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BIOLOGY AND ECOLOGY OF ORIENTAL TERMITES. NO. 5. MOUND-STRUCTURE, NEST AND MOISTURE-CONTENT OF FUNGUS COMBS IN *ODONTOTERMES OBESUS*, WITH A DISCUSSION ON THE ASSOCIATION OF FUNGI WITH TERMITES

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(With 1 Table, 2 Text-figures, and 4 Plates)

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* Earlier numbers of this series are as follows :—

No. 1. *J. Bombay nat. Hist. Soc.*, Bombay, 1954, **52** (2 & 3), pp. 459-452, 1 pl.
No. 2. *Ibid.*, 1954, **52** (2 & 3), pp. 463-467, 1 pl.
No. 3. *Ibid.*, 1955, **53** (2), pp. 234-239, 2 pls.
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CONTENTS

I—INTRODUCTION

Although *Odontotermes obesus* (Rambur) (Isoptera : Termitidae : Macrotermitinae) is the principal mound-building termite of India, there is some lack of clarity about the structure of its mound. This difficulty arises from a confusion, or rather a lack of adequate information, about its taxonomy. In India only a few species build mounds, and all of them seem to be confined to the genus *Odontotermes*—the mound-building species being *bangalorensis* Holmgren, *obesus* Rambur (and its supposed varieties), *redemanni* Wasmann and *wallonensis* Wasmann. Annandale (1923, 1924) has classified these mounds into two types, *viz.*, (i) the *unilocular* type in which there is single large central cavity containing a large fungus comb ; and (ii) the *multilocular* type in which there are several cavities each containing a fungus comb. According to Annandale (1924), the *unilocular* type occurs in *Odontotermes obesus* var. *oculatus* Silvestri, while the multilocular type occurs in the typical form of *O. obesus* (Rambur) and in *O. redemanni* (Wasmann).

There appear to be the following known forms of *Odontotermes obesus* (Rambur) which is a species confined to India :—

(i) *O. obesus* (Rambur) (typical form).—Practically all over India, except in very cold areas.

(ii) *O. obesus*, var. *gurdaspurensis* Holmgren & Holmgren.—Gurdaspur (Punjab).

(iii) *O. obesus*, var. *oculatus* Silvestri.—Barkuda Island (Chilka Lake, Orissa). In this variety the female (queen) is stated by Silvestri (1923) to have larger eyes than in the typical form, but the soldiers and workers are indistinguishable from that form.

If we accept Annandale's descriptions (1923, 1924) of the mounds of *O. obesus* (identifications of the termites were done for him by the late Professor F. Silvestri, the well-known Italian entomologist and an authority on termites), this single species, has at least three widely divergent types of mounds as follows :—

(i) A large, "unilocular" type, with buttresses. Occurring in *O. obesus* var. *oculatus* Silvestri, on the Barkuda Island (Chilka Lake, Orissa), (*vide* Annandale, 1923, p. 246, Fig. 1 ; and 1924, p. 31, Fig. 4).

(ii) A large, sprawling, "multilocular" type, without buttresses. Occurring in *O. obesus* (Rambur) *forma typica*, also on the Barkuda Is. (Chilka Lake), (*vide* Annandale, 1923, p. 247, Fig. 2). Also found in *O. redemanni* Wasm. in West Bengal, southern India and Ceylon (*vide* Escherich, 1911 ; Annandale, 1924, p. 30, Fig. 30 ; Mukerji & Mitra, 1949 ; and others).

(iii) A comparatively small (about 90 cm. high and 90 cm. in basal diameter), formless mass of earth, nearly solid and with only a few narrow passages. Formed by *O. obesus* occurring in the Andaman Islands (*vide* Annandale, 1924, p. 27). Although the specimens from these mounds were identified by Silvestri simply as "*Odontotermes obesus*", Annandale (1924, p. 27, foot-note) remarked : "Possibly males and females of the Andaman form would show some racial peculiarity"

The mounds of *O. obesus gurdaspurensis* Holmg. & Holmg., from the Punjab have not been described.

It seems to me highly unlikely that the various forms of the same species (which can hardly be distinguished from one another) and some times occur in the same locality, as in the Barkuda Island, build such radically different types of mounds. I cannot help suspecting that these forms might be distinct species, but a clarification of this point must await a future careful taxonomic study, correlated with field work, of the Indian species of the genus *Odontotermes.*

Meanwhile, I have studied in some detail the mound-structure, the nest, the fungus combs, etc., of the "form" of *Odontotermes obesus* as occurring in Dehra Dun and its vicinity in western Uttar Pradesh, and these observations are discussed below. For the reasons stated above, the locale of the "material" has been described below in detail so as to enable comparisons to be made in the future.

Observations on the mound, nest, fungus combs and the related fungi of *O. obesus* have been made by Lefroy (1909), Annandale (1923, 1924), Bose (1923), Beeson (1941), and Bakshi (1951), Roonwal & Gupta (1952), Gupta (1953*a*, *b*), Vishnoi (1955*a*) and Roonwal (1958).

In the present account, a description of the mound-structure, particularly of the underground nest, is provided, together with some observations on the structure, distribution and moisture-content of the fungus combs. Fungus combs in termites have been regarded by some authors to serve as "humidity controls" for maintaining a high humidity inside the nest. In view of this opinion, the moisture-content of the combs has been determined. Finally, a brief account is given of the nature of the association of fungi with termites in general, and the function of the associated fungi and the fungus combs.

II—MATERIAL

For the reasons stated below, the provenance of the material studied is indicated precisely.

The material on which the present account is based is from the Dehra Dun and Saharanpur districts of Uttar Pradesh (India), especially from Dehra Dun and its vicinity. These districts lie at the foot-hill of the western Himalayas in western Uttar Pradesh. As already discussed above, the exact taxonomic differentiation of the various species of the termite genus *Odontotermes* and their correlation with the various types of mounds is still a desideratum. The principal species involved in the building of these mounds in India appear to be four as follows :—

O. bangalorensis Holmgren, *O. obesus* (Rambur) and its supposed varieties, *O. redemanni* (Wasmann) and *O. wallonensis* (Wasmann).

Of these, *O. obesus* builds high mounds going up to about 2·6 metres (about 9 ft.) or a little more in height and are characterised by a series of buttresses all around (Pls. 8 and 9). Such mounds occur practically all over northern India except Kashmir, the Punjab, Rajasthan and West Bengal. I have seen such mounds abundantly in the deciduous and moist deciduous forests of Uttar Pradesh (Districts of Dehra Dun, Gorakhpur, etc.), Himachal Pradesh (*sal* or *Shorea robusta* forests

adjoining the western Uttar Pradesh), Bihar (Ranchi), Orissa (Cuttack and Bhuwaneshwar).

The species concerned, as obtained from the material from Uttar Pradesh, is indistinguishable from *Odontotermes obesus* (Rambur) whose type-locality is the Bombay Presidency (India) and as such the material in the present paper is regarded as *O. obesus*. Whether the species forming the tall buttressed mounds in the other areas mentioned above is identical is not known with certainty and the solution of this problem must await further detailed field and taxonomic study.

The other type of mound generally found is one which is dome-shaped, of low height, and without buttresses. Such mounds occur all over India and may belong to *Odontotermes bangalorensis*, *O. redemanni*, *O. wallonensis* and possibly to other as yet unrecognised species and varieties of the genus *Odontotermes*.

III—STRUCTURE OF TERMITARIUM (MOUND AND NEST) OF *ODONTOTERMES OBESUS*

(Text-figs. 1 and 2 ; and Pls. 8-11)

1. *General*

It may be stated at once that the termitaria of *Odontotermes obesus* to be described here are of the "unilocular" and buttressed type of Annandale (1923, 1924) which that author has assigned to *O. obesus* var. *oculatus* Silvestri. I, however, seriously doubt this identification, and would assign them for the present merely to *Odontotermes obesus*, leaving for future consideration whether the Dehra Dun mounds, on which the present description is based, belong to the typical form of *O. obesus* or to some other race. Generally, Beeson (1941) and other entomologists have regarded the Dehra Dun species as *O. obesus*, and for the present I agree with that view. It is highly unlikely that in the same place more than one form or subspecies of a particular species would occur— as would be the case if we accept Annandale's observations on the Barkuda Island.

In the Dehra Dun form studied by me the entire colony of *Odontotermes obesus* is concentrated, except for the foraging galleries, in a single earthen *termitarium**—by which term we may conveniently include both the mound (above the ground) and the nest (underground). Depending upon the size of the mound, its population consists of about 4,500—90,900 individuals and is composed of soldiers (5·5—7·7 per cent), workers (49·0—66·5 per cent), nymphs (28·0—43·3 per cent), and, of course, the royal pair (one king and one queen) (Gupta, 1953*a*). Exceptionally, two kings and two queens are found in the royal cell or chamber (Roonwal & Gupta, 1952).

The termitarium is divisible into two parts : (i) the "mound", or the portion above the ground ; and (ii) the "nest" or the portion below the ground. The size and shape of the two portions are similar, and may be compared to two tumblers lying one over the other, mouth to mouth (Text-fig. 2 ; and Pls. 8 and 9).

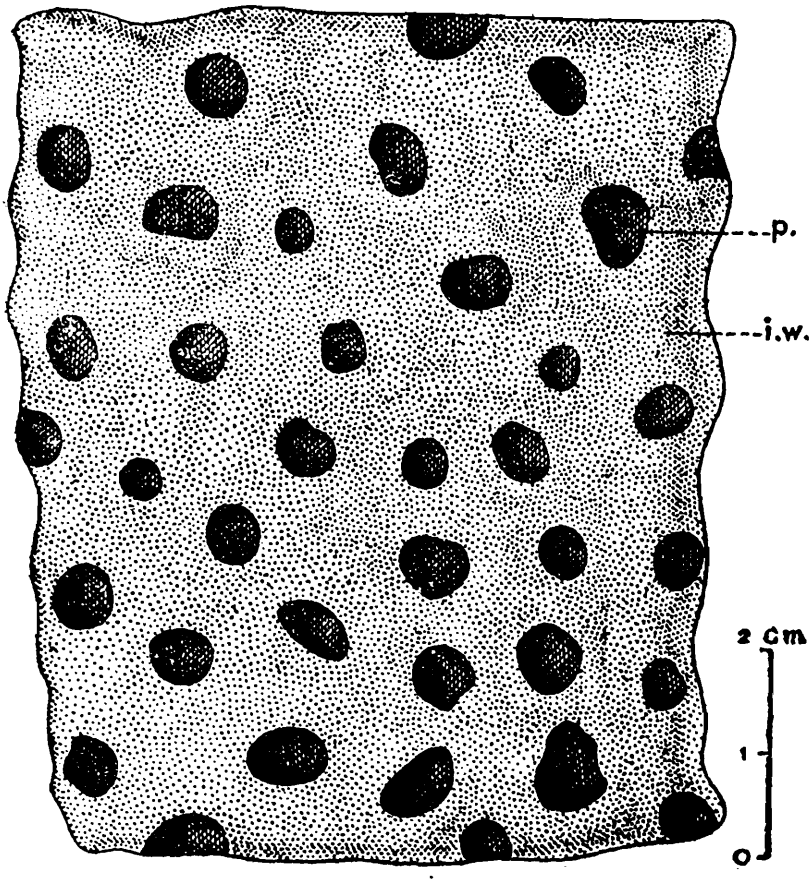
* Snyder (1948, p. 247) has defined the termitarium as follows ; "TERMITARIUM a nest, natural or artificial, or a colony of termites."

2. *The mound-structure*

The mound is made of hard earth cemented together by the termite workers with the help of their saliva. Its colour generally depends upon the colour of the available earth. Thus, in Dehra Dun it is dirty or greyish brown, while in Ranchi (Bihar) it is reddish.

The mound (Pls. 8-10) is a subcylindrical structure, but wider at the base than at the top. When well developed, it may be as much as about 3 metres (*ca.* 10 feet) high and about 1·5 metres (*ca.* 5 feet) in diameter at the base (ground-level). The walls are thick and externally fluted to form a series of about 10-12 hollow buttresses running vertically the entire length of the mound.

When sectioned vertically it is seen to contain usually a wide central shaft (this is sometimes confined to the nest only, *vide* below) which, however, does *not* open to the outside, and a series of irregular chambers and cavities of varying sizes and shapes. The inside wall of these cavities is pitted with numerous small cup-like pits about 5-7 mm. in diameter (Text-fig. 1)*. There are normally no external openings on the mound-



TEXT-FIG. 1.—*Odontotermes obesus* (Rambur). Inner view of a portion of the wall of a mound, to show the pits.

i.w., inside of wall of mound *p.*, pits.

surface (except those caused accidentally through external agencies such as cracking of the wall by excessive drying, or damage by human or other enemies), and it is likely that the termites forage largely through

* According to Annandale (1923, Pl. Fig. 3 ; and 1924, pp. 32-33) these pits are "sentry boxes" in each of which a soldier is stationed at the time of the construction of the wall.

underground galleries, though once they reach the food-object above the ground, such as the bark of a tree, they may make earthen covers or plasters for their movements to and fro. No fungus combs are, as a rule, present in the portion of the mound above the ground.

3. *The nest and the royal cell*

(Text-fig. 2 ; and Pls. 9 and 10)

(a) *General*

The underground nest is usually about as deep below the ground surface as the mound above, and, like the latter, is subcylindrical. Unlike the mound, however, it has no discrete walls, but is merely composed of a central hollow, together with a number large fungus combs, and around them are arranged, irregularly, a number of smaller excavations and tunnels—the former for the lodgement either of one or more fungus combs of varying sizes or of egg-masses, and the latter for the movement of the more active members of the colony.

(b) *The royal cell*

The royal cell usually lies in the nest either at or below (from 0—100 cm.) the ground surface and is generally excentric. Normally it contains a dealated king and a dealated queen, but occasionally (in one out of about 100 cases examined) the royal pair in a cell is duplicated (Roonwal & Gupta, 1952).

A well developed royal cell, containing a large physogastric queen (*i.e.*, a queen in which the abdomen is greatly distended to make room for the large number of eggs produced), is a solid, flat, earthy structure, usually of dark grey colour, and shaped like two irregularly-shaped saucers closed over each other face to face. The outer surface has numerous irregular excrescences, but the inside is smooth and is spindle-shaped in cross-section. (For an illustration *vide* Roonwal & Gupta, 1952, Pl. 1.) A well developed normal royal cell (with one king and one queen) measures about 6—8 cm. in length, 5—6 cm. in width and 2—2·5 cm. in height. The abnormal royal cell described by Roonwal & Gupta (1952), which had two kings and two queens, measured 10 cm. in length, 7·5 cm. in width and 2·6 cm. in height. Tiny round holes about 3—5 mm. in diameter lead from the outside of the royal cell to the royal chamber. These holes are just large enough for the soldiers and workers to pass through and attend upon the royal pair, but are too small for the royal pair itself to creep through—the king has a length (excluding the antennae) of about 10-13 mm. and a maximum width (in the abdominal region) of about 3-4 mm., while an old, well-grown physogastric queen has a length (excluding the antennae) of about 50-75 mm. and a maximum width (in the abdominal region) of about 10-12 mm. The size (length) of the queen is generally directly related to the size of the mound—the larger the mound, the longer the queen (Gupta, 1953*b*). This is evidently an age relationship, as both the mound and the queen grow in size with age.

The inside of the royal chamber was always found scrupulously clean and never was even a speck of food, dirt or refuse met with. A large number of soldiers and workers are found in attendance upon the royal pair.

When the royal chamber is opened, the king usually runs about quite actively, but the queen, because of the weight of its heavy egg-laden abdomen, is hardly able to move. The abdomen of the queen shows regular peristaltic movements from before backwards, and with these movements it extrudes, one by one, a tiny, cylindrical, whitish translucent egg from the hind end of the abdomen at the rate of about one egg per second. (At this rate it would extrude about 3,600 eggs per hour or about 86,400 eggs per day (24 hours). No sooner is an egg extruded, than one of the workers-in-waiting picks it up in its mouth and carries it away presumably to one of the egg-depositories (*vide infra*).

There is some evidence that occasionally, due to causes still unknown, the old royal cell is deserted and, adjoining them, a new royal cell is formed where the royal pair is transferred presumably by the workers. This suggestion received support from the discovery (Gupta, 1953*b*) of deserted royal cells in *Odontotermes obesus*, and the finding by Vishnoi (1955*a*) of very large holes (about 15 mm. wide) in the royal cell through which, according to that author's presumption, the queen is transported to a new royal cell by other members of the colony.

The question whether the royal cell and the queen lie in a particular direction of the compass has been somewhat controversial. Deoras (1944) stated that in the mound-forming termite (species not mentioned, but probably *Odontotermes redemanni* Wasm.) in peninsular India (?. Poona), "the 'queen' invariably lies nearly parallel to the magnetie N. and S. in her cell which is N.-E. or in a very few cases S.-W. of the central point of the 'live' mound". Vishnoi (1955*a*) also stated that in "*Odontotermes obesus* var. *oculatus*", in Dhampur, western Uttar Pradesh, the queen lies in the N.-S. direction in the royal chamber. These claims, however, do not receive support from the detailed work of Gupta (1953*b*) on *O. obesus* in Dehra Dun, who showed that neither the royal cell nor the queen lie in any particular favoured position.

(c) *The egg-depositories and nurseries*

As mentioned above, there are in the nest small rounded excavations of varying sizes (diameter about 4-12 cm. or more). These vaults are flat below and have a dome-shaped roof, and the walls and the ceiling are smooth. Here one finds either fungus combs (one, or sometimes two or three, in each vault) or masses of eggs heaped together in groups of thousands. In a single nest, up to half a dozen such egg-depositories are found. Egg masses are also found inside the cells of some of the fungus combs.

Also in the fungus combs, and sometimes in the vaults serving as egg-depositories, are found numerous tiny nymphs along with a number of workers and a few soldiers. According to the observations of Gupta

(1953*a*), the proportion of nymphs is higher, and of soldiers lower, in the fungus combs than elsewhere in the nest, thus :

	Percentage of various castes		
	Workers	Soldiers	Nymphs
1. IN FUNGUS COMBS : . . .	17·8	2·8	79·4
2. ELSEWHERE IN MOUND :			
(i) In non-mound building months	49·0	7·7	43·3
(ii) In mound-building months .	66·5	5·5	28·0

IV—FUNGUS COMBS OF *ODONTOTERMES OBESUS*

(Text-fig. 2 ; and Pls. 8-10)

1. *General observations*

As mentioned above, a well developed nest of *Odontotermes obesus* usually contains a large number (about 20-30) fungus combs of varying sizes. The peripheral combs are generally smaller than those situated more centrally. Except perhaps initially in the young colony, there is no large central comb as occurs in *O. obesus* var. *oculatus* Silvestri (*vide* below, Annandale, 1923) or as in *O. redemanni* (Wasmann). The combs lie in shelf-like excavations or vaults made by the termite. All the fungal combs lie, as a rule, wholly below the ground surface, except in rare cases when a small portion (about 3 or 4 centimetres high) of the comb-bearing area may lie above the ground surface.

It is noteworthy that the fungus combs are usually found in the "nest" only, *i.e.*, below the ground surface, and not in the "mound" above ground. (This is in contrast to what occurs, according to Annandale (1923, 1924) in *O. obesus*, *forma typica*, and in the allied species, *Odontotermes redemanni* (Wasmann) (Escherich, 1911, and Mukerji and Mitra, 1949) where the combs occur in the mound portion also.

The fungus combs are made by the workers from rounded pellets of excreta. Combs in early stage of formation are shown in Pl. 10, Fig. 3. The individual combs are irregularly rounded spongy masses, coloured greyish-brown with orange or reddish tinge, and vary in size greatly from pieces about 2 cm. or less in diameter to those about 20 cm. or more (Pls. 9 and 10). Each piece usually lies separately in a small earthen rounded excavation in the nest (Pls. 9 and 10).

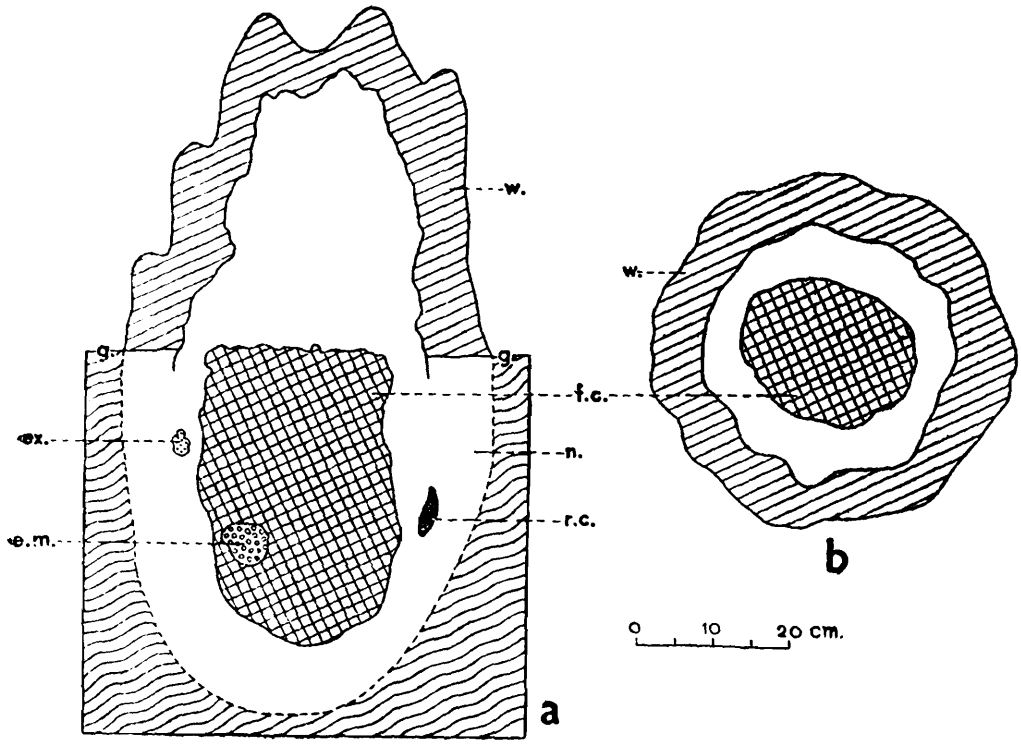
The fungus combs harbour a population of termites consisting of workers, soldiers, nymphs and eggs, the nymphs being more numerous than the others (*vide* above).

The combs also serve as the substratum for the growth of fungal mycelia which throw off numerous tiny translucent white "spheres" (Pl. 11, Fig. 2) which, according to some authors, are eaten by the workers —this question has been discussed in some detail in the next section.

It is noticed that if fungus combs, along with the broken remnants of the nest and colony, are kept in a large closed box, within less than 12 hours the fungal mycelia in the combs throw up long, finger-like, dark-greyish processes of a fungus, which has been identified as *Xylaria nigriceps*, and the entire colony is quickly killed. This "choking" does not happen in the living, flourishing colony in the live nest where the growth of *Xylaria* is, in some unknown manner, prevented.

2. *Development of fungal combs in a young colony*

It would appear that during the development of the mound and the colony, at first a large central fungus comb is formed, and the other smaller ones are formed later as the colony develops. This method is suggested by the study of a small mound of *O. obesus* in a forest near Hardwar (western Uttar Pradesh). The young mound (Text-fig. 2),



TEXT-FIG. 2.—*Odontotermes obesus* (Rambur). A young termitarium, about 45 cm. high, near Hardwar (Uttar Pradesh, India).

(*a*). The termitarium (mound and nest in vertical section). (*b*). Ditto, in cross section, at the ground level.

e.m., egg-mass ; *ex.*, mass of dried excreta ; *f.c.*, fungal comb ; *g.*, ground-level ; *n.*, nest portion of the termitarium : *r.c.*, royal cell ; *w.*, wall of the mound.

which was of the usual unilocular and buttressed type, was about 45 cm. high and had a basal diameter also of about 45 cm. The walls were about 7-8 cm. thick and were smooth outside but heavily pitted on the inside with small circular pits each of which was about 5-6 mm. in diameter. The "nest" was underground and extended about 45 cm. below the mound. There was a single, central, huge, rounded fungus comb, about 22 cm. in diameter and about 38 cm. deep ; it lay almost wholly underground, except for 2-4 cm. of its portion which jutted above the ground surface. The dry weight of the fungal comb (dried at 105°C)

was 1,129 gms. The royal cell, containing a king and a queen, lay on one side of the fungal comb and about 20 cm. below the ground surface.

