently humid atmosphere for the Embiids living in them. It is difficult, however, to substantiate this statement, as among the Embiids kept in the laboratory for observation during the hot month of June, when the maximum temperature rose to as much as 113° Fahrenheit (5th June, 1924), a high percentage of mortality was observed, though practically all the insects were living inside their tunnels. Thus the remark of Grassi and Sandias, that the tunnels help in keeping a humid atmosphere around the Embiids, has to be taken with some reserve. So far as my experience goes, the Embiids cannot survive in too low a temperature. Thus when the temperature at Pusa went down to 40·6° Fahrenheit (17th January, 1925), a high percentage of mortality was again observed among the Embiids kept in confinement.

In a few instances when disturbed or teased out of the tunnel some of the insects were seen to feign death.

That these insects prefer cool shady crevices to brightly illuminated spots was confirmed by the following experiment. A rectangular glass trough was taken and half of the trough was covered with black paper. A piece of cardboard of about the same height and length as the trough was taken and two holes were punched at the sides at heights of about $\frac{3}{4}$ths of an inch from the base. The piece of cardboard, which was placed in the middle of the trough, thus divided it into two chambers—one dark and the other fully exposed to light. Three adult females of *Embia minor* were placed in the uncovered part of the trough which was fully exposed to the light. The insects became restless and scurried about from one end of the chamber to the other. They were left in this condition in the trough for a whole day. Next morning they were found in the darkened half of the trough quietly resting inside a tolerably long tunnel spun in one of the corners of the trough. In passing from the lighter to the darker half of the trough the insects must have travelled through the holes in the cardboard partition. This experiment clearly proves the negative phototropic habits of these insects.

To find out whether the shape of the web depends on the place of confinement of the insects the following experiment was tried. Three females of *Embia minor* were kept confined in a watch-glass for observation. In this case only flat webs, and not tunnels, covering nearly the whole base of the watch-glass was spun by the insects. It is quite possible that they cannot spin tunnels on flat smooth surfaces, where points of attachment for the threads for the construction of the tunnels are absent.

Carnivorous nature of the male.

Michael and Westwood (1876) were the first to definitely state that the Embiids are vegetable feeders. Melander (1902), on the other hand, observed that the insects are more or less carnivorous, and that they do not normally eat anything of a vegetable origin. They were also noticed occasionally to nibble at small pieces of worms or flies, but Melander's observations on the subject are not sufficiently extensive or detailed to be conclusive. Friedrichs (1906) suggested that in the case of the European species only the males are carnivorous. Imms (1913) was of opinion that the slender mandibles of the male without the crushing edge greatly resemble those of other carnivorous insects. He further noted that the larvae could be reared to nymphs purely on vegetable food.

From the above it would seem probable that the males take to a carnivorous habit under special conditions, but that the females are always averse to it. It would, however, be wrong to dogmatize from these laboratory experiments as to what is the exact nature of the food of these insects under natural conditions. I carried out the following experiments under laboratory conditions in a petri dish. Three male nymphs of *Embia minor* were allowed to starve for a day and afterwards supplied with 4 dead nymphs of the Homopteran, *Pyrilla* sp. Three of these nymphs were apparently eaten overnight by the Embiids. On the other hand female Embiids under similar conditions died of starvation rather than feed on dead *Pyrilla* or *Lepisma.*

Adults of both sexes, however, probably nibble at one another's antennae, and this is suggested by the fact that bits of antennae were found in the alimentary canal of a female specimen (text-fig. 6).

7 SUMMARY.

1. The affinities of the order Embiidina, its relationship with other groups of insects, and the geological history of the order are discussed (p. 254).

2. A detailed description of the ♂ and ♀ of *Embia minor*, a new species from Pusa, Bihar, is given and a table showing the differences of this species from the only other known Indian species of the genus is appended (p. 256).

3. The internal anatomy of *Embia minor* is described in detail (p. 266).

4. In the case of the respiratory system, the tracheal connectives, the position, the structure and the size of the spiracles of different regions of the body are dealt with in detail (p. 270).

5. The views of the earlier authors as to the position of the spinning glands are discussed, and Enderlein's statements as regards the position of the spinning glands are considered. Rimsky-Korsakow's view about the apparent absence of a contrivance for the extrusion of the fluid contents of the metatarsal gland vesicle is also discussed (p. 270).

6. A detailed description of the size and the structure of the metatarsal gland-vesicles or the glandular reservoirs and their ducts is included and the minute structure of the glandular reservoirs in the metatarsi is described. The controlling mechanism for the pressing out of the fluid-contents of the glandular reservoirs in the metatarsi is also described in detail (p. 273).

7. Some observations on the habitat of these insects and their feeding habits are recorded. The views of the various authors regarding the formation of the tunnels and their function are considered in detail, and experimental evidence is adduced to show that they are by no means perfect protective recesses in nature (p. 275).

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