Excentrically, on the side opposite the one where the royal cell was situated and about 20 cm. below the ground surface, there was in the fungus comb a large mass (about 5 cm. $\times$5 cm.) composed of thousands of tiny eggs—this was the *egg-nursery* of the termite. Innumerable tiny nymphs were also swarming in the "nursery"

In two places in the nest, by the side of the fungal comb, there were small flat masses (each mass measuring about 2·5 cm. $\times$2·5 cm.) of comparatively dried up excreta (*cf.* fungus combs, which are always moist) assembled in a heap. These were undoubtedly the beginnings of the "fungus combs" which had not yet been innoculated with fungus. Their colour was pale yellowish-brown and the characteristic greyish colour of fungus combs containing active fungus was wanting.

3. *Moisture content of fungus combs*

(Table 1)

The moisture content of the various fungus combs, taken out of a large termitarium in New Forest, near Dehra Dun, in late December was determined (Table 1). Eight samples, composed of a total of 11 different pieces of varying sizes were weighed. Immediately each piece was dug out of the nest it was put in a small air-tight metal box to prevent loss of moisture, and the wet weight was determined in a chemical balance within a few minutes of the collection. The combs were then dried in an air oven at 105°C. until the weight was constant. The wet weight of the individual combs varied from 6·80—343·79 gms., the dry weight from 3·22—164·52 gms. and the moisture-content from 50·4-52·6 per cent (mean 51·63 per cent). This fairly high moisture content would suggest that the combs may serve as a permanent source of moisture for the humidity-conditioning of the nest.

4. *Discussion*

Lefroy (1909, p. 118, Pl. VIII), briefly referred to and illustrated the "fungus chambers" (which are what we today call fungus combs) of *Odontotermes obesus* (his "*Termes obesus*") probably obtained in Pusa (Bihar). According to him there were large "main" and small "subsidiary chambers", but their number in each mound was not mentioned. In the illustrations given by him, the "chambers" are subround ; the large one is about 24 cm., and the smallest one about 15 cm., in diameter. The fungus combs of *O. obesus* (Rambur) *forma typica* and *O. obesus* var. *oculatus* Silvestri, both from the Barkuda Island in the Chilka Lake, Orissa, were described and illustrated by Annandale (1923). According to him (p. 240), the combs of *O. obesus* are compact from the first and even when very small have a distinct "cellular" structure. He further wrote : "In the mounds of *O. obesus* typicus there is no single large fungus garden, but there are many (sometimes as many as twenty or thirty) small gardens. The largest chambers are rarely more than 9-10 cm. in diameter and the gardens in them a few centimetres less, but both vary considerably in size." The internal cells of the fungus comb are regular, transverse (not vertical) and comparatively uniform, the

TABLE 1.—Odontotermes obesus (*Rambur*). *Weight, and moisture-content, etc., of fungus combs collected from a large mound in New Forest, near Dehra Dun, in December.*

Sample No.	Number of pieces	Approximate size (in cm.) after drying	Wet weight (in gms.)	Dry weight (in gms.)	Loss of weight (=water-content) (in gms.)	Percentage of weter-content
1	1	5×5×9	55·20	26·14	29·06	52·6
2	2	4×8×12 ; 3×8×10	125·20	62·13	63·07	50·4
3	3	4×13×15 ; 4×10×14 ; 4×6×6	343·79	164·52	179·27	52·1
4	1	4×7×9	47·24	22·47	24·77	52·4
5	1	4×7×7	25·76	12·62	13·14	51·0
6	1	5×7×8	51·59	25·40	26·19	50·8
7	1	4×7×8	56·37	27·87	28·50	50·6
8	1	3×3×4	6·80	3·22	3·58	52·6
	11	RANGE :	6·80—343·79	3·22—164·52	3·58—179·27	50·4—52.6%
						MEAN : 51·63%

size of each cell being about 6 - 15 mm. × 3 - 5 mm. The combs are similar to those of *O. redemanni* (Petch, 1906).

In *O. obesus* var. *oculatus*, on the other hand, the fungus gardens, according to Annandale (1923), are extremely massive and have a capacity of many litres. " The whole basal part of the mound is occupied by a single large garden, incompletely divided by partitions that hang from the roof or rise from the floor of the large garden-chamber like stalagtites and stalagmites in a cave, the garden nearly fills the chamber, of which it is practically a cast. Sometimes there are two or more tiers of comb " (p. 239). According to the same author, there is a considerable difference in the internal structure of the older and younger parts of the comb. The younger parts, which are situated near the periphery of the mass have the external surface covered with irregular grooves and small circular apertures leading into internal cells or cavities but mostly orientated with their major axis at right angles to that of the whole mass. Superficially the older parts look like the younger ones, but in a section it is seen that the internal cells in the older parts are more vertical and more regular in shape and size (average : 12 mm. high and 5 mm. broad).

Annandale (1923) noted, on the Barkuda Island (Orissa), that the fungus combs of *O. obesus* were shifted from one part of the nest to another, depending upon the season. He noted (p. 241) that in mounds opened in February " the upper garden-chambers which are situated well above ground, will be found to be empty ", but in April or May, " all the garden-chambers in the mound are empty. In both months the interior of the empty chambers is perfectly clean, and no trace of the gardens can be discovered " Annandale concluded that in the dry season, and especially when the weather is hot as well as dry, the workers remove the gardens bodily underground. He gave two reasons for this removal, namely, (i) the impossibility of maintaining the correct temperature and moisture for the growth of the fungi above ground in hot and dry weather ; and (ii) the danger to the community if the upper parts of the nest are occupied too near the surface at such times.

Bose (1923) identified the fungus occurring in the mound of *O. obesus* on the Barkuda Island as an agaric, *Collybia albuminosa* (Berk.) Petch, and stated that different forms of another fungus, *Xylaria nigriceps*, were found in mounds abandoned by the termite colony. Bakshi (1951) has re-studied the fungi occurring in mounds of this species in Dehra Dun (U.P.) and his conclusions, as summarised by Roonwal (1958, p. 87) are as follows :—

" Mycelia and spheres are common within fungus combs. Hyphae are abundant, cottony, thin-walled (or slightly thick-walled), hyaline, separate (simple), and 2-5μ broad. Chalamydospores develop rarely, and when present are about 11-13 × 8-9μ in size. Some of these hyphae unite to form small whitish spheres which are 0·5—0·8 mm. in diameter when mature, and have been identified as *Termitosphaeria duthei* Berkeley belonging to the Moniliales. Such a sphere is composed of a short stalk which swells up into a head, the latter becoming spherical with age. The spheres can be cultured easily in malt-agar. Stoma of *Xylaria nigriceps* were sometimes found on the surface of deserted combs."

V.—DISCUSSION ON THE ASSOCIATION OF FUNGI WITH TERMITES

1. *Historical*

Observations on the "fungus combs" of termites of the Indian region, including Ceylon, have been made by a number of workers, *viz.*, König (1779), Petch (1906-13), Lefroy (1909), Bugnion (1914), Hegh (1922), Annandale (1923-24), Bose (1923), Beeson (1941), Mukerji & Raychaudhuri (1943), Mukerji & Mitra (1949), Bakshi (1951) and Roonwal (1958).

The pioneer observations of König (1779) deserve more than passing attention. He was the first to give an account of the fungus combs of a termite, and his was, in fact, the first scientific account of any aspect of termites ever to be published. He described the mound and fungus combs of an unnamed species, probably *Odontotermes redemanni* (Wasm.), of a southern Indian mound-building termite in Tanjore. He regarded these combs as the "dwellings" of the termite, and wrote as follows (Fletcher's translation, 1921) :—

"Their dwellings [*i.e.*, the fungus combs] have, as stated, the shape of the vault [in which they are placed] except that they are separated everywhere from the inside wall by a small interval ; also on the bottom there is not to be found the slightest trace that they are made firm somehow or other by an adhesive substance or by any other means."

And further :

"They consist of innumerable intercommunicating passages, which are their cells, whereto most entrances enter from below, a few from above and fewest vertically."

König also noticed the fungal conidia growing in these combs, and further thought that they might be the food for newly-patched young ones. He wrote :

"... I must mention a small plant which grows tolerably abundantly and invariably inside the walls of the cells [of the fungus combs]. According to Sir C. von Linné it will be a Mucor and is situated on a stalk bearing rounded composite snow-white bodies [=conidia]. It is very small and has quite a short stalk on which, as its fruit-part, the small head is to be found and this latter is composed of very minute globules and is of snow-white colour. Here and there also, as if strewn, on the aforesaid walls there occur small, bent, white filaments which terminate sometimes in a small head, and sometimes are club-shaped."

And further :

"May not a wise Providence have ordained these minute plants to grow here, perhaps for the immediate nourishment of the newly hatched animals, whilst otherwise no nourishment is present in the nest nor can any foraging be done. This I only suppose ; I have not observed it, because these young animals are all at once very feeble so soon as they come out of the ground into the open air and into daylight."

König also noticed that in these combs were abundantly present the young ones and eggs of the termite, and that some of the combs were full of eggs. He wrote :

"The eggs are usually cylindrical, rounded at both ends, small, smooth, shining, milk-white, somewhat transparent withal, on one side rather more opaque. They were slightly fastened together one upon another, without order, on the walls in the interior of the combs ; some of the large combs were filled out with them, their number was very large at this time of the year. By which of these animals they have been brought there (*i.e.*, into the combs) and how, I have not been able to observe.

2. *Nature of the association of fungi with termites*

As stated above, the association of fungi with termites has been known for a long time, and was first noticed by König (1779) in the southern Indian mound-building termite—species not mentioned, but probably *Odontotermes redemanni* (Wasmann). The main form in which this association occurs is the cultivation of " fungus gardens " by the higher termites (Termitidae) in their nests. These fungus gardens usually take the shape of irregular, spongy masses of varying sizes and shapes constructed by the termites themselves and believed to be composed of their excreta. On these masses or " fungus combs ", which are usually lodged in shelves or other places inside the termitaria, the termites cultivate fungi which are, by some unknown means, prevented by the termites from fruiting. Tiny whitish spheres or conidia, which almost appear to be sessile but actually have a tiny stalk, are, however, formed fairly abundantly, and the termites have been observed to sometimes feed up on them. Removal of these combs from the nest, and the consequent discontinuance of their connection with live termites in the colony do away with the " control " which the termites exercise on fungal growth in some unknown manner, and within a few hours, or a day or so, under favourable conditions of high humidity and high temperature, the fungi grow long, cylindrical, fruiting bodies of a species of *Xylaria* which are often 20-30 cm. long. According to some authors, these *Xylaria* are weeds which come up only when the colony dies, and the original fungus of the combs is a different species. (In this connection the accounts of Doflein (1905-06), Petch (1906-13), Escherich (1909-11), Bugnion (1914), Hegh (1922), Annandale (1923-24), Bathellier (1927), Grassé (1937-59), Grassé & Heim (1950), Grassé & Noirot (1948-58), Ghidini (1938) and Geyer (1951) may be consulted.)

In rare cases, as in the African termite, *Sphaerotermes sphaerothrax* (Sjöstedt), the so-called " fungus combs " are present but they are without fungi (Grassé & Noirot, 1949).

Another form of association of fungi with termites is that which occurs in many of the wood-inhabiting species, such as for example members of the genera *Kalotermes, Reticulitermes, Zootermopsis, Gnathotermes*, etc. Here no " fungal gardens " are cultivated, but several species of fungi occur in the nests and galleries of the termites. Thus, Hendee (1946) isloated representatives of 33 different genera of fungi from colonies of termites of the genera *Kalotermes, Reticulitermes* and *Zootermopsis* in the United States, but found no evidence of any specific relationship between a given species of termite and any genus of the fungi ; the significance of the fungi remained problematic.

3. *Functions of fungi associated with termites.*

The " fungus gardens " in termite nests have been variously regarded as a possible source of food (König, 1779; Petch, 1906-13; Annandale, 1923) and of vitamins (Grassé, 1949), as maintaining the high humidity in termite nests (Ghidini, 1938; Lüscher, 1951), as producing heat and thus maintaining the high temperatures inside mounds (Geyer, 1951 ; Lüscher, 1951), and as egg-depositories and nurseries (König, 1779 ; Annandale, 1924 ; Mukerji & Raychaudhuri, 1943). In the case of the wood-inhabiting species, the fungi may be useful in breaking down

the wood into components which are easily digestible by the termites (Snyder, 1948 ; Grassé, 1959). The more important relevant details may now be discussed.

Direct observations that the fungal conidia are actually eaten by the termites are wanting (except for the rare observation of Lüscher, 1951, *vide* below), and the belief that they serve as food is conjectural. Thus, Annandale (1923, p. 242) wrote about *Odontotermes obesus* as follows :—

> " The royal chamber is apart [from the fungus gardens] and if the adult males and females feed on fungus-products, they must be brought them by the workers. The eggs, however, are carried by the workers to the gardens, in which both they and the young are often found in large numbers, and I have little doubt that the young eat the food-bodies there produced. Possibly the workers and soldiers do so in times of stress, but in damp weather they make long excursions outside the nest to feed on dead wood, dead leaves and other dead organic matter."

Grassé (1945) observed in African termites that though the conidia on the " fungal combs " are sometimes eaten by the workers and are found in the alimentary canal, they cannot be of any great significance as a source of food. He further suggested that they may serve as a source of vitamins (1949). Lüscher (1951) observed in artificial nests of the termite *Synacanthotermes zanzibarensis* Sjöstedt that, except on two occasions, the termites never attacked or ate the fungal conidia. He wrote (pp. 34-35), thus :

> " We may conclude that the conidia are immune for a long period ; but that they are sometimes suddenly attacked and then eaten completely within a very short time [within about 20 minutes], probably after having reached a certain degree of ripeness. This may explain why the actual process of devouring the conidia has never been observed previously, and also why partly destroyed conidia are never found in the ' fungus garden. They are attacked so rarely that they can scarcely play a large part in the nutrition of the termites, though they may possibly serve as a source of vitamins, as Grassè has supposed[5].
>
> [[5]Grassè, P.-P. " Traite de Zoologie ", **9** (Masson, Paris, 1949).]"

Lüscher (1951) has suggested, from field observations on *Macrotermes bellicosus* Smeathman in Africa, that the fungus gardens generate heat, probably by means of fermentation processes going on in them, and thus serve to raise the nest temperature in the region of these gardens ; here the temperature remains constant at about 30°-30·5°C. as contrasted with an appreciably lower and fluctuating temperature in the more superficial wall-layers (*ca.* 27°-29°C.). They also serve to raise the relative humidity which was about 85 per cent in the wall, and 95 per cent in the ' fungus garden ' area.

König (1779) found some of the large combs of a southern Indian mound-building species, probably *Odontotermes redemanni* (Wasm.), full of egg-masses, and Escherich (1911, p. 41) confirmed this observation in *Odontotermes redemanni* (Wasm.) in Ceylon. Escherisch found masses of a large number of eggs either inside the cells of the fungus combs, on their surfaces or between the two adjoining fungus combs. The number of eggs in a mound was estimated by Escherich as several hundred thousand—a single fungus comb, with a surface area of 250 sq. cm. might contain as many as 300,000 to 350,000 eggs. Mukerji & Raychaudhuri (1943) noted in that same species (in West Bengal, India) that the smaller fungus combs in the mound serve as " nurseries

since the larvae or immature forms occur there along with the mature or adult soldiers and workers" (p. 175). In addition, these latter authors noted another kind of fungus comb which contains only eggs, and thus serves as an "egg-depository" They wrote (p. 175) :

> "Quite different from this type of combs or the fungus gardens there is another comb which is exceedingly moist and is dark brown in colour and papery in texture. It is of a different pattern from the rest and is the largest in size. It is located deep down in the centre of the mound. In this comb, eggs alone, but no larvae or other stages, are found. Close to this, but quite separate from it, the royal chamber is situated."

Mukerji & Mitra (1949) further noted in the same species that, because of its close proximity to the royal chamber, eggs laid by the queen are first stored in the large central fungus comb mentioned above and then transferred to the neighbouring combs.

As stated above, in rare cases, as in *Sphaerotermes sphaerothorax* "fungus combs" are present but are without fungi (Grassé & Noirot 1949).

In the case of certain wood-feeding genera (*vide supra*). there is some evidence that the fungi present in the nest and the galleries break down the cellulose and lignin of the wood into easily digestible components. For the North American genus *Amitermes* (*Gnathamitermes*), Snyder, (1948, p. 100) stated as follows :—

> "Since species of *Gnathamitermes* do not contain the usual symbiotic intestinal protozoa, either fungi alter the vegetation so as to make it available to them as food, or the fungi themselves are important in the diet of the termites. These termites will also cover wood with similar earth mats and eat off or scour the surface, but never bore into or destroy wood ; they merely erode the surface."

Grassé (1959) has brought forth evidence that the fungi serve to break down cellulose and lignin. He has further shown that the termites of the subfamily Macrotermitinae present a case of double symbiosis which is unique in the animal kingdom—first, symbiosis with a fungus, and secondly, symbiosis with bacteria. Both these methods help the termites to digest wood.

VI—SUMMARY

1. Results of observations, as made in the region of western Uttar Pradesh (Dehra Dun and Saharanpur Districts), are given on the structure of the termitarium (mound and nest) and fungus combs of the termite *Odontotermes obesus* Rambur (Isoptera : Termitidae : Macrotermitinae).

2. The "termitarium", which contains the entire colony, is composed of two parts of subequal diamensions—the earthen "mound" above the ground and the "nest" below the ground. In shape these two parts may be compared to a pair of tumblers touching each other mouth to mouth.

3. The mound is a high, subcylindrical, thick-walled earthen structure, narrowing somewhat at the top, and rising up to about 3 metres (10 ft.) in height, and is further characterised by a ring of about 10-12 vertical buttresses running the entire length of the mound. The inside of the mound has a wide central shaft and a number of galleries and excavations.

4. The nest lies immediately below the mound and is similarly shaped, but in reverse. It does not have any discrete walls, but consists of a series of large to small chambers (or vaults) and galleries—the former for the lodgement of fungus combs and egg-masses, etc. (egg-depositories and nurseries) and the latter for the passage of the active members of the colony.

5. The queen lays eggs at the rate of about one per second. No sooner is an egg extruded than one of the workers-in-attendance picks it up in its mouth and carries it away, presumably to one of the egg-depositories.

6. There is generally a large central fungus comb and numerous smaller ones. They have on their walls numerous tiny, white spheres or conidia of fungi.

7. The fungus combs contain about 50·4 - 52·6 per cent. (mean 51·63 per cent.) water. Dried fungus combs may weigh from about 3 to 1129 gms., depending upon their size.

8. The development of fungus combs in a young colony was observed.

9. The association and function of fungus combs and fungi with termites in general is discussed.

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PLATE 8

Odontotermes obesus (Rambur). An earthen mound in a deciduous sal (*Shorea robusta* Gaerten f.) forest near Dehra Dun (western Himalayas, Uttar Pradesh, India). The mound is about 2·6 metres (*ca.* 8·7 ft.) high and has several buttresses all around running along its entire length. (*After* M. L. Roonwal, 1958.)

FIG. 1.—The whole mound.

FIG. 2.—The same, in vertical section, to show the arrangement of the galleries.

1

2

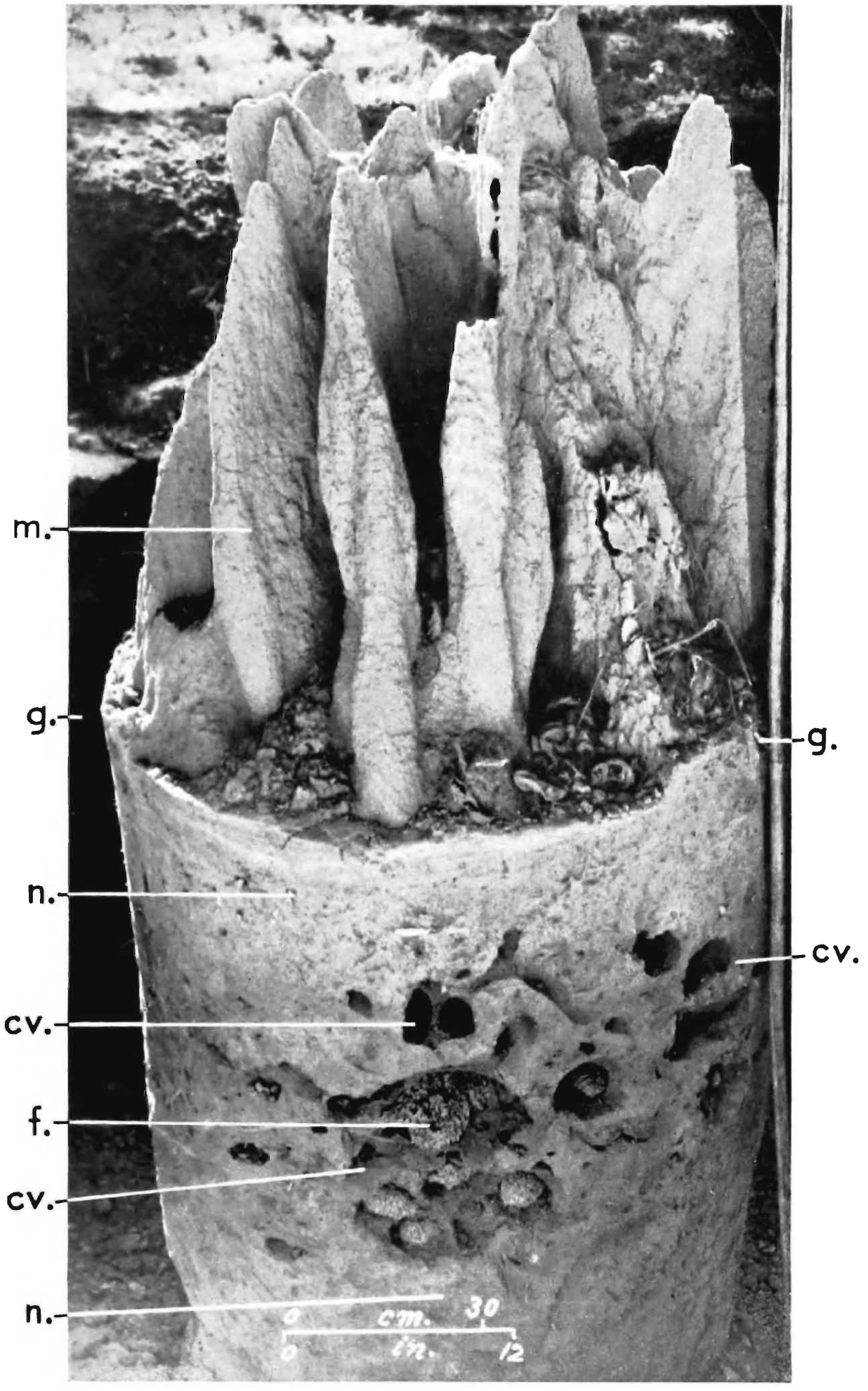
Whole mound (Fig. 1) of *Odontotermes obesus* (Rambur) and a vertical section (Fig. 2) of the same, showing arrangement of galleries.

PLATE 9

Odontotermes obesus (Rambur). New Forest, Dehra Dun (Uttar Pradesh, India). A " termitarium ", showing the " mound " (above ground) and the exposed " nest " (below ground). Note the fungus combs lying *in situ* in neat cavities (shelves or vaults) made in the nest.

Size of mound.—Height above ground-level, *ca.* 122 cm. ; depth of nest (below ground level), *ca.* 90 cm.

cv., cavities (shelves or vaults) in nest ; *f.*, fungus combs ; *g.*, ground-level ; *m.*, " mouud " portion (above ground) of termitarium; *n.*, " nest " portion (below ground) of termitarium.



Termitarium of *Odontotermes obesus* (Rambur), showing the mound and the exposed nest.

PLATE 10

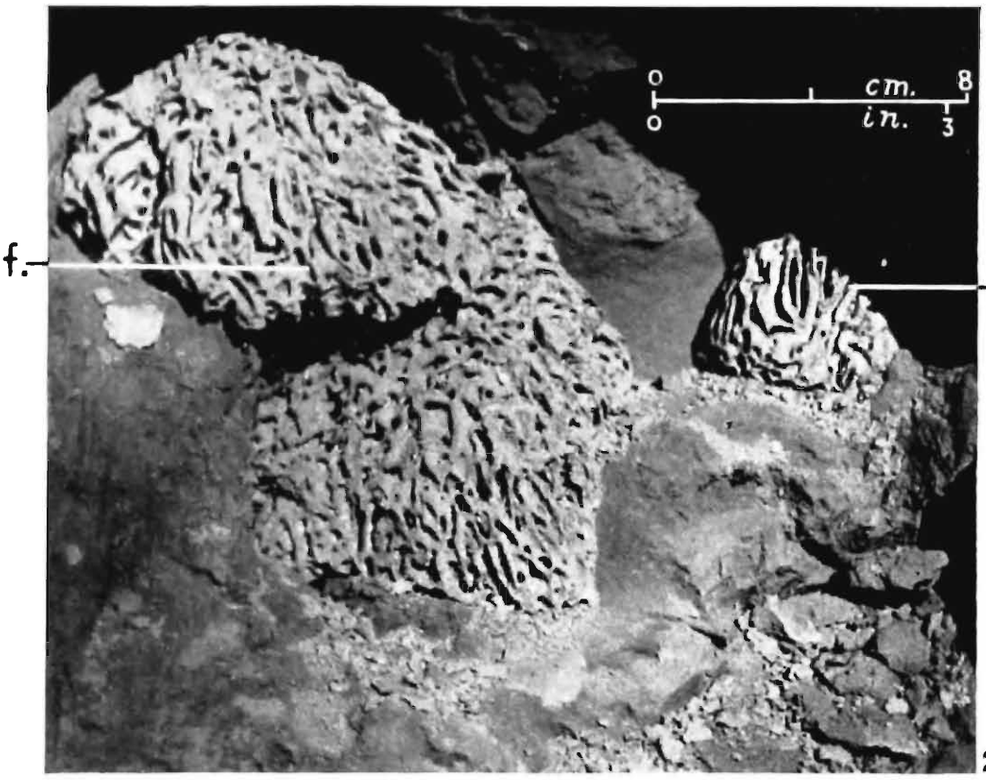
Odontotermes obesus (Rambur). New Forest, Dehra Dun (Uttar Pradesh, India). Fungus combs and their structure. (Material from same termitarium as in Plate 9).

FIG. 1.—Portion of the nest (same as in Plate 9) enlarged to show some empty cavities and others containing fungus combs.

FIG. 2.—Fungus combs (*in situ*), enlarged.

FIG. 3.—Some " fungus combs " in early stages of formation. The conidia-like fungal spheres have not yet been formed (compare Plate 11).

cv., cavities (shelves or vaults) in nest ; *f.*, fungus combs ; *g.*, ground-level ; *m.*, "mound " portion (above ground) of termitarium ; *n.*, "nest portion " (below ground) of termitarium.



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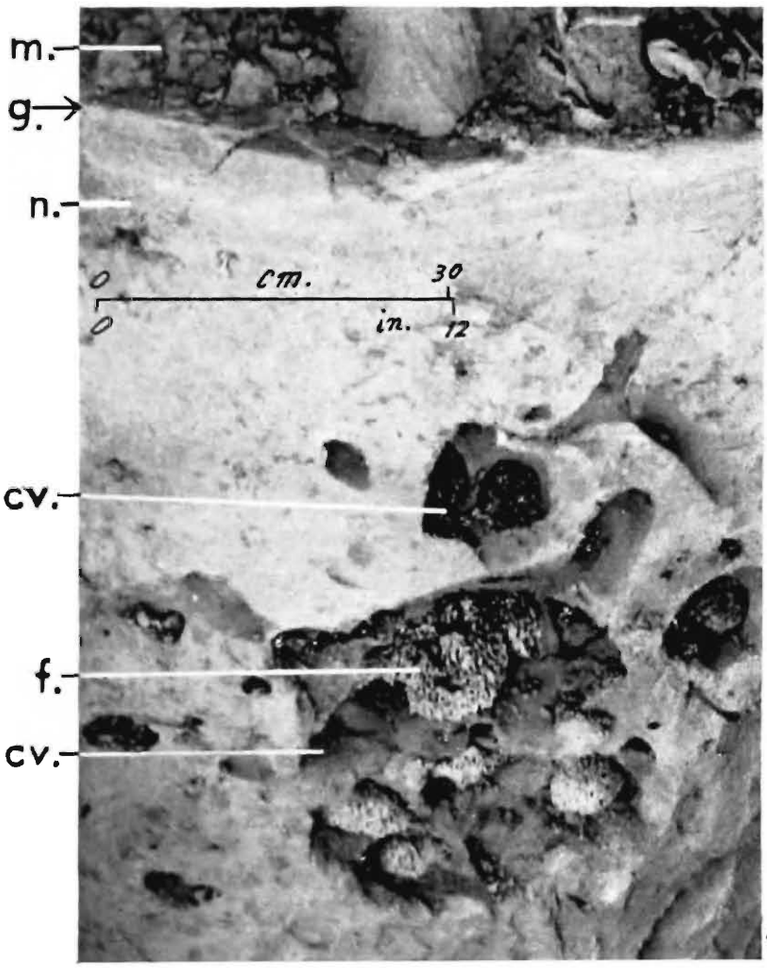

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3

Fungus combs and a portion of the nest of *Odontotermes obesus* (Rambur).

PLATE 11

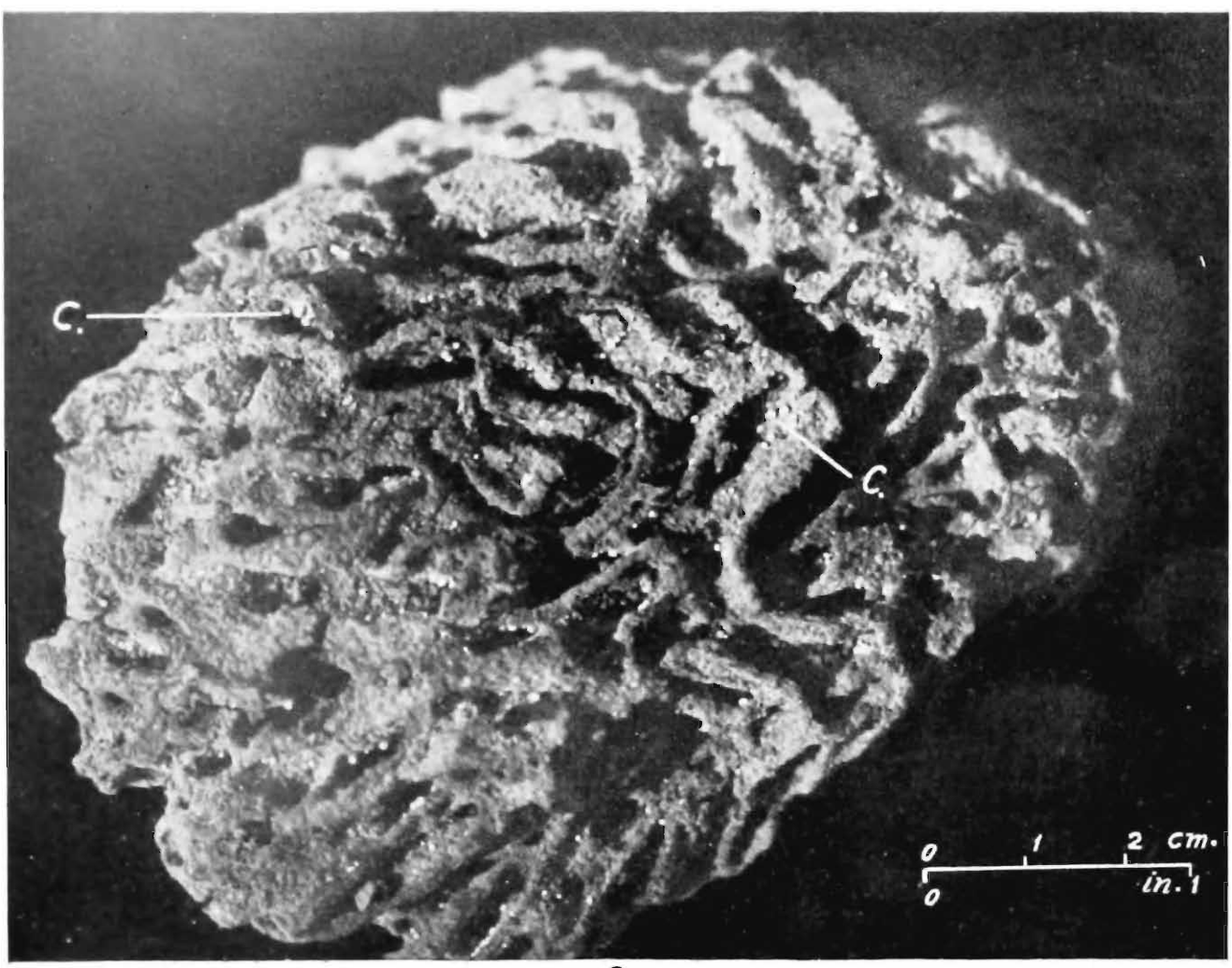
Odontotermes obesus (Rambur). New Forest, Dehra Dun (Ottar Pradesh, India). Fungus combs taken from the termitarium shown in Plate 9.

FIG. 1.—Several fungus combs, to show variation in size. Some combs are larger than the largest one (maximum diameter *ca.* 20 cm.) shown here.

FIG. 2.—A fungus comb freshly taken from the mound. Note the white fungal spheres (conidia). Approximate diameter of comb : maximum 12 cm. ; minimum 8 cm.

c., conidia or fungal spheres.

1



2

Fungus combs of *Odontotermes obesus* (Rambur).

AN AFRICAN GENUS, *PSAMMOTERMES*, IN INDIAN TERMITE FAUNA, WITH FULLER DESCRIPTION OF *P. RAJASTHANICUS* FROM RAJASTHAN, INDIA

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(With 2 Tables, 2 Text-figures and 2 Plates)

CONTENTS

I—INTRODUCTION

The termite genus *Psammotermes* Desneux (Isoptera, family Rhinotermitidae, subfamily Psammotermitinae) is mainly Ethiopian. It is the only genus of the subfamily Psammotermitinae. Out of the six species so far known to exist, five are from Africa (four Ehtiopian ; and one Palaearctic) and one from Madagascar (Malagasy Region), as follows (*vide* Snyder, 1949, pp. 64-66) :—

(*a*) AFRICA

(*i*) Ethiopian :

P. allocerus Silverstri.—Zululand.

P. assuanensis Sjöstedt.—Upper Egypt ; Eritrea ; Zululand.

P. fuscofemoralis (Sjöstedt).—Red Sea area ; Egypt ; Nubia ; Sudan ; Senegal.

P. senegalensis Sjöstedt.—Senegal.

(*ii*) Palaearctic :

P. hybostoma Desneux.—Algeria.

(*b*) MADAGASCAR (Malagasy Region) :

P. voeltzkowi Wasmann.—Madagascar.

Recently, while studying the termites of the Rajasthan desert area of western India, we came across soldiers and workers of a new species of *Psammotermes* which was briefly described recently (Roonwal & Bose, 1960), and a fuller description is given below. This is the first record of this predominantly African genus from India.

The genus *Psammotermes* is generally confined to the arid or semi-arid zones of Africa, and it is interesting that it has been found in India also in the arid zone. Since it spreads over the whole of North Africa in the west to western India in the east, its future discovery in the intervening areas of West Asia, which are ecologically more or less similar to North Africa and western India, may be expected.

II—FULLER DESCRIPTION OF THE SPECIES FROM RAJASTHAN

Psammotermes rajasthanicus Roonwal & Bose*

(Text-fig. 2 ; Pls. 12 and 13 ; and Tables 1 and 2)

(a) *Material*

All the collections listed below are from the Jaisalmer and Barmer Districts of Rajasthan, India, and were collected by *K. K. Tiwari and S. Biswas*, in January and February, 1958. This is a hot, arid, sandy area, with an annual rainfall of only about 250 mm. (10 inches) or less, and with practically no vegetation except in small irrigated patches.

(i) Three soldiers and several workers in spirit, in a vial, mixed with *Microtermes anandi* Holmg., from Balana, *ca.* 27° 10′ N. lat. and 71° 20′ E. long., about 20 miles east of Mohangarh (Jaisalmer District, Rajasthan). Field Coll. No. 2/14-1-58, 14th January, 1958, ex " below stones and cowdung ".

(ii) Several soldiers and workers in spirit, in a vial, 3 miles north-east of Mohangarh, *ca.* 27° 20′ N. lat. and 71° 15′ E. long. (Jaisalmer District, Rajasthan). Field Coll. No. 4/12-1-58, 12th January, 1958, ex " below loose mounds of earth and cowdung ".

(iii) Several soldiers and workers in spirit, in a vial, from Mohangarh (*ca.* ½ mile south-east of the Fort), *ca.* 27° 17′ N. lat. and 71° 14′ E. long. (Jaisalmer District, Rajasthan). Field Coll. No. 3/15-1-58, 15th January, 1958.

(iv) Eight soldiers and several workers in spirit, in a vial, from Tamlone village (Field Collecting Station No. 7, 13 miles from Gadra Road), *ca.* 25°40′ N. lat. and 70°35′ E. long. (Barmer District, Rajasthan). Field Coll. No. 2/3-2-58, 3rd February, 1958.

(v) One soldier and several workers in spirit, in a vial, mixed with *Microtermes anandi* Holmg., from Pachpadra Salt Depot, *ca.* 25° 55′ N. lat. and 72° 12′ E. long. (Barmer District, Rajasthan). Field Coll. No. 4/15-2-58, 15th February, 1958, ex " below dried up bark of tree ".

(vi) Thirteen soldiers and several workers, in spirit, in a vial, from Pachpadra Salt Depot, Field Coll. No. 4/16-2-58, 16th February, 1958.

(b) *Description*

1. IMAGO.—

Unknown.

2. SOLDIER (Table 1 ; Pl. 12 ; and Text-fig. 2).—

General.—Head-capsule pale yellow with a brownish streak running from fontanelle to base of anteclypeus ; anterior part brownish yellow ; postclypeus, edges of antennal sockets and labium, brownish yellow

*For a preliminary description, see Roonwal and Bose, *Sci. & Cult.*, Calcutta, 26 (1), 1960, pp. 38-39.

anteclypeus whitish ; mandibles brown, basally yellowish brown ; teeth dark brown ; thorax, legs and body yellowish white. Head sparsely, and body densely, pilose. Total length (without antennae) *ca.* 4·0—5·35 mm.

TABLE 1.—*Body measurements (in mm.) and indices of* Psammotermes rajasthanicus *Roonwal & Bose.* (10 specimens measured.)

Caste.—Soldier.

Body-parts	Range (in mm.)	Holotype
I—GENERAL		
1. Total body-length (excluding antennae) (approx.)	4·0—5·35	5·35
II—HEAD		
2. Head-length upto base of mandibles .	1·08—1·40	1·40
3. Max. width of head .	0·85—1·05	1·05
4. Max. height of head . .	0·63—0·75	0·70
5. Head Index I. (Width/Length) . .	0·75—0·80	0·75
6. Head Index II. (Height/Width) .	0·67—0·80	0·67
7. Head Index III. (Height/Length) .	0·50—0·60	0·50
8. Median length of labrum . . .	0·30—0·43	0·38
9. Max. width of labrum . .	0·30—0·43	0·36
10. Minimum length of mandibles :		
(a) Left mandible	0·75—0·98	0·93
(b) Right mandible	0·75—0·98	0·93
11. Minimum median length of postmentum .	0·80—1·05	1·05
12. Max. width of postmentum . .	0·33—0·45	0·43
13. Width, at waist, of postmentum . .	0·25—0·30	0·28
14. Width, at anterior margin, of postmentum	0·25—0·28	0·28
III—THORAX		
15. Max. length of pronotum .	0·38—0·53	0·50
16. Max. width of pronotum .	0·63—0·83	0·78
17. Max. width of mesonotum . .	0·63—0·73	0·73
18. Max. width of metanotum . .	0·65—0·75	0·73

Head.—Head-capsule subrectangular with rounded corners, rather flat ; longer than broad (index Head-width/Head-length 0·75—0·80) ; sides substraight, posterior margin rounded. *Fontanelle* : Prominent, round, with a brown chitinoid border and lying a little above the middle of head ; with a tube running upto base of labrum. *Eyes and ocelli* : Absent. *Antennae* : With 14 segments ; segment 1 longest, cylindrical ; 2 shortest ; 3 larger than remainder ; 4 markedly smaller than 3 and slightly smaller than 5 ; 5 to penultimate one gradually decreasing in length ; last (14th) ovate, longer than penultimate one. (For abnormalities in the antennae, *vide infra*). *Clypeus* : Postcylpeus flat, subtrapezoidal, with convex posterior margin ; weakly pilose. Anteclypeus narrow, apilose, subtrapezoidal. *Labrum* : Large, pear-shaped, proximal part broad, with subparallel sides, and distal part subtriangular, with a fairly pointed tip ; broadest a little above the middle ; with 2 long and about 4 short setae at apex on either side ; and another group of shorter hairs on body near middle and base. *Mandibles* : Long, sabre-shaped, broad basally ; weakly incurved at apex. Right mandible with inner margin bearing teeth as follows :—One pointed apical ; one large tooth at distal third and 3-6 smaller teeth in middle one-third ; 1 or 2 small teeth usually present (rarely absent) distally to the large one (Text-fig. 2*b*). Left mandible with the inner margin bearing teeth as follows :—One pointed apical ; one large tooth (shorter than the one in right mandible) a little above the distal third ; and 6-8 smaller teeth (usually 1 distal and 4-6 proximal to the large one). *Postmentum* : Club-shaped ; widest in the distal one-fourth, whence the sides gradually narrowing both in front and behind ; narrowest (waist-like) a little below the middle-point between the level of maximum width and the hind-margin ; anterior margin substraight ; posterior margin concave.

Thorax.—Pronotum : Flat, pilose, narrower than head-capsule ; subtrapezoidal, with rounded corners ; broader than long (width 0·63—0·83 mm. ; length 0·38—0·53 mm.) ; anterior margin weakly concave, with a weak median depression ; posterior margin straight. *Mesonotum* : Slightly narrower than pronotum ; sides rounded ; posterior margin straight. *Metanotum* : As wide as mesonotum, but shorter in length ; sides rounded : posterior margin straight. *Legs* : Moderately long, pilose. Tarsi 4-segmented ; apical tibial spur-formula 3 : 2 : 2.

Abdomen.—Oblong, moderately pilose ; 10-segmented. Cerci 2-jointed ; 0·08—0·10 mm. long. Styli short, finger-like, 1-jointed ; 0·05—0·08 mm. long.

Abnormalities in antennae of soldiers (Text-fig. 2*c*).—Some abnormalities noticed in the antennae of soldiers are described below :—(*a*) In a specimen collected 3 miles north-east of Mohanagarh (*vide* "Material" (i) above) the left antennae has only 11 segments (as against the normal 14), and a small additional segment is seen sprouting from the junction of segments 8 and 9 (Text-fig. 2*c*). The right antenna is normal, with 14-segments. (*b*) In another soldier, from the same lot as No.(*a*) above, the right antenna is abnormal—segment 3 is smaller and more slender than 4, and the remaining distal segments become increasingly longer. The left antenna is normal. Both the antennae are damaged—the right one has only 8 segments left, and the left one 9. (*c*) In a soldier collected near Mohangarh, *vide* "Material" (iii) above, the left antenna (which is broken and has only 11 segments left) is abnor-

mal—segment 3 is shorter than usual, and segments 5-8 longer than usual. The right antenna is normal, with 14 segments. (*d*) In a fourth soldier, from the same lot as No. (*c*), the right antenna is abnormal segments from 3 onward are more slender and longer than usual. The right antenna is normal. Both the antennae are partly damaged, with only 8 segments left in the right antenna and 11 in the left. (*e*) One specimen from ' Material ' (v) and two from Material (vi) above have either the right or the left antenna abnormal. The 3rd segment is shorter than the 4th (usually the 4th is shorter than the 3rd), and the remaining distal segments are comparatively much longer than the corresponding ones in the normal antennae.

3. WORKER (Table 2 ; and Pl. 13).—

General.—Head-capsule pale yellow, frons whitish ; anteclypeus and postclypeus pale yellowish white ; labrum yellowish, medially white ; antennae whitish, apically pale yellowish white ; mandibles pale yellow with brownish teeth ; thorax and body white. Head and body moderately pilose. Total length (without antennae) *ca.* 3·30—3·90 mm.

Head.—Head-capsule rounded, with subparallel sides ; broader than its length to base of mandibles (width 0·93—1·03 ; length 0·80-0·88 mm.) ; broadest anteriorly a little above the antennae ; posterior margin convex, rounded. *Fontanelle :* Indistinct. *Eyes and ocelli :* Absent. *Antennae :* With 14 segments ; pilosity increasing distally ; segment 1 cylindrical, longest ; 2 cylindrical, about half of 1 ; 3 shorter than 2 ; 4 smallest ; 5 shorter than 3 and 6 ; 6 to penultimate one progressively increasing in length ; last (14th) longer than penultimate one and ovate. *Clypeus :* Postyclypeus swollen, with a few hairs ; divided into right and left halves by an incomplete, median suture. Anteclypeus narrow, a little projecting in front ; apilose. *Labrum :* Short and broad ; narrower basally, broader anteriorly and narrowing to a rounded pointed tip ; with several short hairs ; no long setae present. *Mandibles :* Of typically *Psammotermes*-type. Right mandible with an apical and 3 marginal teeth ; apical large, finger-like ; 1st marginal small, rudimentary ; 2nd slightly larger than apical ; 3rd short, blunt and widely separated from molar area. Left mandible with an apical and 3 marginal teeth ; apical large, finger-like ; 1st marginal small but well marked ; 2nd large, straight, subequal to apical ; 3rd large, pointed downwards separated from molar area by a narrow gap.

TABLE 2.—*Measurements (in mm.) of workers of* Psammotermes rajasthanicus *Roonwal & Bose.* (10 specimens measured.)

Body-parts	Range (in mm.)
1. Total body-length (without antennae) (approx.)	3·30—3·90
2. Length of head upto base of mandibles	0·80—0·88
3. Maximum width of head	0·93—1·03
4. Maximum height of head	0·48—0·53
5. Maximum length of pronotum	0·30—0·40
6. Maximum width of pronotum	0·53—0·63

Thorax.—Pronotum : Flat, trapezoidal, much narrower than head-capsule ; broader than long (width 0·53—0·63 mm. ; length 0·30—0·40 mm.) ; sides straight, converging posteriorly ; corners rounded ; anterior margin with a weak median notch, posterior margin straight. *Mesonotum :* Broader than pronotum ; sides rounded ; posterior margin straight. *Metanotum :* Similar to but broader than mesonotum ; posterior margin straight. *Legs :* Long, slender ; moderately hairy ; apical tibial spur-formula 3 : 2 : 2. Tarsi 4-segmented.

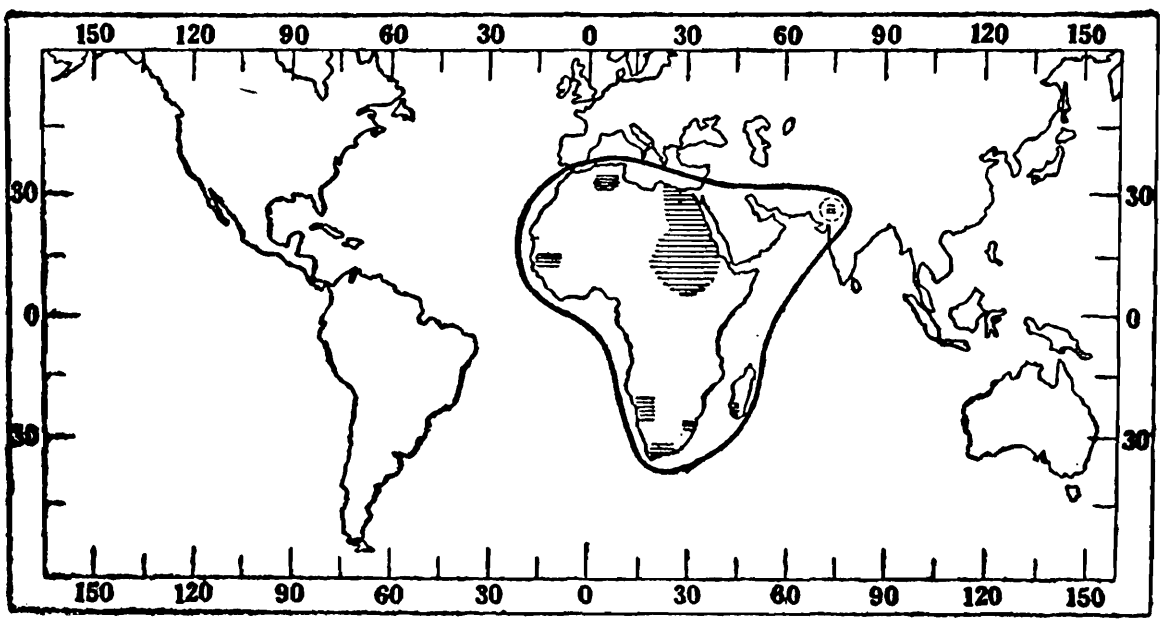
Abdomen.—Elongate, densely pilose. Cerci short, finger-like, 2-jointed ; 0·1 mm. long. Styli short, 1-jointed ; 0·1 mm. long.

(c) *Type-specimens*

Holotype (*vide* " Material " (i) above).—One soldier, Z.S.I. Reg. No. 2447/H8, in spirit, in a vial, from Balana, approximately 27°10′ N. latitude and 71° 20′E. longitude, about 20 miles East of Mohangarh (Jaisalmer District, Rajasthan, India), coll. *K. K. Tiwari and S. Biswas,* 14th Jan., 1958. Deposited in the National Zoological Collections with the Zoological Survey of India, Calcutta.

Morphotype.—One worker, Z.S.I. Reg. No. 2450/H8, deposited in the National Zoological Collections with the Zoological Survey of India, Calcutta. Other data as in holotype.

Paratype and Paramorphotypes.—Deposited as follows :—(i) Two paratype soldiers and 2 paramorphotype workers (*vide* " Material ",



TEXT-FIG. 1.—Map of the world, to show the distribution (areas shaded in horizontal lines) of the genus *Psammotermes* Desneux.

(i) above), in a vial, Z. S. I. Reg. No. 2448/H8 ; and three paratype soldiers and four paramorphotype workers (*vide* Material (ii) above), in a vial, Z. S. I. Reg. No. 2449/H8, all with the Zoological Survey of India, Calcutta. (ii) Two paratype soldiers and two paramorphotype workers, in a vial, with Prof. A. E. Emerson, University of Chicago, Chicago, U. S. A. (iii) One paratype soldier and 2 paramorphotype workers, in a vial, in Entomological Collections, Forest Research Institute, Dehra Dun.

(d) *Type-locality*

INDIA : Rajasthan : Balana (approx. 27°10′ N. lat. and 21° 20′ E. long.), *ca.* 20 miles east of Mohangarh (Jaisalmer District, Rajasthan).

(e) *Geographical Distribution*

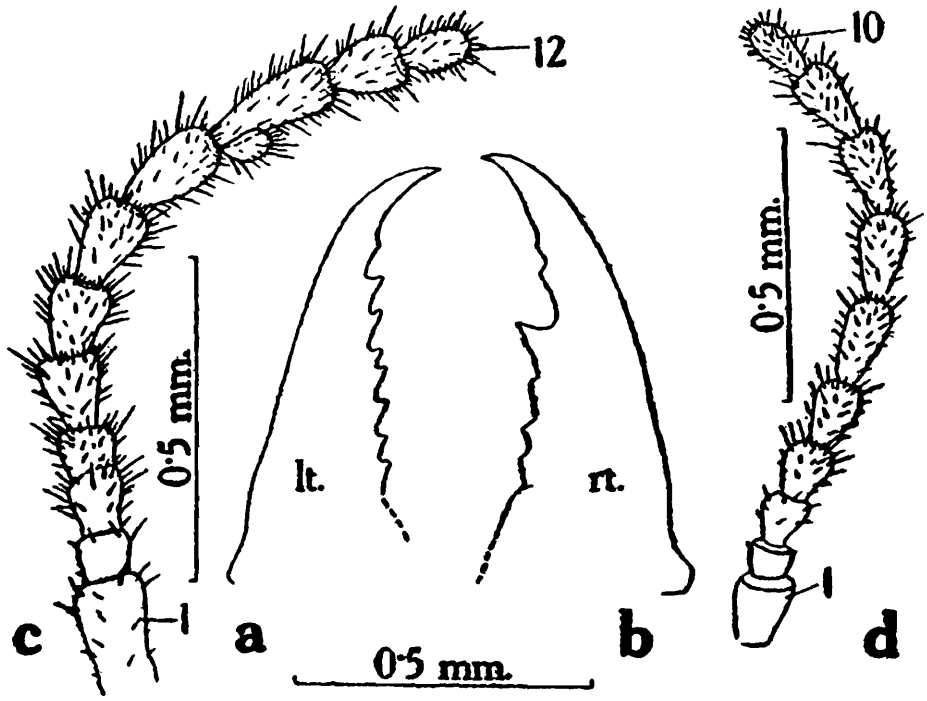
INDIA : Rajasthan : Balana (type-locality) (*ca.* 20 mlles east of Mohangarh) and Mohangarh (both in Jaisalmer District). Pachpadra (Barmer District).

This is the first record of the genus *Psammotermes* from India. The genus was hitherto recorded only from Africa and Madagascar (*vide* discussion in Introduction above ; and Text-fig. 1).

(f) *Comparison*

Psammotermes rajasthanicus Roonwal & Bose, is closest to *P. fusco-femoralis* Sjöstedt, of North Africa, but differs from it as follows :—

(a) *Soldier.*—Has 7-9 teeth on left mandible, and 4-7 teeth on right mandible (*vs.* 8 on left and 5 on right in *P. fuscofemoralis*). (ii) The



TEXT-FIG. 2—*Psammotermes rajasthanicus* Roonwal & Bose. Soldiers (collected 3 miles N.-E. of Mohangarh, Jaisalmer District, Rajasthan) showing abnormalities.

(*a*). Left mandible (*cf.* variations from Pl. 12, Fig. *e*). (*b*). Right mandible (*cf.* variations from Pl. 12, Fig. *f*). (*c*). Left antenna, showing an abnormal segment protruding at the junction of segments 8 and 9. Also note that the total number of segments (apart from the abnormal one) is only 11 as against the normal number 14 : the right antenna of this specimen is normal. (*d*). Right antenna, showing the following abnormalities :—(i) Only 10 segments present, as against the normal 14 ; (ii) 3rd segment shorter than 4th (normally it is longer).

lt., left ; *rt.*, right.

smaller teeth usually lying towards distal end of both mandibles (in *P. fuscofemoralis*, only the larger teeth lying distally). (iii) Two groups of hairs, each with several hairs, present on labrum (only a few scattered hairs present on tip of labrum, in *P. fuscofemoralis*). (iv) Labrum

broadest distally to middle (broadest in middle in *P. fuscofemoralis*). (v) Antennal segments not appreciably slender towards apex (slender in *P. fuscofemoralis*). (iv) Antennae 14- segmented (15- segmented in *P. fuscofemoralis*).

(b) *Worker.*—Antennae 14- segmented (16- segmented in *P. fuscofemoralis*).

III—SUMMARY

1. The termite genus *Psammotermes* Desneux (Isoptera, family Rhinotermitidae, subfamily Psammotermitinae) has hitherto been recorded only from Africa and Madagascar.

2. The genus is now recorded for the first time from India (western Rajasthan) where it is represented by a new species, *Psammotermes rajasthanicus* Roonwal & Bose, which is fully described. (A preliminary description was published earlier.)

3. *Psammotermes rajasthanicus* is closely allied to *P. fuscofemoralis* Sjöstedt of N. Africa, but differs as follows :—(*a*) *Soldier* : (i) 7-9 teeth on left mandible and 4-7 on right (*vs.* 8 on left and 5 on right). (ii) The smaller mandibular teeth present distally (only larger teeth present distally in *P. fuscofemoralis*). (iii) Several hairs present distally on labrum (*vs.* only a few scattered hairs on tip). (iv) Labrum broadest distally to middle (*vs.* broadest in middle). (v) Antenae 14- segmented (*vs.* 15- segmented). (*b*) *Worker* : Antennae 14-segmented (*vs.* 16. segmented).

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PLATE 12

Psammotermes rajasthanicus Roonwal & Bose. Soldier caste.

All drawings are from *holotype* soldier, Z. S. I. Reg. No. 2447/H8, from Balana, about 20 miles east of Mohangarh, Jaisalmer District, Rajasthan, India, coll. *K. K. Tiwari and S. Biswas*, 14th January, 1958.

Fig. *a*.—Whole soldier, in dorsal view.

Fig. *b*.—Head and thorax, enlarged, in dorsal view.

Fig. *c*.—Head and thorax, enlarged, in lateral view.

Fig. *d*.—Labrum, in dorsal view.

Fig. *e*.—Left mandible.

Fig. *f*.—Right mandible.

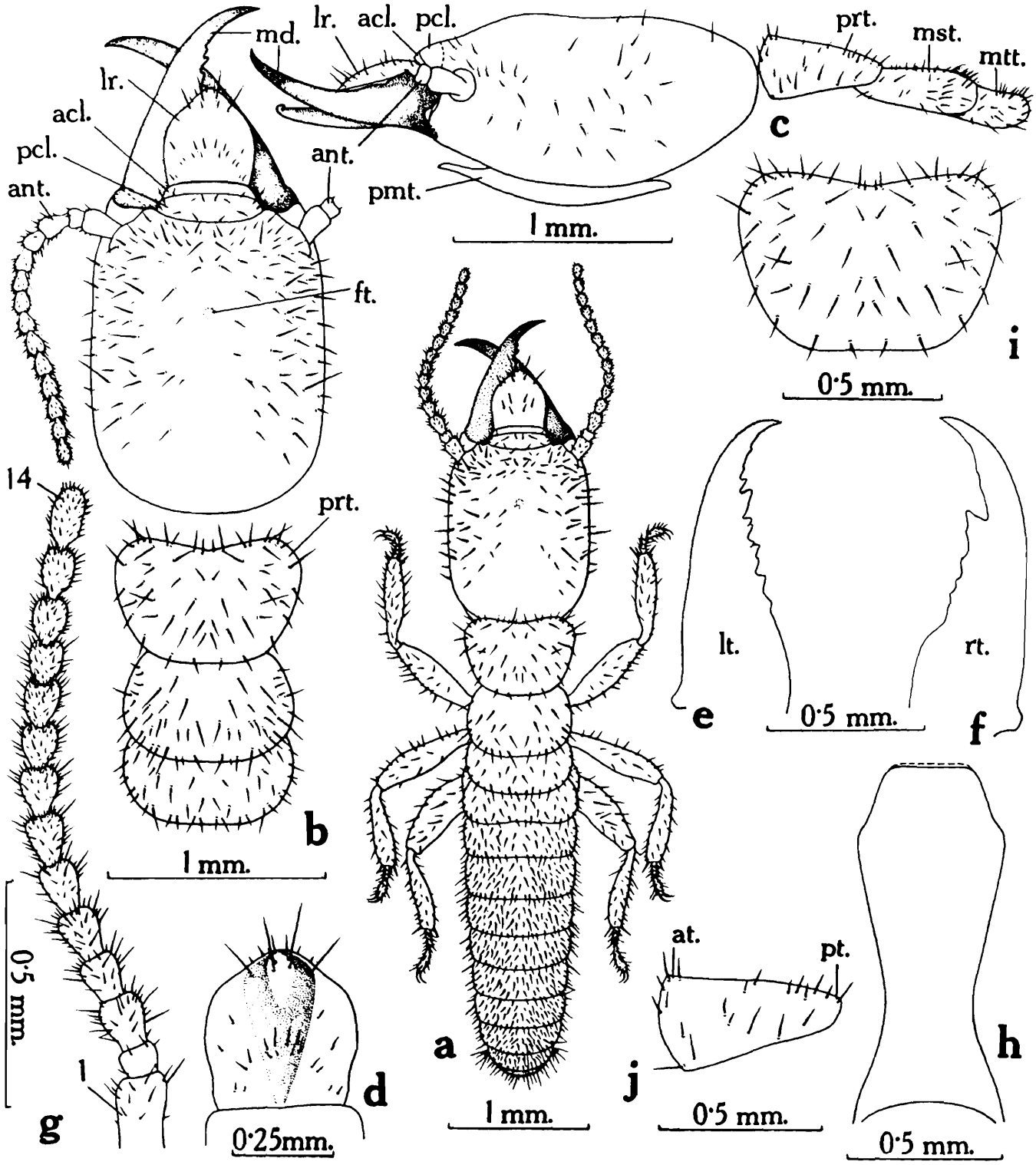
Fig. *g*.—Left antenna.

Fig. *h*.—Postmentum.

Fig. *i*.—Pronotum, in dorsal view, enlarged.

Fig. *j*.—Pronotum, in lateral view, enlarged.

acl., anteclypeus ; *ant.*, antenna ; *at.*, anterior ; *ft.*, fontanelle ; *lt.*, left ; *lr.*, labrum ; *md.*, mandible ; *mst.*, mesonotum ; *mtt.*, metanotum ; *pcl.*, postclypeus ; *prt.*, pronotum ; *pt.*, posterior ; *rt.*, right.



Soldier: *Psammotermes rajasthanicus* Roonwal & Bose.

PLATE 13

Psammotermes rajasthanicus Roonwal & Bose. Worker caste.

All drawings are from the *paramorphotype* worker, Z. S. I. Reg. No. 2448/H8, from the holotype colony (same data as in Pl. 12).

Fig. *a*.—Whole worker, in dorsal view.

Fig. *b*.—Head and thorax, enlarged, in dorsal view.

Fig. *c*.—Head and thorax, enlarged, in lateral view.

Fig. *d*.—Labrum, enlarged, in dorsal view.

Fig. *e*.—Left mandible.

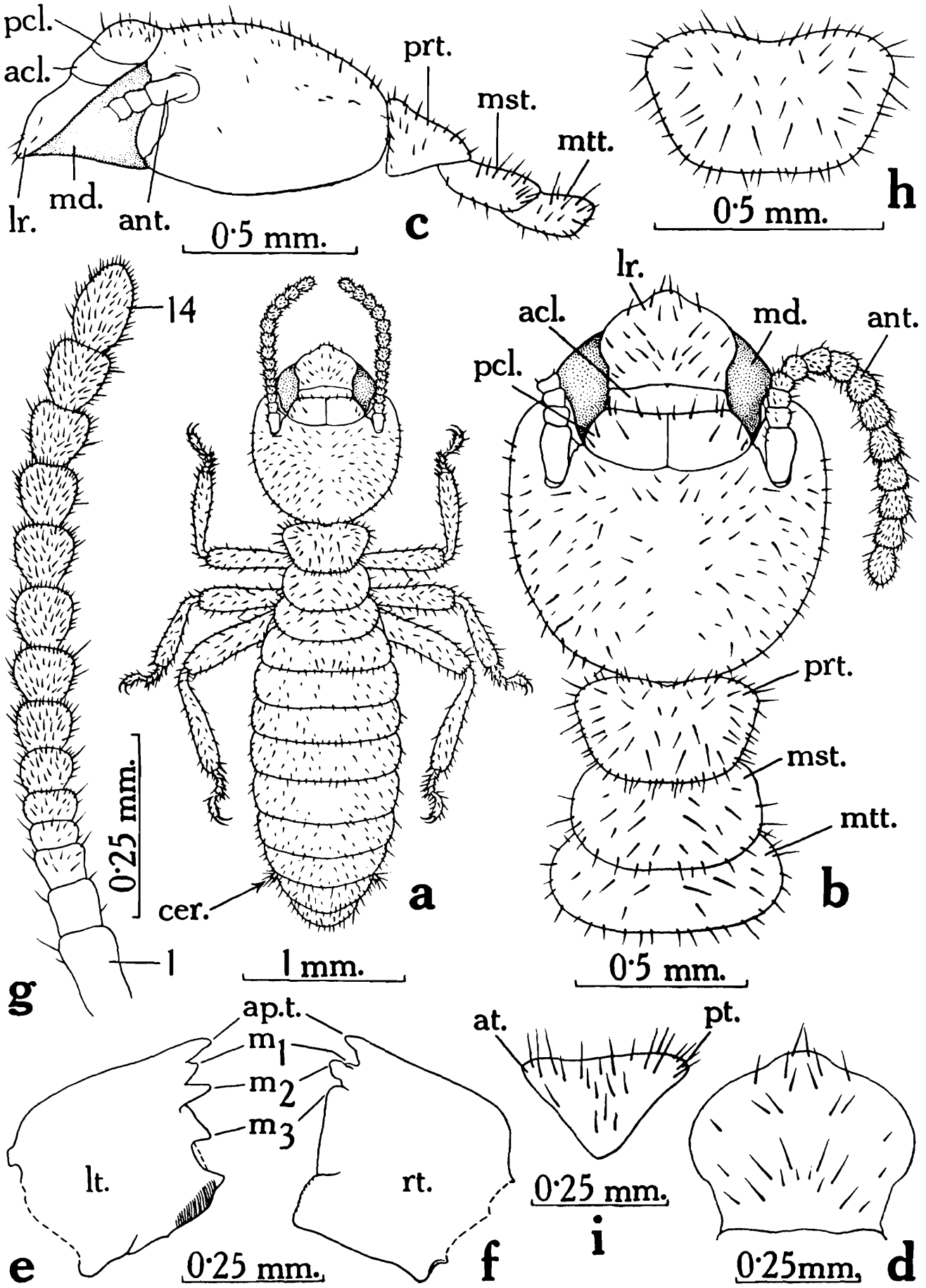
Fig. *f*.—Right mandible.

Fig. *g*.—Left antenna.

Fig. *h*.—Pronotum, enlarged, in dorsal view.

Fig. *i*.—Pronotum, enlarged, in lateral view.

acl., anteclypeus ; *ant.*, antenna ; *ap.t.*, apical tooth ; *at.*, anterior ; *cer.*, cerci ; *lr.*, labrum ; *lt.*, left ; *md.*, mandible ; m_1, m_2, m_3, mandibular teeth ; *mst.*, mesonotum ; *mtt.*, metanotum ; *pcl.*, postclypeus ; *prt.*, pronotum ; *pt.*, posterior.



Worker: *Psammotermes rajasthanicus* Roonwal & Bose.

A NEW NEOTROPICAL ELEMENT (*ANOPLOTERMES*) IN THE INDIAN TERMITE FAUNA, WITH FULLER DESCRIPTION OF *A. SHILLONGENSIS* FROM ASSAM*

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(With 3 Tables, 2 Text-figures and 1 Plate)

CONTENTS

I—INTRODUCTION

There is a group of termites in the *Anoplotermes*-complex (Isoptera, Family Termitidae, Subfamily Amitermitinae) in which the soldier caste is absent†, and only the worker caste and the reproductives (alates : male and female) are known to occur. The complex consists of two closely allied genera, *Anoplotermes* Müller and *Speculitermes* Wasmann.

The genus *Anoplotermes* was erected by Müller (1873) to accommodate a new Neotropical species, *A. pacificus* Müller, from Peru. Later on, Wasmann (1902) erected the genus *Speculitermes* to accommodate a new species, *S. cyclops* Wasm., from India. Holmgren (1912), however, reduced *Speculitermes* to the status of a subgenus of the parent genus *Anoplotermes* which thus had two subgenera, *Anoplotermes* and *Speculitermes*. Some authorities (*e.g.*, Grassé, 1949, p. 537) have accepted this new status, while others continue to hold the two groups as of generic rank (Snyder, 1949). There is no doubt that the two genera are very closely allied, but as there are marked and clear differences, it is perhaps best to regard them as two full genera which are separable

* For a preliminary account, see Roonwal, M. L. and Chhotani, O.B. (i) *Nature*, London, **184**, pp. 1967-1968, 19th Dec., 1959 ; and (ii) *Sci. & Culture*, Calcutta, **25**(12), p. 701, June, 1960.

† While this paper was in the press, we discovered the soldier caste in the genus *Speculitermes*, from two collections of *S. cyclops sinhalensis* Roonwal & Sen-Sarma, from southern India (*vide* Roonwal & Chhotani, *Sci. & Culture*, Calcutta, **26**(3), pp. 143-144. Sept. 1960.

as in the following key, while a more detailed comparison is given in Table 1.

Key to workers of the genera of the Anoplotermes*-complex.*

1 (2). Body pale. Smaller (head and body *ca.* 2·7-6·3 mm. long ; head-width 0·4-1·2 mm.). Mid-dorsal spot on head either absent or very weak and reduced to a point. Antennae shorter, *ca.* 1·2-1·6 times the head-width ; with 14 segments ; 3rd segment generally smaller than 2nd. Fore-tibia markedly swollen. Tibial spur formula variable, generally either 3 2 : 2 (Ethiopian species) or 2 : 2 : 2 (Neotropical and Oriental species). Left mandible with an apical and either 2 or 3 marginal teeth ; the 3rd marginal, when present, very small.

... *Anoplotermes* Müller

2 (1). Body dark. Larger (head and body *ca.* 4·0-7·0 mm. long ; head-width 1·0-1·4 mm.). Mid-dorsal spot on head ("Stirnocellus" of Wasmann) large and prominent. Antennae longer, *ca.* 1·5-2·0 times the head-width ; with 14 (rarely 15) segments ; 3rd segment longer than 2nd (rarely subequal). Fore-tibia not swollen. Tibial spur formula 2 : 2 : 2. Left mandible with an apical and 2 marginal teeth.

...*Speculitermes* Wasmann.

TABLE 1.—*Comparison of worker characters of the genera* Anoplotermes *and* Speculitermes.

Anoplotermes	*Speculitermes*
1. Generally pale	1. Generally dark coloured.
2. Smaller species :	2. Larger species :
Total length *ca.* 2·7—6·3 mm.	Total length *ca.* 4·0—7·0 mm.
Max. head-width 0·4—1·2 mm.	Max. head-width 1·0—1·4 mm.
3. Head weakly chitinized	3. Head usually strongly chitinized.
4. Mid-dorsal spot on head either absent or very weak and reduced to a point.	4. Mid-dorsal spot on head ("Stirnocellus" of Wasmann) large and prominent and of varying shape — round or triangular.
5. Antennae shorter, length 1·2—1·6 times the head-width ; 14-segmented ; 3rd segment generally shorter than 2nd.	5. Antennae longer, length 1·5—2·0 times the head-width , generally 14-segmented (15-segmented in *S. proratus* Emerson) ; 3rd segment generally longeg than 2nd (subequal in *S. proratus*).
6. Fore-tibia markedly swollen	6. Fore-tibia slender, not swollen.
7. Tibial spur formula variable. In Ethiopian species 3:2:2, and in Neotropical species 2:2:2 (Silvestri, 1914). In *A. shillongensis* Roonwal and Chhotani from Assam, fore-tibial spurs varying within the species from 2-3.	7. Tibial spur formula 2:2:2.
8. Left mandible with an apical and either 2 or 3 marginal teeth ; 3rd marginal, when present, very small and lying a little above the molar plate.	8. Left mandible with an apical and 2 marginal teeth.

TABLE 2.—*Zoogeographical distribution of the species of* Anoplotermes *and* Speculitermes.

Zoogeographical Regions	Continents, etc.	Species	
		Number	Percentage
	I—Anoplotermes		
1. Neotropical	South & Central America; West Indies.	32	72·7
2. Ethiopian	Africa	11	25·0
3. Nearctic	Southern U.S.A.	1 Common with Neotropical	2·3 Common with Neotropical
4. Oriental	India (Assam)	1	2·3
	TOTAL	44 (excluding 1 Nearctic which is common with Neotropical)	100
	II—Speculitermes		
1. Neotropical	South America	4	57·1
2. Oriental	India, Burma, Ceylon	3	42·9
	TOTAL	7	100

II—NEW FIND OF *ANOPLOTERMES* IN INDIA, AND FULLER DESCRIPTION OF *A. SHILLONGENSIS* ROONWAL & CHHOTANI

The genus *Anoplotermes* has hitherto been known to have representatives from the Neotropical (S. America), the southern Nearctic (southern United States) and the Ethiopian (Africa) Regions, and none from the Oriental. Recently (Roonwal & Chhotani, 1959, 1960), we discovered the existence of the genus in India (Assam), where it is represented by a single new species, *Anoplotermes shillongensis* Roonwal & Chhotani,

which was briefly described by us (1960) some time ago, and a fuller, illustrated description is given below :—

Anoplotermes shillongensis Roonwal and Chhotani

(Table 3; and Plate 14)

1960. *Anoplotermes shillongensis* Roonwal & Chhotani, *Sci. & Cult.*, Calcutta, **25**(12), p. 701. (Preliminary description).

(a) *Material*

(i) Several workers, in a vial, in spirit, Shillong (Bishop Falls), Assam (91° 56′ E. long.; 25° 34′ N. lat.), India, coll. *A. P. Kapur*, 22nd December, 1958.

(ii) Four workers, in a vial, in spirit, Rongrengiri, District Tura, Assam (approx, 90° 45′ E. long.; 25° 45′ lat.), coll. *A. N. Fernandez*, 13th January, 1957, *ex* "earth in the forest around Rongrengiri" (Found mixed with a new species of *Speculitermes* to be described elsewhere; now separated and kept in another vial.)

Also, two slides, Nos. 6 and 7, from lots (i) and (ii) above.

(b) *Fuller Description*

1. IMAGO.—

Unknown.

2. SOLDIER.—

Unknown in the genus.

3. WORKER (Table 3; and Pl. 14).—

General.—Head-capsule pale yellow; postclypeus of same colour as head-capsule; anteclypeus whitish hyaline; labrum pale yellow, whitish hyaline anteriorly; antennae, thorax and legs pale yellow, paler than head-capsule; mandibles pale yellow, with dark brown toothed margins; abdomen dirty grey because of food matter in the intestines visible through sclerites. Head and body rather densely hairy. Total-length of head and body (excluding antennae) *ca.* 3·6-4·2 mm.

Head.—Head-capsule subcircular; broader than its length to base of mandibles (width 0·85-0·90 mm.; length 0·70-0·75 mm.); broadest a little behind the level of antennae; sides rounded and narrowing posteriorly; posterior margin round; a faint, circular, tiny, whitish mid-dorsal spot usually present (sometimes absent); Y-suture absent. *Eyes :* Two lateral, rudimentary, brown eye-spots, one on either side, usually present (sometimes absent). *Ocelli :* Absent. *Antennae :* With 14 segments; moderately pilose; pilosity gradually increasing distally; segment 1 longest, cylindrical; 2 about half the length of 1, and cylindrical; 3 somewhat shorter than 2; 4 shorter than 3; 5-8 club-shaped, and gradually increasing in length; 9-13 club-shaped, and gradually decreas-

ing in length ; last (14th) ovate, longer than the penultimate one. *Clypeus* : Divided into an ante- and a postclypeus. Postclypeus weakly swollen, pilose ; a little shorter than half its width ; divided into right and left halves by a median suture ; posterior margin convex, medially incurved, forming a notch. Anteclypeus whitish, hyaline, apilose ; subtrapezoidal ; shorter in length than postclypeus. *Labrum :* Slighty broader than long ; broadest in middle ; in front somewhat narrowing ; anterior margin rounded. *Mandibles :* Somewhat longish; outer margins incurved. Left mandible with an apical and 3 marginal teeth ; apical finger-like ; 1st marginal slightly smaller than apical ; second smaller than 1st and widely separated from it ; 3rd very minute, located just above the molar-plate. Right mandible with an apical and 2 marginal teeth ; apical finger-like ; 1st marginal somewhat shorter than apical and broader ; 2nd shorter than 1st and finger-like.

Thorax.—Pronotum : Saddle-shaped ; narrower than head-capsule ; much broader than long (width 0·53-0·55 mm. ; length 0·25-0·28 mm.) ; anterior lobe rounded and greatly upturned ; anterior margin not notched ; sides strongly narrowing posteriorly ; posterior margin substraight. *Mesonotum :* Narrower than pronotum ; posterior margin substraight. *Metanotum :* Broader than pronotum ; posterior margin straight. *Legs :* Long and thin ; fore-tibia *swollen*, middle-tibia a little less swollen, and hind-tibia slender and not swollen. Tibial spur formula variable, either 3 : 2 : 2 or 2 : 2 : 2, thus : Tibia generally with 2 apical spurs in the forelegs, sometimes (approximately 16 per cent) with a third minute rudimentary spur on outer side ; middle and hind-tibiae with 2 apical spurs each. Tarsi 4-jointed.

TABLE 3.—*Body measurements (in mm.) and indices of* Anoplotermes shillongensis *Roonwal and Chhotani.* (10 specimens measured.)
Caste.—WORKER.

BODY-PART	RANGE	HOLOTYPE
I—MEASUREMENTS		
1 Total body-length (approx.)	3·6—4·2 mm.	3·8 mm.
2. Head-length to lateral base of mandibles	0·70—0·75 mm.	0·70 mm.
3. Max. width of head .	0·85—0·90 mm.	0·90 mm.
4. Max. height of head	0·33—0·38 mm.	0·33 mm.
5. Diameter of mid-dorsal spot (when present).	0·05—0·07 mm.	0·05 mm.
6. Length of antennae	1·33—1·35 mm.	1·35 mm.
7. Max. length of pronotum	0·25—0·28 mm.	0·25 mm.
8. Max. width of pronotum . .	0·53—0·55 mm.	0·55 mm.
9. Length of hind-tibiae	0·75—0·78 mm.	0·78 mm.
II—INDICES		
1. Antennal-length/head-length	1·77—1·93	1·93
2 Antennal-length/head-width	1·50—1·56	1·50

Abdomen.—Elongated, hairy. Cerci 2-jointed, short about 0·05 mm. long. Styli absent.

Measurements.—See Table 3 above.

(c) *Type-specimens*

Holotype.—From "Material" (i) above ; one worker, Z.S.I. Reg. No. 2445/H8, in spirit, in a vial ; Shillong (Bishop Falls) Assam, India, coll. *A. P. Kapur*, 22. xii. 1958. Deposited in the National Zoological Collections in the Zoological Survey of India, Calcutta.

Paratypes.—Deposited as follows : (i) Five workers, Z.S.I. Reg. No. 2446/H8, in Zoological Survey of India, Calcutta. (ii) Two workers in Entomological Collection, Forest Research Institute, Dehra Dun. (iii) Two workers with Professor A.E. Emerson, Department of Zoology, University of Chicago, Chicago (U.S.A.).

(d) *Type-locality*

INDIA : Bishop Falls, Shillong (Assam), 25° 34′ N. lat. and 91° 56′ E. long.

(e) *Geographical Distribution*

INDIA : *Assam :* Rongrengiri (District Tura) ; and Shillong (type-locality).

(f) *Comparison*

The worker of *Anoplotermes shillongensis* Roonwal & Chhotani is close to that of the two Ethiopian species, namely, *A. pacatus* Silvestri and *A. quietus* Silvestri, but differs from them as follows :—

(1) From *A. pacatus :* (i) Head broader (0·85-0·90 *vs.* 0·83 mm.). (ii) Antennae longer both absolutely and comparative to head-length and head-width (length 1·33-1·35 *vs.* 1·20 mm.) ; index antennal length/head-length 1·77-1·93 *vs.* 1.66 ; and index antennal length/head-width 1·50-1·56 *vs.* 1·44. (iii) Hind-tibia longer (0·75-0·80 *vs.* 0·72 mm.).

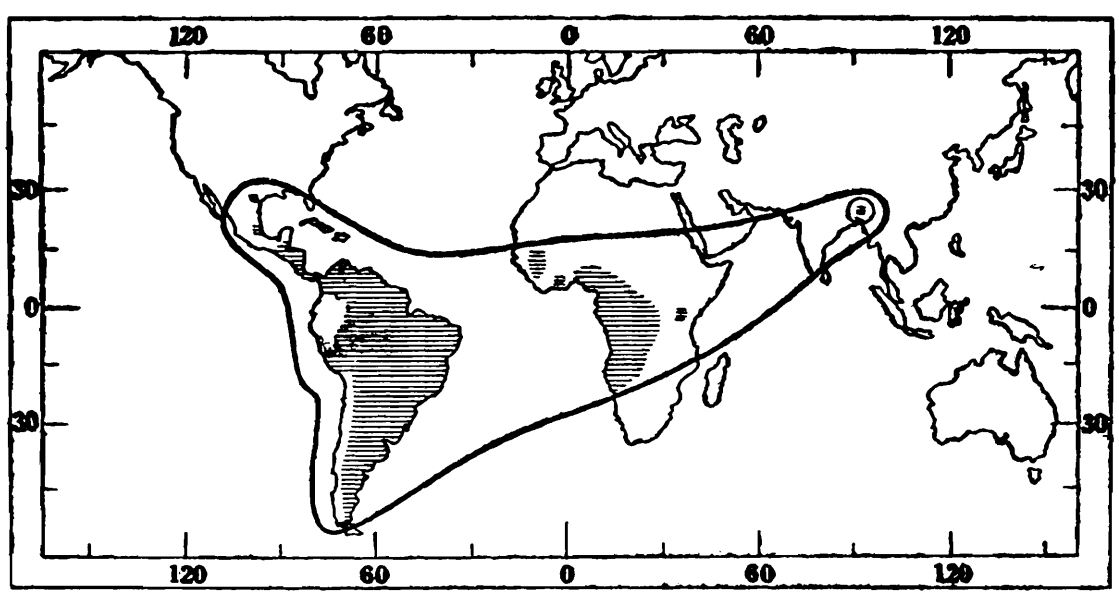
(2) From *A. quietus :* (i) Head broader (0·85-0·90 *vs.* 0·84 mm.). (ii) Antennae longer both absolutely and comparative to head-length and head-width (length 1·33-1·35 *vs.* 1·20 mm.) ; index antennal-length/head-length 1·77-1·93 *vs.* 1.54 ; index antennal-length/head-width 1·50-1·56 *vs.* 1·43. (iii) Hind-tibia shorter (0·75-0·80 *vs.* 0·85 mm.).

III—DISCUSSION

(Table 2 ; and Text-figs. 1 and 2)

Out of about 44 known species of *Anoplotermes* (Silvestri, 1901, 1914 ; Holmgren, 1912 ; Emerson, 1925 ; Sjöstedt, 1925 ; Snyder, 1949) the majority are Neotropical (72·7 per cent, one Nearctic, a few Ethiopian (25 per cent) and one Oriental (present paper), *vide* Table 2 and Text-fig. 1.

The closely allied but smaller genus, *Speculitermes* (regarded by some authorities as a subgenus of *Anoplotermes*), where only 7 species are known (*vide* Snyder, 1949 ; Roonwal & Sen-Sarma, 1959 ; and Roonwal & Chhotani, present paper), is also largely Neotropical (57.1 per cent) but is also well represented in the Oriental Region (42·9 per cent), *vide* Table 2 ; and Text-fig. 2. It has so far not been recorded from the



TEXT-FIG 1.—Map of the world, showing the known geographical distribution areas shaded in horizontal lines) of genus *Anoplotermes* Fr. Müler.

Ethiopian Region. The Oriental forms of *Speculitermes* comprise three species, one of which has two subspecies, as follows :—

1. *S. cyclops* Wasmann.

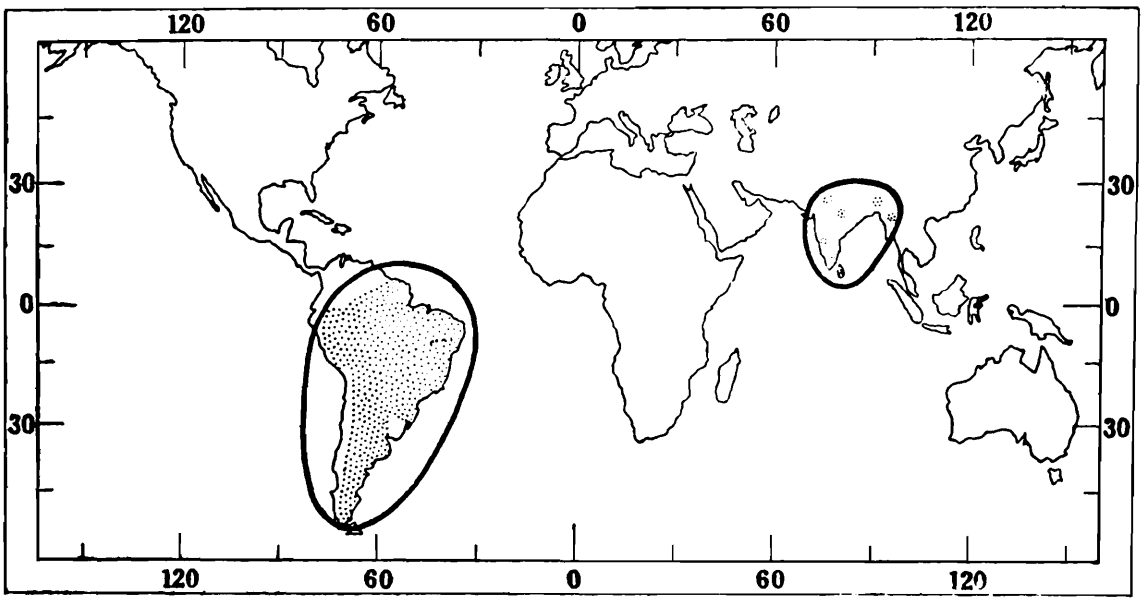
   S. cyclops, cyclops, Wasmann.—All India (except extreme south of the Peninsula, and the eastern region, *e.g.*, Bihar, Bengal and Assam) ; and Burma.

   S. cyclops sinhalensis Roonwal & Sen-Sarma.—Peninsular India ; and Ceylon.

2. *S. triangularis* Roonwal & Sen-Sarma.—India (Uttar Pradesh).

3. A new species of *Speculitermes* to be described elsewhere).—India (Assam).

From the abundance and variety of the species of both the genera of the *Anoplotermes-Speculitermes* complex, which comprises a total of about 51 species, it will be evident that the complex was most probably evolved in the Neotropical Region (South America) and thence spread



TEXT-FIG. 2.—Map of the world, showing the known geographical distribution (areas shaded with smali dots) of genus *Speculitermes* Wasmann.

to Africa and the Indo-Malayan Region while these land-masses were still contiguous and before they had started to drift apart according to Wegener's Hypothesis (Wegener, 1922 ; van der Gracht, 1928). Alternatively, one can regard the group to have evolved independently in S. America, Africa and India, a contingency which appears to be unlikely to have happened. Accepting the former view, we may suppose that the *Anoplotermes*-element, which is the stronger one (44 out of 51 species) spread to Africa, and one species, *A. shillongensis* R. & C., reached as far east as Assam (India).

The *Speculitermes*-element of this complex, which is relatively weak (7 out of 51 species), also appears to have been evolved in South America, but whether it initially occurred and evolved in the Indo-Malayan Region as well, or spread there later, is not clear, and its total absence in the intervening land-mass of Africa is puzzling.

IV—SUMMARY

1. The termite genus *Anoplotermes* Müller (Isoptera, Termitidae, Amitermitinae) is, along with the closely allied genus *Speculitermes* Wasmann, characterised by the absence of the soldier caste*—only workers and the reproductives (male and female alates) being present.

2. *Anoplotermes* was hitherto known mainly from the Neotropical (32 species) and the Ethiopian (11 species) Regions, with one of the Neotropical species extending north to the Nearctic Region (southern U.S.A.).

*Since the above was written, the soldier caste has been found in the genus *Speculitermes* by Roonwal & Chhotani, *viele* foot-note on p. 159.

3. Recently (Roonwal & Chhotani, 1959, 1960*a*), the genus has been found to occur in India (Assam) where it is represented by a single species, *A. shillongensis* Roonwal & Chhotani, which is described in detail ; a brief, preliminary description was given earlier (Roonwal & Chhotani, 1960*a*).

4. The discovery of a mainly Neotropical element in the Oriental Region is of considerable zoogeographical significance.

5. The allied genus *Speculitermes* (with 7 known species), which some authors regard as a subgenus of *Anoplotermes*, has been recorded from the Neotropical Region (S. America) and the Oriental Region (India), but is, curiously enough, totally absent in the intervening landmass of Africa (Ethiopian Region).

6. The *Anoplotermes-Speculitermes*-complex was presumably evolved in the Neotropical Region where it still dominates. The *Anoplotermes*-section thence spread to the Ethiopian Region, and also sent an offshoot to the Indian Region (a single species). The *Speculitermes*-section is well represented in both the Neotropical and the Oriental Regions, and its absence from the intervening Ethiopian Region is quite puzzling.

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PLATE 14

Anoplotermes shillongensis Roonwal and Chhotani. Worker Caste.

All figures from the paratype workers from Shillong (Assam, India), coll. *A. P. Kapur*, 22. xii. 1958.

FIG. *a*.—Whole body, in dorsal view.

FIG. *b*.—Head and thorax, in dorsal view.

FIG. *c*.—Head and thorax, in side view.

FIG. *d*.—Labrum, in dorsal view. (Slide No. 6.)

FIG. *e*.—Left mandible, in dorsal view. (Slide No. 6.)

FIG. *f*.—Ditto, right mandible.

FIG. *g*.—Right antenna, in dorsal view. First and last (14th) segments numbered.

FIG. *h*.—Pronotum, in dorsal view (*in situ*).

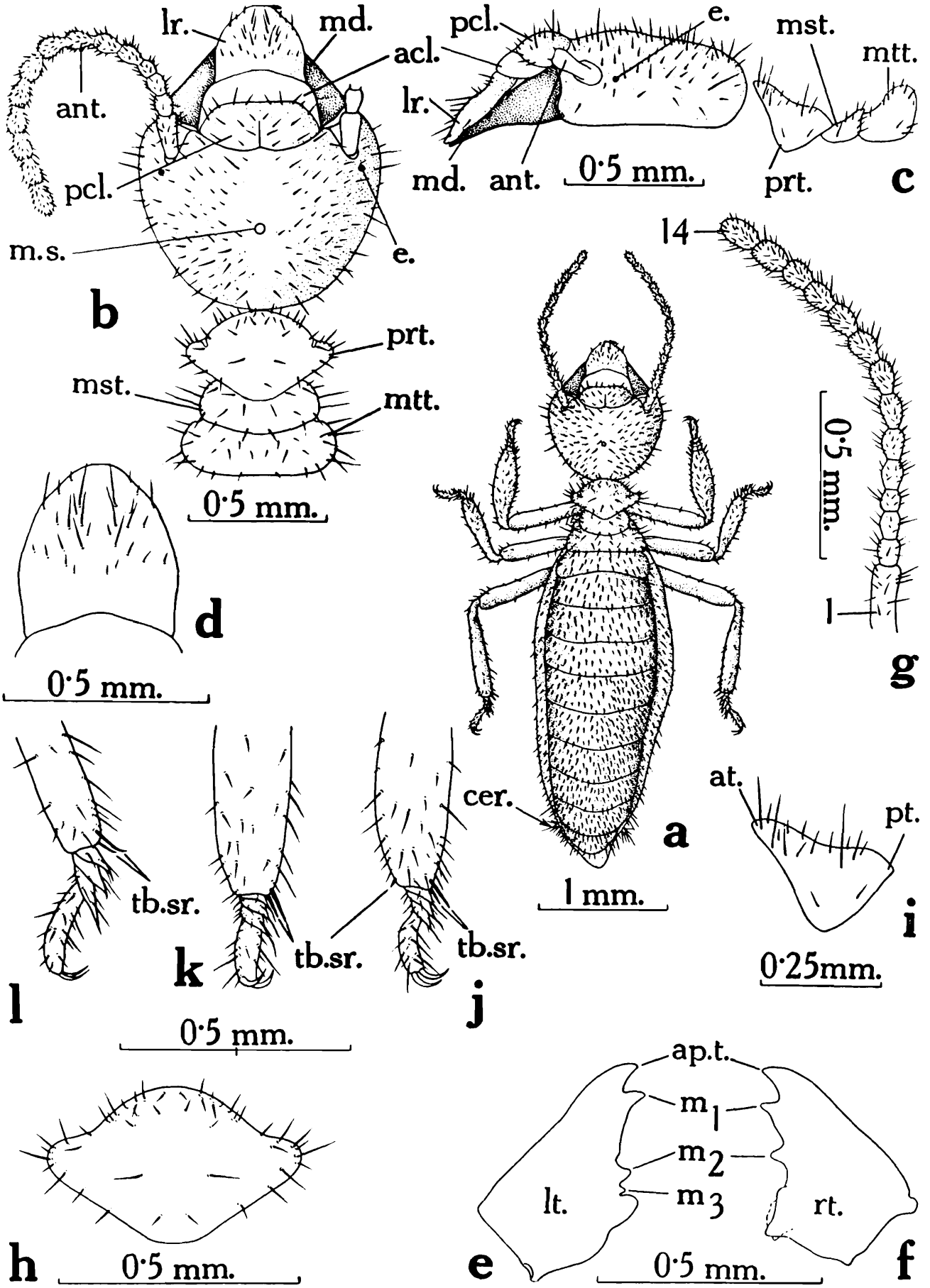
FIG. *i*.—Pronotum, in side view (*in situ*).

FIG. *j*.—Fore-tibia, with three apical tibial spurs.

FIG. *k*.—Fore-tibia, with two apical tibial spurs.

FIG. *l*.—Hind-tibia, with two apical tibial spurs.

acl., anteclypeus ; *ant.*, antenna ; *ap. t.*, apical teeth cf mandibles ; *at.*, anterior ; *cer.*, cercus ; *e.*, rudiments of eyespots ; lr., labrum ; *lt.*, left ; m_1-m_3, first to third marginal teeth of mandibles ; *md.*, mandible ; *m. s.*, mid-dorsal spot of head ; *mst.*, mesonotum ; *mtt.*, metanotum ; *pcl.*, postclypeus ; *prt.*, pronotum ; *pt.*, posterior ; *rt.*, right ; *tb. sr.*, tibial spurs.



Worker: *Anoplotermes shillongensis* Roonwal & Chhotani.

MORPHOLOGY OF THE PRIMITIVE TERMITE *ANACANTHOTERMES MACROCEPHALUS* (DESNEUX) (ISOPTERA: HODOTERMITIDAE). PART 1. EXTERNAL MORPHOLOGY OF THE SOLDIER CASTE

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(With 3 Tables and 8 Text-figures)

CONTENTS

I—INTRODUCTION

Our knowledge of the morphology of Indian termites is very meagre. Imms (1919) studied in detail the morphology of the primitive termite *Archotermopsis wroughtoni* Desneux (family Hodotermitidae). Bugnion and Popoff (1912), and Mukerji and Raichoudhury (1942, 1944,) have studied particular organs and systems in the various castes of *Odontotermes redemanni* (Wasm.) (their *Termes redemanni* Wasm.). Vishnoi (1956) has described the structure, musculature and feeding mechanism of *Odontotermes obesus* (Rambur), and Kushwaha (1960) has given a detailed account of the external morphology of the same species which is one of the higher evolved and mound-building termites of India.

Anacanthotermes macrocephalus (Desneux), the species I have chosen for study in detail, belongs, like *Archotermopsis wroughtoni* Desneux, to the family Hodotermitidae, but is more highly evolved than the latter in having a worker caste. It inhabits the desert regions of West Pakistan and western India and lives mainly on grass. It has so far been recorded from Karachi and Multan in West Pakistan; and from the Bikaner and Jodhpur Divisions of Rajasthan in India. The present series of papers deal with its morphology.

Acknowledgments.—I am extremely grateful to Dr. M. L. Roonwal, Director, Zoological Survey of India, Calcutta, for guidance. I am also indebted to the Principal, Dungar College, Bikaner, for allowing me the laboratory facilities where the work was mainly done, and to Prof. K. S. Kushwaha for kindly reading through the manuscript and suggesting improvements.

II—MATERIAL AND METHODS

The material was collected from fields and open lands on the outskirts of Bikaner city in Rajasthan. The actual method of catching them is of interest. They were captured either when the insects were foraging in the open or were pulled out of the burrow-holes individually. In the latter case the following procedure was successful : A 'wet', (*i.e.*, active) " mound " or earth-heap, built by the termite was swept aside to expose the ground hole and a grass blade was pushed in through the hole leading to the underground passages. The blade was invariably caught by a soldier, and as soon as this happened it was pulled out to bring the soldier with it.

The material was examined either fresh after killing by dropping the insect in boiling water, or preserved in rectified spirit. Individual structures were dissected out, cleared in 5 per cent KOH for about 24 hours, dehydrated, stained in the usual way with eosin (in 90 per cent alcohol) and mounted in canada balsam on a glass slide.

Three castes are present, *viz.*, the soldiers, workers, and the reproductives (alate males and females). In the present paper the external morphology of the soldier is described.

III—EXTERNAL MORPHOLOGY OF THE SOLDIER

(Text-figs. 1 and 2)

(a) *General*

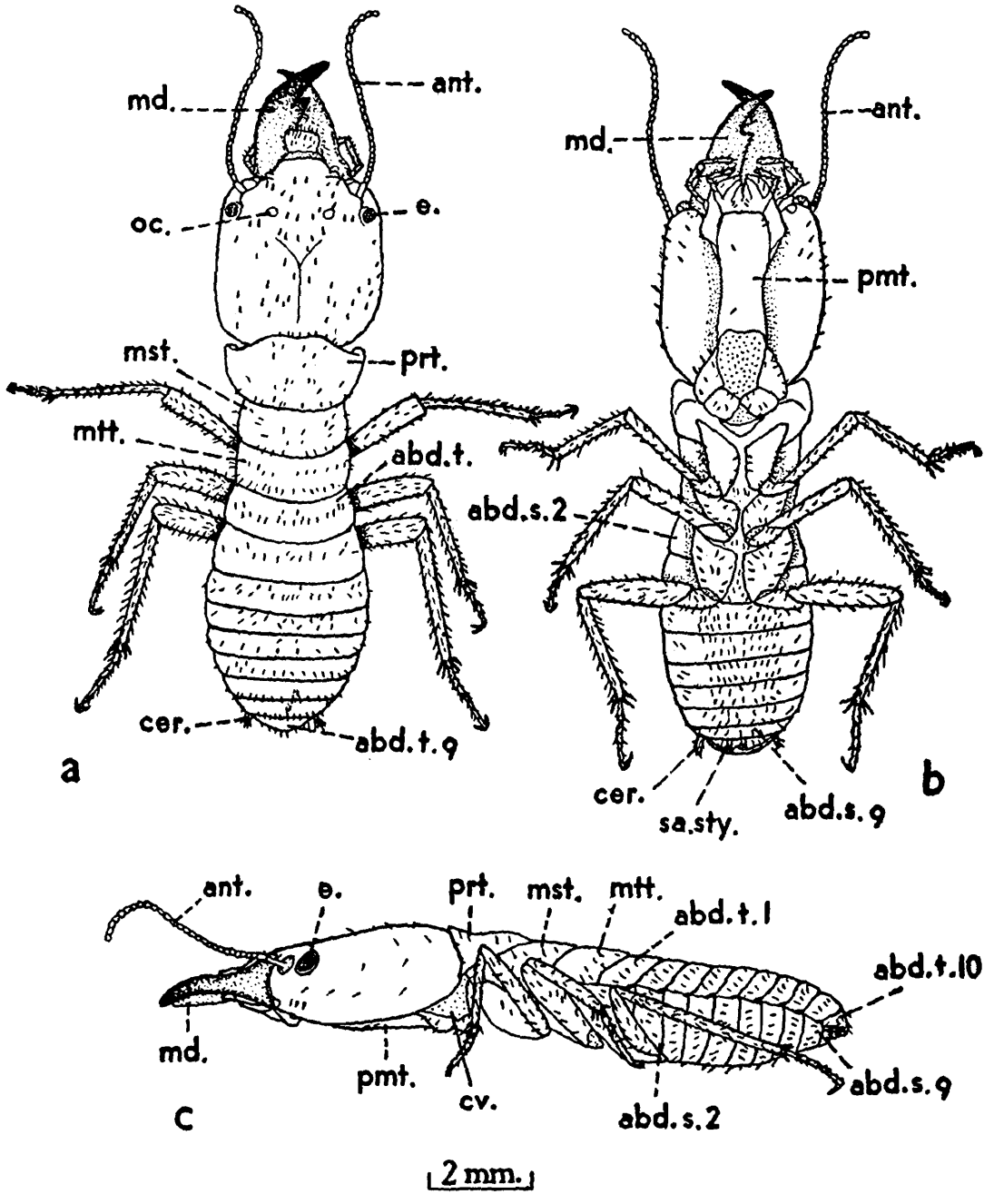
Coloration.—The head is rust brown, paler posteriorly and darker anteriorly in the clypeal region. The anteclypeus is whitish, the labrum, antennae, maxillary palps and prementum of labium pale yellow-brown, and the margins of the mental plate are dark brown. The eyes are black. The mandibles are dark brown at the base and glossy black in the anterior portion.

The prothorax, like the head, is rust brown, gradually becoming paler posteriorly. The abdomen, the cerci and the styli are pale yellow. On account of the presence of fat bodies below the body wall, the abdomen, whose sclerites are transluscent, appears dirty white. The leg segments are pale yellow, and the claws dark-brown.

Setae.—The whole body is sparsely beset with irregularly distributed fine bristles or setae. On the head and thorax the setae are longish and more numerous on the dorsal side than on the ventral. On the abdomen the case is the reverse and the bristles are concentrated in the mid-ventral region, the ventro-lateral region having only scattered bristles. The thoracic legs, the cerci and the styli all carry long bristles.

Both the sexes have the styli and the cerci, and it is thus not possible to distinguish the sexes externally in the soldier caste.

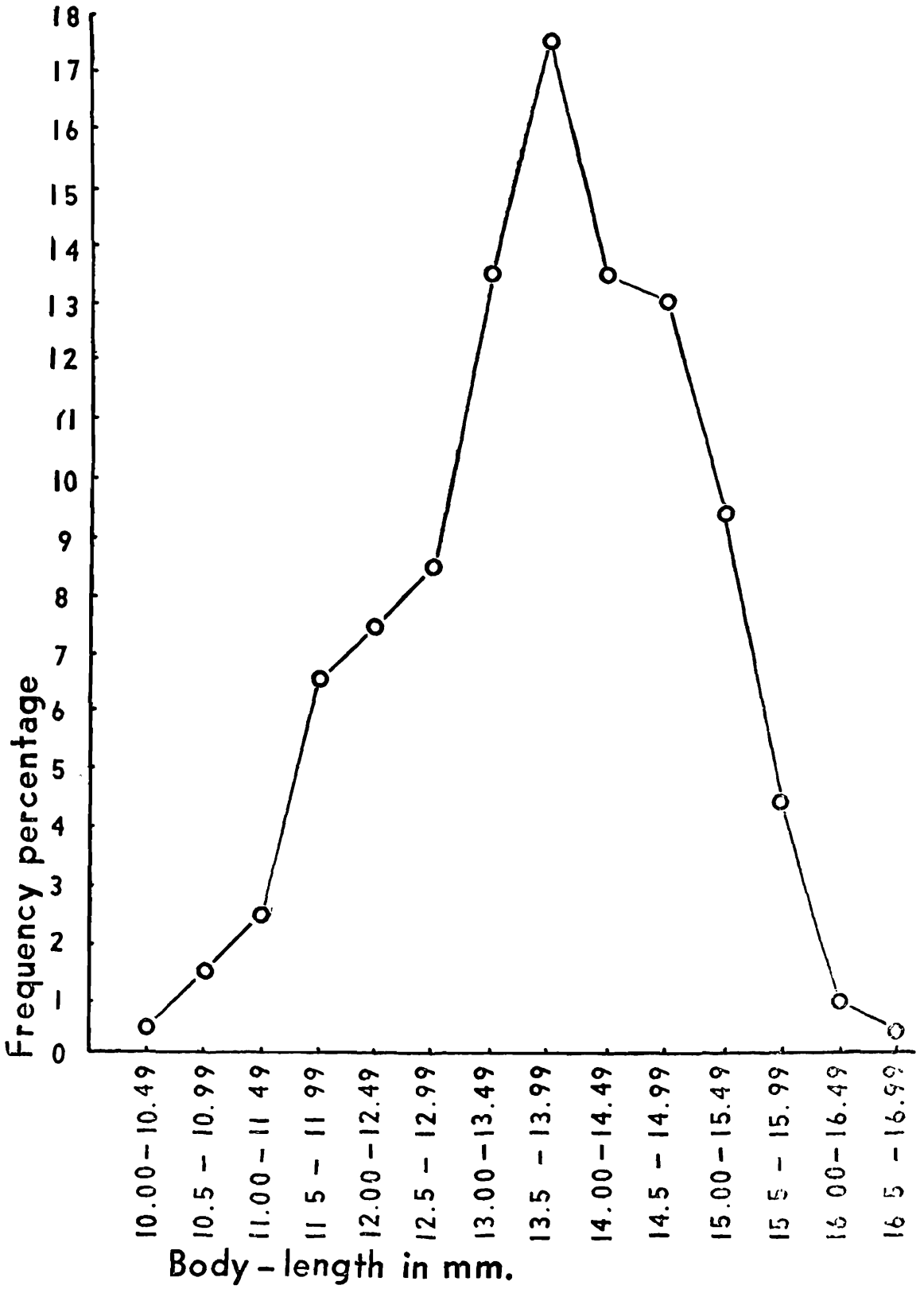
Size.—The soldiers, like those of *Archotermopsis wroughtoni* Desneux (Imms, 1919), show great variation in size. In 200 individuals



TEXT-FIG. 1.—*Anacanthotermes macrocephalus* (Desneux). Soldier caste. (*a*). Whole body in dorsal view. (*b*). Ditto, in ventral view. (*c*). Ditto, in lateral view

preserved in rectified spirit, the body-length (as measured between the foremost tip of the mandible and the last segment of the abdomen) ranged from 10·0 mm. to 16·7 mm. When this length-data was arranged into

0·5 mm. frequency classes, and plotted on a graph (Table 1 and Text-fig. 2) a unimodal curve was obtained which showed that only one type of soldier occurs.



TEXT-FIG. 2.—*Anacanthotermes macrocephalus* (Desneux.) Soldier caste.

Graph, showing the frequency percentage of distribution of body-length (foremost tip of mandibles to tip of abdomen) in 200 individuals preserved in rectified spirit. (Also *Vide* Table 1).

TABLE 1.—*Frequency distribution (arranged in 0·5 mm. classes) of the body-length (foremost tip of mandibles to the tip of abdomen) in 200 individuals of* Anacanthotermes macrocephalus *(Desneux), soldier caste.* (From specimens preserved in rectified spirit).

Class	Frequency	Per cent of total
10·00—10·49	1	0·5
10·5 —10·99	3	1·5
11·00—11·49	5	2·5
11·5 —11·99	13	6·5
12·00—12·49	15	7·5
12·5 —12·99	17	8·5
13·00—13·49	27	13·5
13·5 —13·99	35	17·5
14·00—14·49	27	13·5
14·5 —14·99	26	13·0
15·00—15·49	19	9·5
15·5 —15·99	9	4·5
16·00—16·49	2	1·0
16·5 —16·99	1	0·5

(b) *The head*

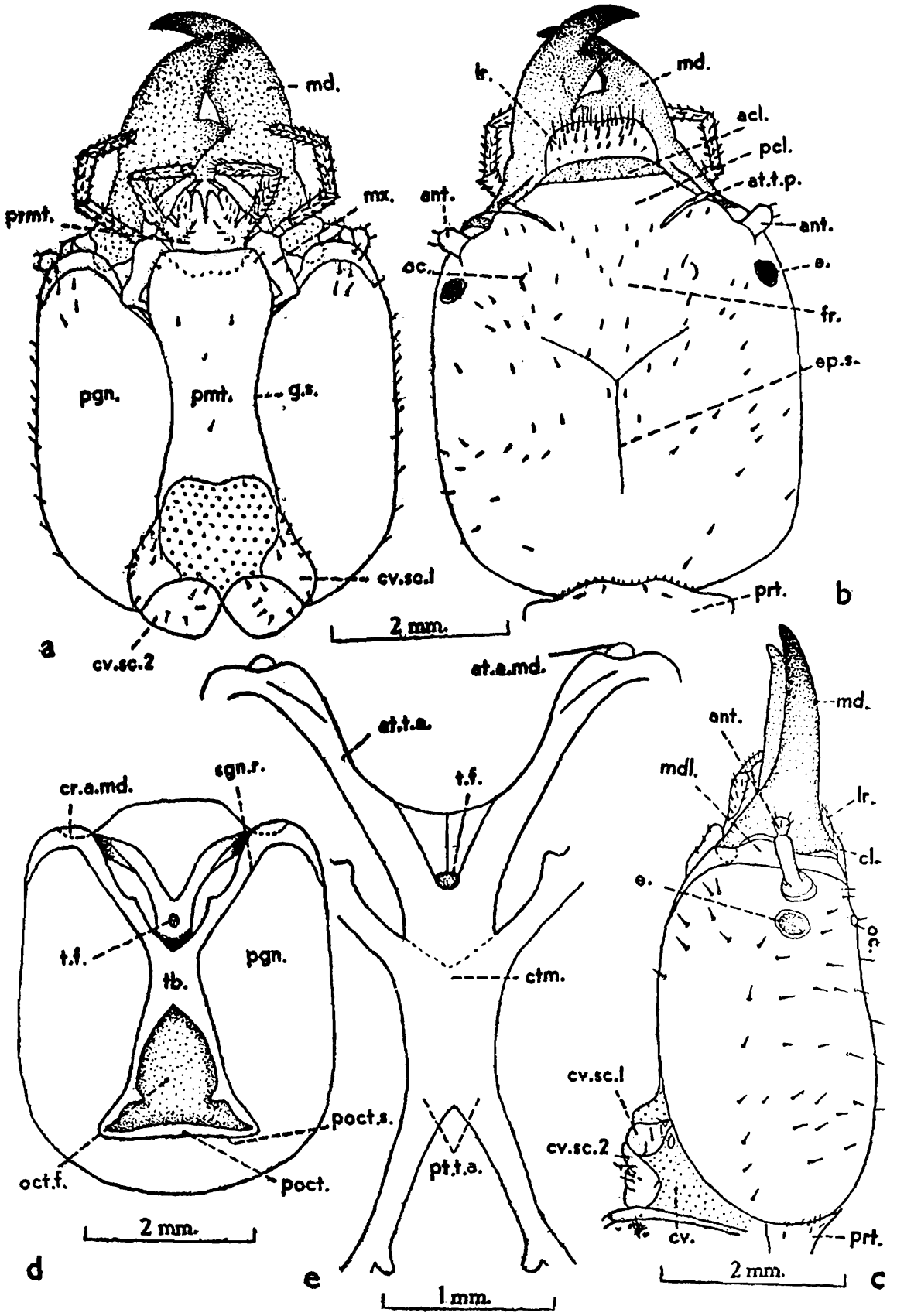
(Text-fig. 3)

The head is prognathous (*i.e.*, the mouth-parts are directed forwards), sub-squarish, bilaterally symmetrical (except for the mandibles), dorso-ventrally flattened and slightly longer than broad. The postero-lateral angles of the head-capsule are broadly rounded. At its hind margin the head is slightly covered by the pronotum. The head-capsule measures as follows :—

Length, from hind margin to lateral base of mandibles	4·21—4·66 mm
Length, from hind margin to tip of left mandible	6·44— 7·1 mm.
Maximum width of head ..	3·63— 4·1 mm.
Height of head ..	2·1—2·63 mm.

The facial area is directed upwards, and the mandibles, maxillae and labium forwards. The labrum overlies the mandibles as a free lobe above the oral cavity. There is a pair of dark coloured compound eyes, one on either side, and situated dorso-laterally immediately behind the antennal sockets. Lying along the imaginary line connecting the two compound eyes there are two small, transparent, subcircular areas which

appear to be rudimentary lateral ocelli, but their true nature is not yet clear. Lodged in the antennal sockets are a pair of long 28 to 31-jointed



TEXT-FIG. 3.—*Anacanthotermes macrocephalus* (Desneux). Soldier caste.

(*a*). Head in ventral view along with lateral cervical sclerites. (*b*). Head in dorsal view. (*c*). Head in lateral view along with the cervix. (*d*).Head-capsule (appendages removed) in ventral view, showing tentorium in ventral view. (e). Tentorium in dorsal view.

antennae. The fontanelle is absent. The occipital foramen is situated at the postero-ventral end of the head-capsule.

The mouth-parts are of the " mandibulate type " The mandibles and maxillae take their origin laterally, the labrum projects from the anterior margin of the cranium and the base of the labium lies transversely to the long axis of the head in front of the occipital foramen. Between the labrum above and the labium below lies, inside the oral cavity, the hypopharynx.

(i) *The head-capsule*

(Text-figs. 3 and 4)

The various regions of the head are indistinct, the sutures being ill-defined or absent (Text-fig. 3). Beginning from the posterior end, the vertex of the head is made up of two *epicranial plates* (*ep. pl.*) separated from each other by the stem of a fine Y-shaped *epicranial suture* (*ep. s.*). The two facial arms (transverse sutures of some authors), are directed outwards and forwards and indistinctly separate the epicranial plates from the fronto-clypeal region. In *Archotermopsis wroughtoni* Desneux, this suture is V-shaped, the stem being faintly visible in few soldiers (Imms, 1919), and in most termite soldiers (*vide* Light, 1934), it has been reported as imperfect, suppressed or absent. In each epicranial area there lies anteriorly the antenna and the compound eye of its side.

The fronto-clypeal region has no distinct epistomal suture delimiting the *frons* (*fr.*) from the *clypeus* (*cl.*). This region is bounded anteriorly by the base of the labrum. The clypeus is distinguishable into an anterior membranous *ante-clypeus* (*acl.*), and a posterior well chitinised *post-clypeus* (*pcl.*). There is no intra-clypeal suture. The ante-clypeus lies reflexed under the post-clypeus when labrum is in the retracted condition.

The epicranial plates on either side are continued laterally and ventrally into the *genae* (*gn.*) and the *postgenae* (*pgn.*), there being no sutures separating these sclerities. The postgenae are separated from the *post-mentum* (*pmt.*) by the longitudinal *gular* or *postmental sutures* (*g.s.*).

The *subgenal sutures* form a *subgenal ridge* (*sgn. r.*) which runs close to the anterior edge of the cranial wall. The ridge starts from the *posterior tentorial pits* (*pt. t. p.*), that is, in front of the gular sutures, runs forwards and outwards and finally arches upwards to a point just above the *anterior articulation of the mandibles* (*at. a. md.*). It is not continued into an epistomal suture dorsally. According to the terminology of Snodgrass (1935) the ventral portion of the ridge posterior to the mandibles is called hypostomal and the portion lying just lateral or above the mandibles, pleurostomal. It forms a narrow but distinct and highly chitinised rim which thus strengthens the cranial wall for the attachment of the gnathal appendages. The region of the subgenal ridge in which the mandibles articulate has also been termed by some authors as the *mandibularia* (*mdl.*) or the *trochantin of the mandible* (Fuller, 1915).

The occipital suture is absent. The *post-occipital suture* (*poct.s.*) closely surrounds the *occipital foramen* (*oct. f.*) posteriorly and laterally forming a narrow rim constituting the *occipital arch* (*poct.*).

The *ocular* (*o.s.*) and the *antennal sutures* (*ant. s.*) demarcate the ocular and antennal sclerites respectively.

The *labrum* (Text-figs. 3 and 4*a*, *lr.*) is a flat lobe nearly twice as broad as long (about 0·68-0·77 mm. × 1.02—1.2 mm.). Proximally it is attached with the clypeus along a well defined *clypeo-labral suture* (*lr. s.*), and is slightly overlapped by the former. This feature provides for its mobility in the vertical plane. Antero-medially its margin is slightly inflexed. The dorsal surface has numerous longish setae ; along the anterior margin are 10-12 setae which appear to be bilaterally arranged. On the otherwise smooth cuticular undersurface, short thick and pointed peg-ike denticles are seen to be arranged in two stripes, running from the clypeal plate to the apical border of the labrum midway between the imaginary median axis and the lateral border. These structures have been reported in the winged and worker castes of *Odontotermes obesus* (Rambur) but not in the soldier caste (Vishnoi, 1956). In the postero-lateral angles between the labrum and the clypeus, there lies a pair of oblique, obtuse-angled bar-shaped sclerites, the *tormae* (*tm.*), extending into the epi-pharyngeal surface of the clypeus and directed medially ; the right tormae is slightly bigger than the left. In *Archotermopsis wroughtoni* (Imms, 1919) a group of hairs on either side in a similar position are present, and are probably homologous with the structures described here.

The tentorium (Text-fig. 3).—The *tentorium* constitutes the endoskeleton of the head-capsule. It consists of two *anterior arms*, two *posterior arms* and a central plate, the *corporotentorium*. In *Archotermopsis wroughtoni* Desneux (Imms, 1919) and *Odontotermes obesus* (Rambur) (Kushwaha, 1956) also, the structure is similar.

The two *anterior arms* (*at. t. a.*) originate in the faintly elongated slit-like *anterior tentorial pits* (*at. t. p.*) immediately above the articulation of the *mandibles*. They are widely expanded anteriorly and are firmly attached to the head-capsule antero-laterally extending in a curvate manner to the rim of the antennal ridge. Each arm is twisted slightly and runs downwards, backwards and forwards to meet its counterpart from the other side and also the corporotentorium. On its way each anterior tentorial arm gives off a broad inwardly directed process which meets its fellow from the other side to form a medianly carinate plate, the *frontal plate* or the *antrior tentorial bridge*. This anterior bridge between itself and the *corporotentorium* encloses a distinct aperture, the *tentorial foramen* (*t.f.*). Through this aperture the circumoesophageal connectives of the nerve cord pass towards the brain.

The *posterior tentorial arms* (*pt. t.a.*) take their origin in the lengthened *postmental sutures* (*g.s.*) and the *posterior tentorial pits* (*pt. t. p.*) are also elongated. The arms are plate-like and arched and meet medially forming a *tentorial bridge* (*t.b.*) lying above the postmentum (*vide infra*) ; below it pass the salivary ducts and the ventral nerve connectives from the thorax.

The *corporotentorium* (*ctm.*) in insects is formed by the fusion of the tentorial arms at their inner ends. In termite soldiers, consequential to the prognathous condition of head, it has become a greatly elongated median plate extending between the tentorial foramen and the occipital foramen. Topographically it may be said to embrace two regions—one, obliquely hanging in the cranial cavity behind the tentorial foramen

and demarcated by a flexure from the other, the tentorial bridge, lying above the postmental plate of the labium (*vide supra, t.b.*). Just at their junction the corporotentorium gives off two lateral arms, one on either side, which become continuous with the submarginal subgenal ridge of the cranial wall to further strengthen the articular points of the maxillae. Similarly, the tentorial bridge is continued into a pair of backwardly directed arms which become confluent with the lateral margin of the postoccipital arch.

The hypopharynx (Text-fig. 5*a*, *hyp.*)—The hypopharynx is a large, conical median lobe situated between the labium and the clypeus separating the dorsal buccal or oral cavity from a small ventral pocket, the *salivarium* (*slv.*) at the base of which the salivary duct opens. In the normal position it lies in close approximation with the ligula of the prementum. Its ventral adoral wall is reflected over the labium at the base of the prementum enclosing a small pocket, the *salivarium* (*slv.*). On the dorsal surface proximally there is a median depression, which, with the opposing epipharyngeal surface of the clypeus, forms a pocket, the *cibarium* (*cb.*).

In the lateral wall of the hypopharynx, there are a pair of *lateral sclerites* (*l.ss.*) the posterior ends of which reach the salivarium. They provide the surface for the attachment of the retractor muscles of the hypopharynx. Proximally the two sides are flanked by a group of sclerites constituting the *suspensoria* of the hypopharynx. Each suspensorium consists of a pair of broad chitinised plates, the *suspensorial sclerites* (*ss.*). The end of the dorsal arm of each suspensorial sclerite lies close to the corresponding end of its fellow from the other side. Posterior to the broad middle portion of these sclerites are two sclerities, a dorsal and a ventral. The dorsal sclerite is L-shaped and is called the *stomodaeal branch* (*ss. br.* 1) ; it leads to the lateral wall of the stomodaeum. The ventral or the *mandibular branch* (*ss. br.* 2) extends laterally to the base of the adductor apodeme of the mandible, and proximally it is loosely attached to the stomodaeal branch. The oral surface of the hypopharynx is beset with numerous small, fine hairs.

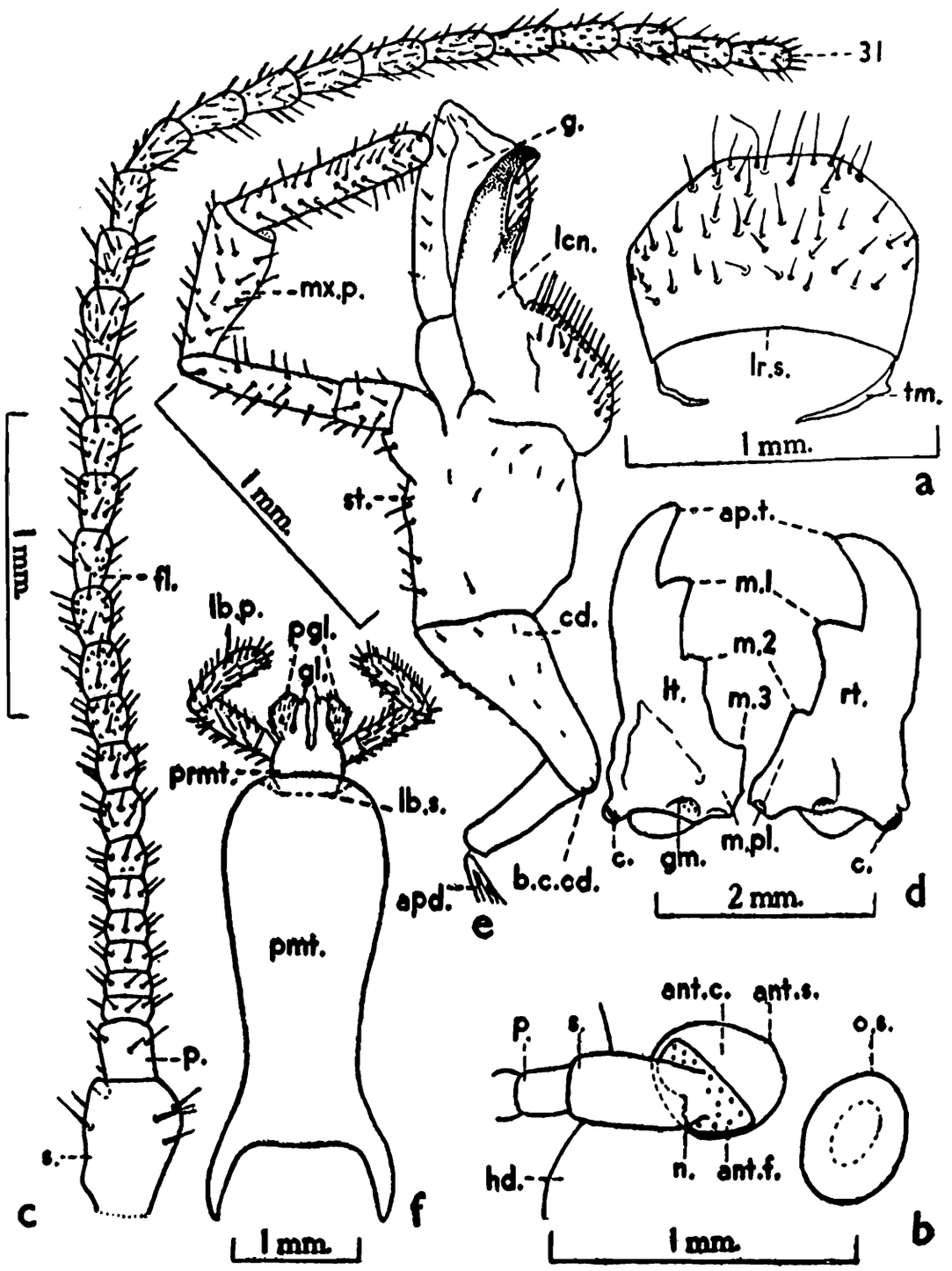
The compound eyes (Text-fig. 4*b*).—A pair of dark pigmented, oval *compound eyes*, one on either side, is placed laterally behind the antenna. Each eye measures about $0{\cdot}39 \times 0{\cdot}31$ mm. in diameter and lies obliquely to the long axis of the head. The bulging facets are roughly hexagonal and number about 127. The margin of the eye is surrounded by an apodemal inflexion of the cranial wall forming an *ocular sclerite*. (*o.s.*).

(ii) *Head-appendages.*

The antennae (Text-fig. 4*c*, *ant.*).—Each *antenna* is moniliform, about 5·9 mm. long and has 28-31 segments. It is lodged in a small membranous area, the *antennal socket* or *antennal foveolae* (*ant. f.*), the rim of which is strengthened by an internal submarginal ridge enclosing the *antennal sclerite.* The antennal socket is overhung by a projection called the *antennal carinae* (*ant. c.*). From the rim of the antennal socket arises, in the ventro-lateral side, a small pivot-like process the *antennifer* (*n.*), on which the antenna can move in all directions.

The antenna can be divided into two parts, namely, (i) *the body* consisting of a basal segment or *scape* (*s.*) and a second segment or

pedicel (*p.*), and (ii) the *flagellum* (*fl.*) made up of remaining 26-29 segments. The scape is the largest segment, being slightly more than double the pedicel in length. The third and the fourth segments together are nearly equal in length to the second. The flagellar segments increase



TEXT-FIG. 4.—*Anacanthotermes macrocephalus* (Desneux). Soldier caste.

(*a*). Labrum in dorsal view.(*b*). A portion of cranium, showing ocular and antennal sclerites in dorsal view. (*c*). Left antenna, showing 31 segments. (*d*). Left and right mandibles in dorsal view. (*e*). Left maxilla. (*f*). Labium in ventral view.

in length gradually, the first being the smallest and the last nearly thrice its size. The number and distribution of setae on various segments is not uniform, there being 3-5 setae on the scape, 6-8 arranged in a whorl

on the third to seventh or eighth segments. Beyond the eighth segment the number of whorls in each segment gradually increases with a corresponding increase in the number of setae also.

TABLE 2.—*Variations in the number of antennal segments of the right and left antennae of* 82 *individuals of* Anacanthotermes macrocephalus *(Desneux), Sodier caste.*

Item	Number of individuals	Number of segments	
		Right	Left
(a) With one segment more in the right antenna.	6	30	29
	12	29	28
	1	28	27
	1	26	25
	Total 20		
	Per cent 24·4		
(*b*) With one segment more in the left antenna.	3	30	31
	4	29	30
	9	28	29
	4	27	28
	1	26	27
	1	25	26
	Total 22		
	Per cent 26·8		
(*c*) With equal number of segments in both antennae.	9	31	31
	5	30	30
	17	29	29
	6	28	28
	2	27	27
	1	26	26
	Total 40		
	Per cent 48·8		

TABLE 3.—*Frequency distribution of the number of antennal segments in 82 individuals of* Anacanthotermes macrocephalus (*Desneux*), *Soldier caste.*

Number of antennal segments	Right antenna		Left antenna	
	Number of individuals	Approx. per cent.	Number of individuals	Approx. per cent.
31	9	11·0	12	14·6
30	14	17·0	9	11·0
29	33	40·3	32	39·0
28	16	19·5	22	26·8
27	6	7·3	4	4·9
26	3	3·7	2	2·4
25	1	1·2	1	1·2
Total	82	100	82	100

The number of segments in the two *i.e.*, the right and left, antennae of an individual is not always equal. In a random collection of 82 soldiers, it was found (Table 2) that 51·2 per cent individuals have one segment in excess in either of the antenna, whereas 48·8 per cent cases had equal numbers in both. The most frequent number, occurring in about 39 per cent cases (Table 3), is 29.

The mandibles (Text-fig. 4*d*).—The two mandibles are slightly asymmetrical, the left one being somewhat larger than the right. Both the mandibles are strongly chitinised and incurved structures, with pointed apices and triangular bases. In the normal position of rest, the left mandible, in all cases examined so far, crosses over the right. Each mandible articulates with the cranium at two specialised points, the *ginglymus* (*gm.*) and the *condyle* (*c.*). The ginglymus is dorsally placed concavity receiving a condyle (the anterior articulation of the mandible) from the mandibular segment of the cranium (also called mandibularia). On the ventro-lateral side a condyle fits into a cup-shaped cavity in the cranial wall—this constitutes the *cranial articulation of the mandible* (*cr. a. md.*).

The inner surface of each mandible is differentiated into a distal part, the toothed *incisor lobe* (*i.pl.*), and a proximal part, the *molar plate* (*m.pl.*). The first or the *apical tooth* (*ap. t.*) of the incisor lobe forms the incurved apex of the mandible. The two following teeth are the first and the second *marginal teeth* (*m.*1 ; *m.*2.). The left mandibleis asymmetrical in the possession of an additional well developed tooth (*m.*3) just in front of the molar plate, as in *Archotermopsis wroughtoni* Desneux

(Imms, 1919). The surface of the molar plate of the right mandible is strongly convex and prominently ridged and grooved and that of the left jaw somewhat concave, the two surfaces forming a pestle-and-mortar arrangement. Two apodemes are attached with the base of each mandible, a small one at the outer angle and a large well-developed one at the inner angle.

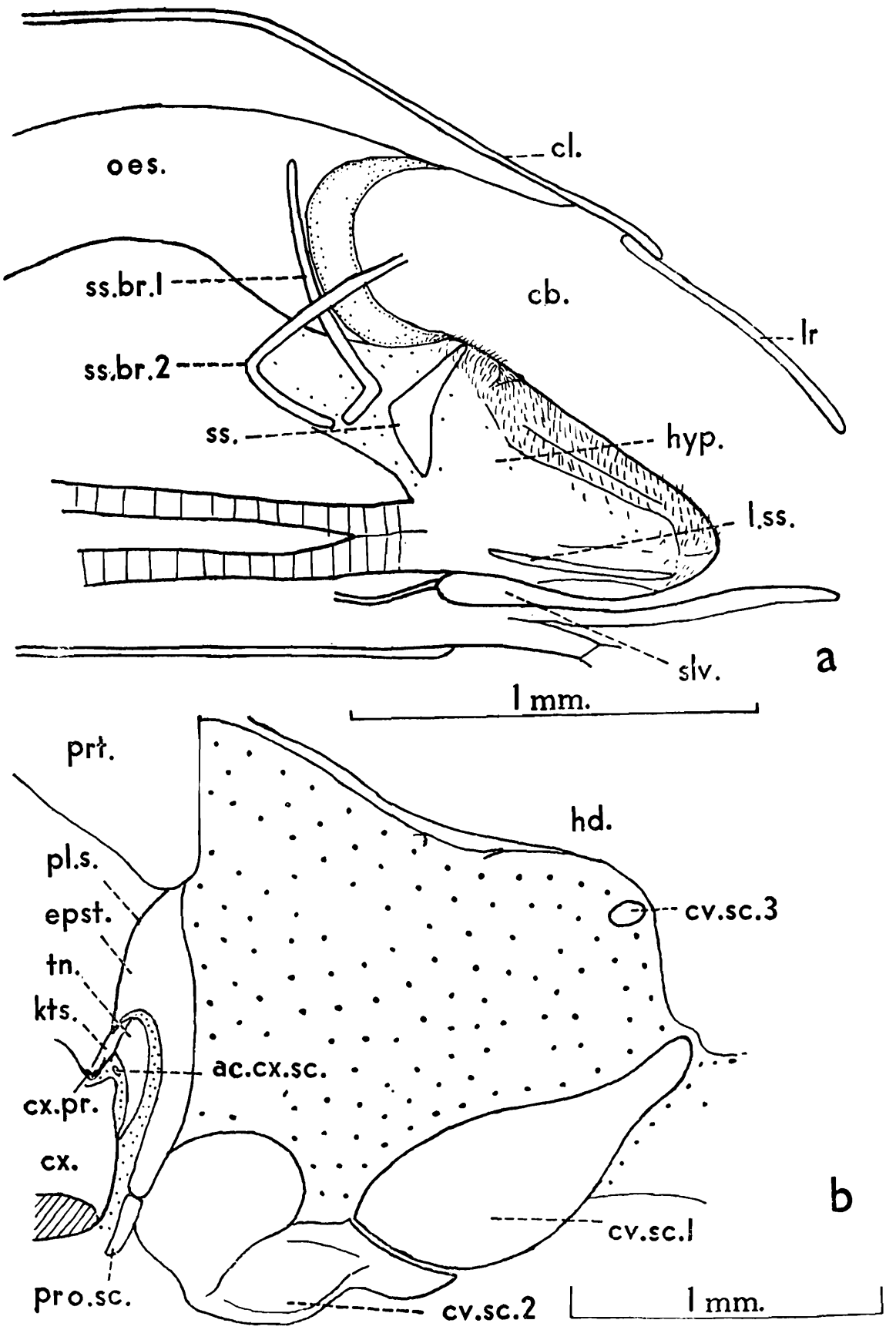
The first maxilla (Text-fig. 4*e*).—The maxillary base is elongate and two-segmented—the proximal segment is the *cardo* (*cd.*), and the distal the *stipes* (*st.*). The cardo is bent outwardly in an obtuse angle. The angle of the bend has a condylar articulation called the *basal condyle of cardo* (*b.c.cd.*), which articulates with the socket in the hypostomal region of the subgenal ridge of the head-capsule. Proximally, the cardo is attached to an apodeme, which at its anterior end is broadly attached to the stipes. Along the inner margin of stipes some muscles are inserted in a groove, the *sutural groove of stipes* (*su.g.*). At its distal end the stipes bears two lobes—an outer *galea* (*g.*) and a mesal *lacinia* (*lcn.*). Laterally it bears 5-segmented *maxillary palp* (*mx.p.*).

The galea is a soft, broad, leaf-like, 2-jointed lobe, which is thickly coated with setae along its inner margin. Dorsally it is excavated to partly receive the lacinia when at rest. The lacinia is highly sclerotised and has a broad proximal portion which distally tapers to an incurved incisor-like tooth. A similar tooth also arises from the middle of the inner margin. The inner margin of the plate-like main portion is fringed with longish setae together with other smaller and sparsely distributed ones. The palpus, which is beset with numerous large and small setae, is 5-jointed, the first segment being the smallest (0·16mm. long) ; the following segments are about 0·27, 0·55, 0·7 and 0 8 mm. long. A characteristic elbow flexure exists between the third and the fourth segments. There is no palpifer.

The labium (Text-fig. 4*f*).—The labium consists of two distinct segments, the distal *prementum* and the more sclerotised plate-like *postmentum* (gula of Snodgrass, 1935), hinged together along the *labial suture* (*lb.s.*). The *prementum* (*prmt.*) is anteriorly cleft in the middle. At its distal end it bears two pairs of terminal lobes, *viz.*, an outer *paraglossa* (*pgl.*) and an inner *glossa* (*gl.*), and a palr of *labial palpi* (*lb. p.*). The paraglossa and the glossa together constitute the *ligula*. The labial palpi, which bear numerous setae, are smaller than those of the maxilla and are 3-segmented, the segments from the basal onwards measuring about 0·17, 0·58 and 0·76 mm. in length. The second and third segments of each palpus are inwardly elbowed at the joint. There is no palpiger.

The *postmentum* (*pmt.*) is a large, median, rectangular sclerotised plate with waist-like concavities in the middle. It is broadly attached to the ventral wall of the head, and its lateral margin lies parallel to the posterior tentorial arms along postmental sutures (Text-fig. 3, *g.s.*). Posteriorly, the basal angles are drawn into tapering outgrowths which get wedged in between the postgenae and neck membrane and articulate with the tapering anterior end of the *first cervical sclerite* (*cv.sc.1*). Distally, a small part of the postmentum is membranous and lies folded over it in such a manner that it is not seen from the ventral side, and the sclerotised part projects forwards to give support to the movable

permentum. The prementum is attached to this membranous portion along a well defined *labial suture* (*lb.s.*).



TEXT-FIG. 5.—*Anacanthotermes macrocephalus* (Desneux). Soldier caste.

(*a*) Sagittal longitudinal section of anterior region of head to show the position of hypopharynx and its attachments (semi-diagrammatic). (*b*). Lateral view of cervix and a portion of prothorax.

(c) *The neck*

(Text-fig. 5*b*, *cv.*)

The *cervix* or neck is a short, narrow, flexible membraneous region of the body lying between the head and the thorax. Dorsally it is concealed by the overlapping pronotum. On its ventro-lateral sides are seen two pairs, one on either side, of well developed *cervical sclerites* (*cv.sc.*1 and 2), hinged on each other. Just behind the head-capsule and dorsal to the anterior cervical sclerite there is, on either side, a small circular chitinised plate—the *dorsal sclerite* (*cv. sc. 3*). Ordinarily it is concealed from view by the folds of the neck membrane. There are no ventral sclerites. The dorsal sclerite is feebly developed in *Archotermopsis wroughtoni* (Imms, 1919).

The *anterior cervical sclerite* (*cv.sc.*1) is flask-shaped and its anterior end tapers gradually to form a fulcral knob, which articulates with the tip of the drawn out lateral process of the postmentum as also on the side of the occipital foramen. This arrangement permits the head to move in both the vertical and the horizontal directions. The *posterior cervical sclerite* (*cv.sc.*2) has a ribbed surface due to the presence of folds. Besides being broadly hinged on the anterior cervical sclerite of its side, it is similarly hinged on the episternum of the prothorax. The two posterior sclerites of each side meet in the mid-ventral line.

(d) *The thorax*

(Text-fig. 6)

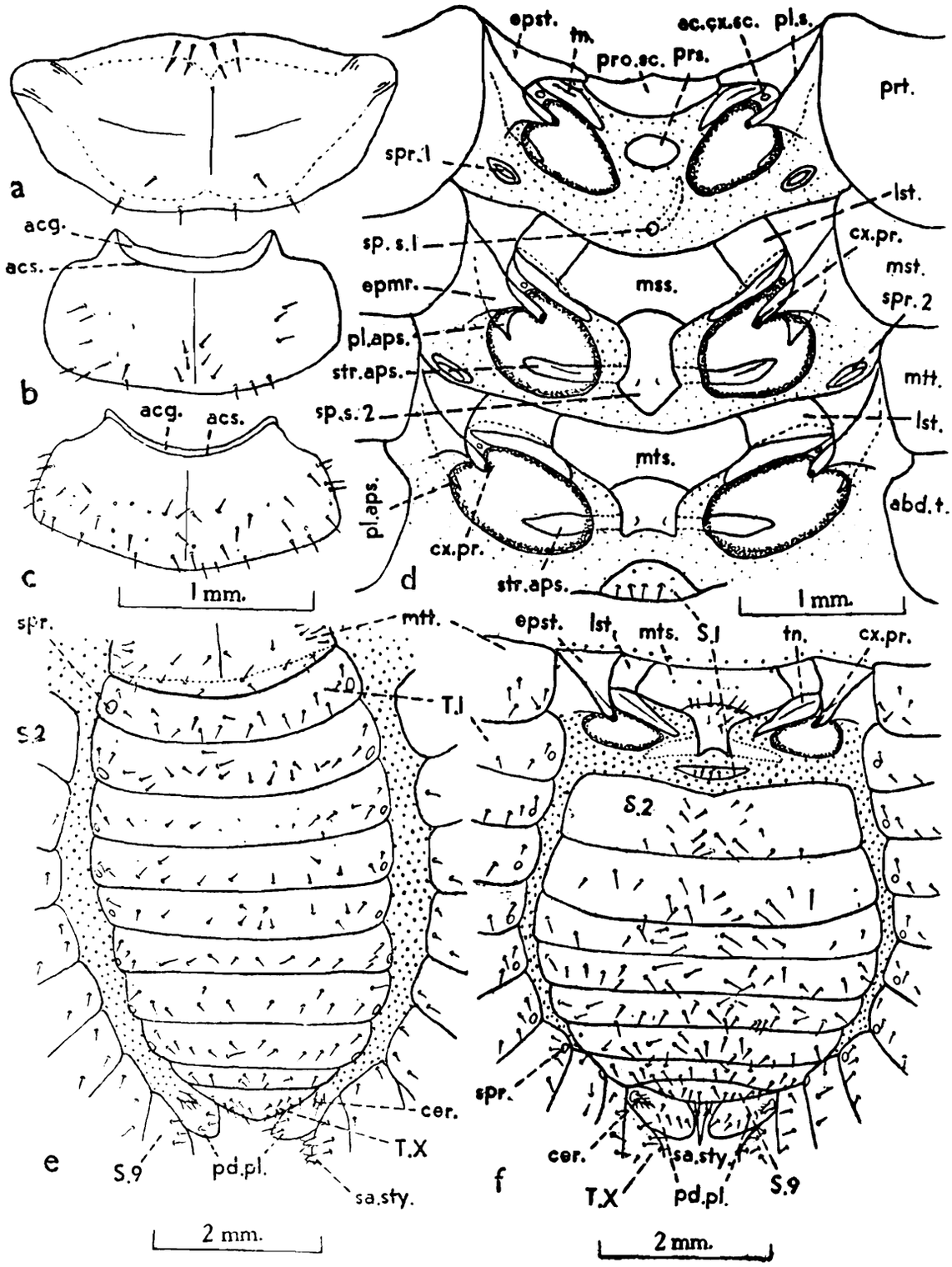
The thorax is made up of three distinct segments, *viz.*, the pro- meso- and metathorax. Each segment consists of three sclerotised plates, *viz.*, a dorsal tergal plate or *notum*, a lateral plate or *pleuron* and a ventral plate or *sternite*.

The tergites.—The prothorax is highly modified and differs markedly from the meso- and the metathorax. The *pronotum* (*prt.*) is a large saddle-shaped plate which is broader than long and measures about 3·1 mm. at its broadest and 1·6 mm. medially. Its anterior portion is elevated and the antero-lateral ends drawn downwards and outwards, ending in a spout. Thus a transverse groove appears to run from either corner to nearly the middle, dividing the pronotum into an anterior lobe and a posterior lobe. The anterior and posterior margins are faintly notched medially. The whole of the marginal area is infolded downwards to a small extent, thus reduplicating the whole margin. This feature is greatly marked along the anterior margin which becomes continuous with the neck.

The dorsal surface of the pronotum is marked by an incomplete sagittal suture which does not extend from end to end. The transverse groove referred to above shows an apodemal inflexion ventrally. These internal ridges are meant for muscle attachment. On the dorsal surface, there are prominent bristles. Along the infolded anterior margin, the bristles are smaller and more numerous.

The *meso-*(*mst.*) and *metanota* (*mtt.*) are subequal and more or less similar plates, which are broader than long. In both cases, the notum is crossed anteriorly by a transverse groove, the *antecostal suture* (*acs.*) dividing it into a small, flat, anterior *precostal acrotergite* (*acg.*) and

a large *postcostal* tergite. The outer margins of the postcostal tergites are stretched out considerably on either side immediately behind the acrotergite and run more or less parallel and ultimately turn round so that their hinder margins meet each other. The external intersegmental



TEXT-FIG. 6.—*Anacanthotermes macrocephalus* (Desneux). Soldier caste.

(*a*). Pronotum in dorsal view. (*b*). Mesonotum in dorsal view. (*c*). Metanotum in dorsal view. (*d*). Ventral and lateral sclerites of thorax with the tergites cut medially and spread on either side. (*e*). Tergites of the abdomen, with sternites cut medially and spread on either side. (*f*). Metathoracic and abdominal sternites with the tergites cut medially and spread on either side.

groove, forming the antecostal suture externally, forms internally a submarginal ridge, the *antecosta.*

A faint sagittal suture and corresponding to it an internal ridge, meant for attachment of the muscles, run from the antecostal ridge almost back to the hinder margin, but are not forked as is the case in some winged termites (Fuller, 1924).

The metanotum differs from the mesonotum in having a relatively smaller precostal acrotergite. The hind and lateral margins of both the tergites are infolded or reduplicated.

The distribution of setae on both the meso- and metanota is sparse and is restricted to the posterior region of the tergal plates. The number of setae on the metanotum is larger than on the mesonotum.

The pleurites.—The meso- and metathoracic pleura are similar to each other but differ slightly from that of the prothorax. The pleural plate surrounds the base of *coxa* (*cx.*) anteriorly and dorsally and is divided by a *pleural suture* running from the coxal articulation in the antero-dorsal axis into two subtriangular regions, *viz.*, presutural *episternum* (Text-fig. 6*d*, *epst.*) and a postsutural *epimeron* (*epmr.*). Internally the pleural suture forms a massive apodemal implex, the *pleural ridge* (entopleurum of Fuller, 1924), which gradually diminishes in size towards the dorsum (tergite) where the pleuron ends in a thickened point which articulates with the side of the tergum of its segment. The pleural ridge is broadest ventrally where it is produced into an *apophysis* (*pl.aps.*) which is connected with the sternal apophysis (*str. aps.*) of its side by means of muscles.

The epimeron is a large, slightly convex subtriangular sclerite. Its posterior border is ill-defined, being weakly chitinised. Ventrally it narrows to a slip lying against the coxal condyle. The *episternum* is a triangular sclerite lying in front of the pleural suture. Towards the dorsum it becomes narrow. Ventrally it articulates with the *laterosternite* and in the region of the coxal condyle with the *trochantin.*

In between the base of the coxa and the episternum lies an elongated somewhat triangular sclerite, the *trochantin* (*tn.*). Its dorsal edge is attached by folds of membrane to the outer margin of the coxal condylar region of the episternum ; its sternal apex articulates with the margin of the coxa. It is also connected with the laterosternite and the sternum by membraneous folds. Along its long axis the trochantin shows an inflexion which divides it into two somewhat triangular portions.

The *accessory coxal sclerite* (Text-fig. 5*b*, *ac. cx. sc.*) is a small sclerite in the form of a cuticular apodeme lying angaist the margin of the coxa close to the coxal condyle. Internally, a muscle is attached to it. The *laterosternite* (*lst.*) is a rectangular sclerite lying between the sternum and the episternum with which it fuses to form the precoxal bridge or the precoxale. Its borders are demarcated by submarginal sutures. The laterosternites are present only in the meso- and metathoracic segments and absent in the prothorax.

The *epimeron* does not extend ventrally to form a postcoxale, which is found in certain other insects.

The pleuron of the prothorax (Text-fig. 5*b*) differs from the pleura of the meso- and metathorax. In addition to the epimeron and the epi-

sternum mentioned above, a *katepisternum* (*kts.*) is present as a continued arm of the coxal condyle (*cf.* Fuller, 1914) articulating with a reduced and slender trochantin. The episternum here is a highly chitinised and rib-like structure. Above, at the point of its fusion with the pronotum, it is flat and faces forwards ; below, it hangs down as a slip and is fused with the *prosclerite* (*vide infra*) to form a complete loop with its counterpart of the opposite side. The epimeron appears to be attached to the base of the episternum below the pronotum, and is directed backwards. In this segment the pleural plates surround the coxa anteriorly, dorsally and to some extent posteriorly to form a massive pillar-like structure.

The sternites.—The sternum in insects is a complex and variable structure. It consists of segmental and intersegmental sclerites either free or fused. However, basically the intersegmental sclerites between the pro- and mesosterna, and meso- and metasterna are either free or, when united, they do so with the preceding segmental sterna. The primary intersegmental sclerite behind the metasternum is generally lost or is united with the abdominal sternum behind. Here the sterna of the three segments are weakly chitinised and differ from each other not only in chitinisation but also in structure and relative size.

(a) *The prosternum* : The segmental sternum (eusternum of Snodgrass, 1935) of the prothorax reported wanting in most termite soldiers, is present here as a small, very faintly chitinised, weakly pigmented, subcircular plate situated between the coxae of the first pair of legs. It bears a number of microscopic setae.

The two episterna, which appear to meet each other (*vide supra*) to form the rigid collar band, show a demarcating line between them and a median keeled sclerite, which appears to have been formed by the union of two sclerites in the median line, called the *prosclerites* (*pro.sc.*). In other termites the episterna of either side closely approximate with each other but do not fuse. In alates of some termites, Fuller (1924) has reported the presence of two sclerites lying behind the episterna and regarded them as the laterosternites of the prothorax. It is likely that in the present species these sclerites have fused with each other and with the episterna on either side to complete the arched loop of the collar band.

The first intersegmental sternite bearing internally a forwardly directed apophysis, called *spinasternum* by Snodgrass (1935), lies freely embedded in the intersegmental membrane in front of the mesosternum.

(b) *The mesosternum* : The mesosternum is a composite sclerite and is the largest of the three thoracic sterna. It is T-shaped, the top part of which is flanked on either side with the *laterosternites* (*lst.*), which, in their turn, meet the episterna of their side to form the precoxale. The stem portion of the plate lies wedged in between the coxae of the second pair of legs. It is strongly chitinised and shows a prominent transverse flexure at its base ; the tip ends in a diamond-shaped plate, bearing internally a Y-shaped *sternal apophysis* (*str. aps.*), called furca, which runs outwards and upwards towards the ends of the pleural apophysis of the pleural ridge. This portion of the sternum is referred to by Snodgrass (1935) as *'furcasternellum'* The second spinasternum is fused with the 'furcasternellum' to form the diamond-shaped plate referredt o above.

(c) *The metasternum :* Like the mesosternum, the *metasternum* (*mtt.*) is a T-shaped plate but differs in being less chitinised, in showing a stronger flexure at the base of the 'furcasternellum' and in the absence of the third spinasternum. The furcasternellum ends broadly.

There are two pairs of *thoracic spiracles* (*spr.* 1 & 2) lying posterolaterally in the pro- and mesothoracic pleura. In embryonic stages of all insects except Diplura these spiracles are formed in the meso- and metathoracic pleura (Snodgrass, 1935) and thus, here in the adult soldier their position indicates migration anteriorward from the primitive position.

(e) *The legs*

(Text-figs. 7 and 8)

The three pairs of legs, a pair to each of the three thoracic segments, have all the usual components of insect legs, from base onward, *viz.*, a *coxa*, a *trochanter*, a *tibia*, a *tarsus* and a *pretarsus*. Each leg bears prominent setae which are more numerous on the tibia than elsewhere. The first and second pair of legs are subequal ; the third is the largest.

The basal articulation of the legs.—The basal segment or *coxa* (*cx.*) is attached proximally to the body by an articular membrane surrounding it on all sides except where it has an outer articulation with the *coxal process* (Text-fig. 6*d*, *cx.p.*) of the pleuron of its segment ; anteroventrally it further articulates with the *trochantin* (*tn.*). There is no inner sternal articulation.

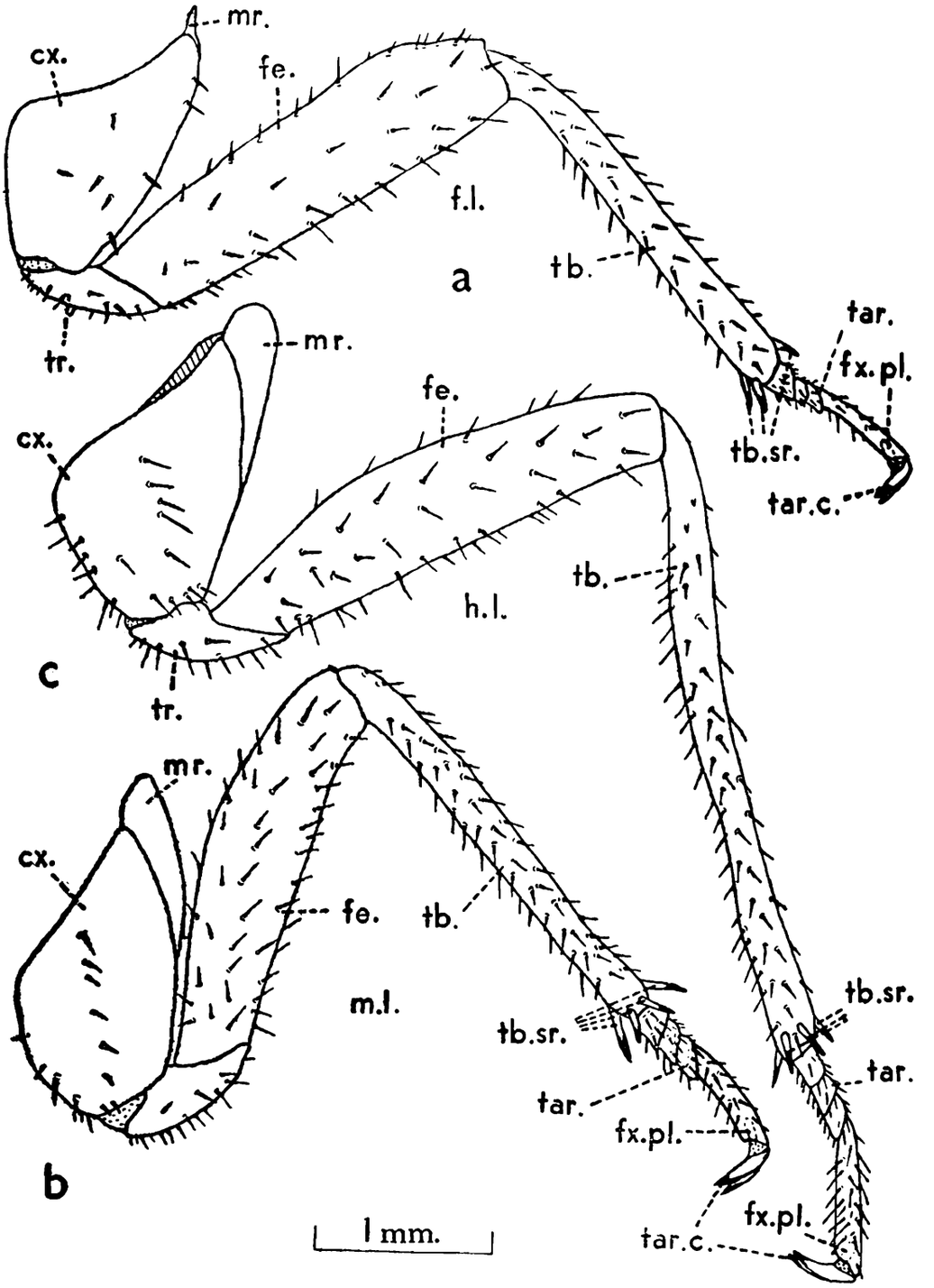
The coxa.—The coxa is the functional base of the leg. The coxae on all the legs are thick, truncated, conical and nearly subequal in length, but coxa of the third leg is the thickest of all (Text-fig. 8). The base of each coxa is girdled by a submarginal *basicostal suture* and the internal ridge so formed is called *basicosta* ; the latter strengthens the base of the coxa and separates a marginal flange, the *basicoxite*. The basicosta is enlarged on the outer wall and mesally becomes weak and confluent with the coxal margin. Opposite to the coxal process of the pleuron, there is a mesal inflexion of the basicosta, bearing a small concavity for the articulation with the former. The coxal inflexion divides the outer basicoxite into a small anterior or prearticular and a large posterior or postarticular part, the *meron* (*mr.*), corresponding to the divisions of the pleuron ; the two parts appear as marginal lobes. The meron of the prothoracic leg is the smallest and that of the metathoracic leg, the largest. On account of the largeness of the meron the coxa appears to be divided into an anterior piece, the '*coxa genuina*' (*cx.g.*), and the posterior, meron. The coxal suture is absent in the three coxae. Distally the coxa articulates with the *trochanter* (*tr.*).

The trochanter.—This is a very small segment lying between the coxa and the femur. Proximally it is movably hinged to the coxa. Distally it is rigidly fixed to the femur.

The femur.—This is the third and the stoutest segment of the leg. It is cylindrical and slightly narrows towards the ends.

The tibia.—This is a slender elongated segment slightly longer than the femur. At the proximal end it articulates with the femur. Distally it bears the *tibial spurs* (*tb. sr.*), 3 being on the first and 4 each on the second and third pair of legs. In *Archotermopsis wroughtoni* Desneux

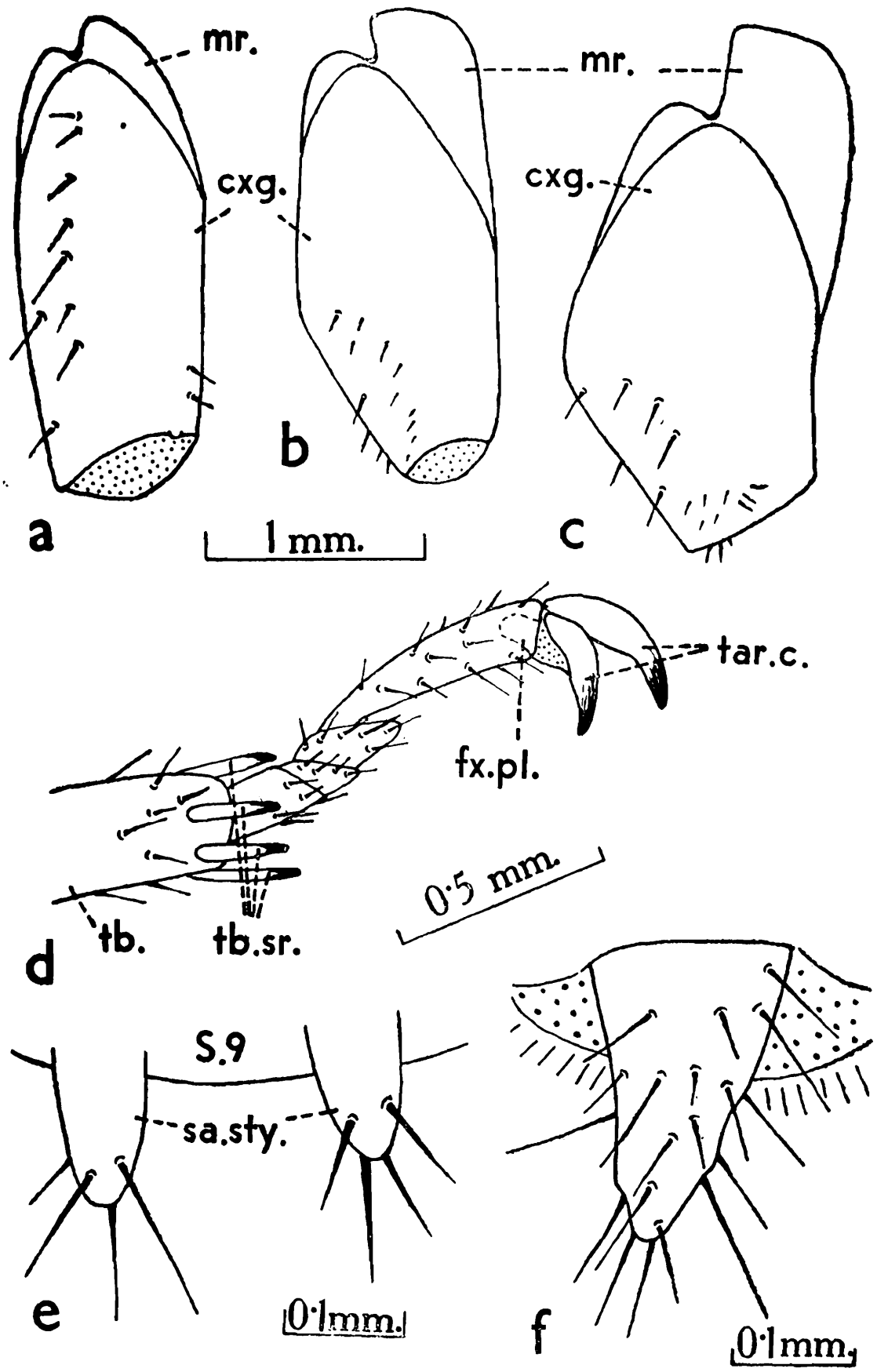
(Imms, 1919) the three tibiae carry a variable number of spines along the external and internal borders ; the number of tibial spurs or apical spines also is variable in the three legs—" Those of the fore-legs are armed with from three to five prominent spines, disposed in a longitudinal



TEXT-FIG. 7.—*Anacanthotermes macrocephalus* (Desneux). Soldier caste.

(*a*). Fore-leg in ventral view. (*b*). Left middle-leg in ventral view. (*c*). Left hind-leg in ventral view.

row along its external border. There are, furthermore, three or four spines situated around the distal extremity of the tibia. In the middle pair of legs the tibiae carry a variable number of 1-4 spines along the external border, and 4-6 spines along the inner border ; there are also



TEXT-FIG. 8.—*Anacanthotermes macrocephalus* (Desneux). Soldier caste.

(*a*). Coxa of the left fore-leg in outer view. (*b*). Coxa of the left middle-leg in outer view. (*c*). Coxa of the left hind-leg in outer view. (*d*). Tarsus and pretarsus. (*e*). Subanal styles. (*f*). Cercus.

two or three spines at their distal extremity. The hind legs, as a rule, bear no spines along the outer border, but there are usually 4-6 present along their inner margin and two apical spines. A feature of these spines is their extreme variability, even the legs of the same pair often differ in respect to the number of spines they carry." Such lateral tibial spines are wanting in *Anacanthotermes macrocephalus*.

The tarsi.—All the three legs have 4-jointed *tarsi* (*tar.*) which are movably hinged upon each other. The first or basal segment, the *basitarsus*, is larger than the second and the third, and is subcylindrical. The fourth segment or *distitarsus* is greatly elongated. At the distal end it is produced medio-dorsally into a very small process, the *unguifer*, which carries apically two claws or *ungues* (*tar. c.*), one on either side.

The pretarsus.—It is the terminal part of the leg, and consists of a membraneous base supporting two claws articulating with the unguifer of the distitarsus. There is no arolium or empodium. At the base there is a small sclerite, the *flexor plate* (*fx. pl.*), (the unguitractor of Snodgrass), which lies retracted into the distitarsus.

(f) *The abdomen*

(Text-fig. 6*e*, *f*)

The abdomen shows the typical segmentation into ten simple sclerites, each sclerite being composed as usual of a dorsal or tergal and a ventral or sternal plate, the two plates being connected laterally by the membranous pleuron. Posteriorly the margin of each tergum and sternum overlaps the succeeding sclerite with which it is connected by means of an articular membrane. The anterior part of the abdomen comprising the first four segments is broad ; behind the fourth sclerite it becomes narrower, ultimately ending in a semicircular terminal sclerite.

The tergites.—The first nine tergites are broad and more or less rectangular plates with infolded lateral margins, while the tenth is subtriangular. The distal tip of the abdomen is slightly curved downwards. The fourth tergite is the largest. The first eight tergites have a pair of spiracles situated on the incurved postero-lateral margins.

The sternites.—There are ten abdominal sternites corresponding to the ten abdominal tergites ; the sternum of the first segment is rudimentary and the remaining are well developed. The fourth sternite is the broadest. The sternites of the second and third segments show a strong ventral keel-shaped flexure. The tenth sternite forms a pair of *podical plates* (*pd. pl.*).

A pair of small, setose, unsegmented *subanal styles* (Text-fig. 8, *sa. sty.*) are situated on the ninth sternum slightly in front of its posterior margin—one on either side of mid-ventral line.

The paired *cerci* (Text-fig. 8, *cer.*), one on either side, are short, unsegmented, and setose structures arising laterally from the pleural region of the tenth abdominal segment adjacent to the base of the podical plate. In *Archotermopsis wroughtoni* Desneux the cerci are 5 to 8-jointed (Imms, 1919). Also *cf.* Roonwal (1956*a*, *b*) for the structure of terminal abdominal segments in the Isoptera.

The sexes are indistinguishable externally.

IV—SUMMARY

1. The external morphology of the soldier caste of the primitive termite, *Anacanthotermes macrocephalus* (Desneux) is described.

2. The head is prognathous and has mandibulate mouth-parts. The sutures of the cranium of head-capsule are either ill-defined or absent.

3. The mandibles are somewhat asymmetrical, the left one being slightly larger than the right. The other mouth-parts are of the Orthopteroid type. A pair of compound eyes are present, each compound eye having about 127 facets. A pale spot on each side appears to represent rudimentary ocelli, though this point needs further study. The fontanelle is absent. The antennae are moniliform and with 28-31 segments each. There are no dorsal arms in the tentorium.

4. There are two main pairs of cervical sclerites, the anterior and the posterior. There is no trace of the ventral sclerites. The dorsal sclerites are feebly developed.

5. The pronotum is saddle-shaped and slightly overlaps the head-capsule. The pro-, meso- and metanota have reduplicated margins. The prosclerites fuse with the episternum of the prothorax to form a rigid collarband supporting the neck membrane and the posterior cervical sclerites. The katepisternum, which is a continued arm of the coxal condyle, is present in the prothorax. The sternum of the prohthorax, reported as wanting in the soldiers of most other termites, is present here as faintly chitinised and pigmented sclerite. The first spinasterna is found embedded in the membranous region in front of the mesosternum ; the second spinasternum is fused with the tip of the " furcasternellum" of the mesosternum ; the third spinasternum is wanting.

6. There are three pairs of thoracic legs, each with the usual number of joints. The formula for the apical tibial spines is 3 : 4 : 4. There are two tarsal claws and no arolium or empodium. An unguitractor or flexor plate is present.

7. The abdomen consists of the usual number of 10 segments. The first sternal plate is rudimentary and the remaining nine sterna are well developed. The tenth sternum forms a pair of podical plates. There is a pair each of the subanal styles and cerci both of which are setose and unsegmented.

8. There are ten pairs of spiracles, 2 being thoracic and 8 abdominal.

9. The sexes are indistinguishable externally.

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VI—ABBREVIATIONS USED IN THE TEXT-FIGURES

abd., abdomen.
abd. s., abdominal sternite.
abd. t., abdominal tergite.
ac. cx. sc., accessory coxal sclerite.
acg., acrotergite.
acl., anteclypeus.
acs., antecostal suture.
ant., antenna.
ant. c., antennal carinae.
ant. f., antennal foveolae.
ant. s., antennal suture.
ap. t., apical tooth of the mandible.
apd., apodeme (of any body-part).
aps., apophysis (of any body-part).
at., anterior.
at. a. md., anterior articulation of the mandible.
at. t. a., anterior tentorial arm.
at. t. p., anterior tentorial pit.
b.c. cd., basal condyle of cardo.
bcs., basicostal suture of coxa.
c., condyle of mandible.
cb., cibarium.
cd., cardo.
cer., cercus.
cl., clypeus.
cr.a.md., cranial articulation of the mandible.
ctm., corporotentorium.
cv., cervix.
cv. sc. 1., first or anterior cervical sclerite.
cv. sc. 2, second or posterior cervical sclerite.
cv. sc. 3, dorsal cervical sclerite.
cx., coxa.
cxg., coxa genuina.
cx. pr., coxal process.
e., *eye.*
epmr., epimeron.
ep. pl., epicranial plate.
ep. s.,epicranial suture.
epst., episternum.
fe., femur.
fl., flagellum of antenna.
f.l., fore leg.
fr., frons.
fx. pl., flexor plate (between claws and distitarsus).
g., galea.
gl., glossa.
gm., ginglymus.
gn., genae.
g.s., gular (or postmental) suture.
hd., head.
hd., c., head-capsule.
hyp., hypopharynx.
i.pl., incisor lobe of the mandible.
kts., katepisternum.
l.ss., lateral sclerites of hypopharynx.
lb., labium.
lb.p., labial palp.
lb.s., labial suture.
lcn., lacinia.
lgl., ligula.
lr., labrum.
lr.s., labral suture.
lst., laterosternite.
lt., left.
m.1, *m.2*, *m.3*, marginal teeth of the mandible.
md., mandible.
mdl., mandibularia. (or trochantin of mandible).
m.pl., molar plate of mandible.
mr., meron.
mss., mesosternum.
mst., mesonotum.
mts., metasternum.
mtt., metanotum.
mx., maxilla.
mx.p., maxillary palp.
n., antennifer.
oc., ocellus.
oct., occiput.
oct.f., occipital foramen.
oes., oesophagus.
o.s., ocular suture.
p., pedicel of antenna.
pcl., postclypeus.
pd.pl., podical plate.
pgl., paraglossa.
pgn., postgenae.
pl. m., pleural membrane.
pl.s., pleural suture.

pl. aps., pleural apophysis.
pmt., postmentum.
poct., postocciput.
poct.s., postoccipital suture.
prmt., prementum.
pro.sc., prosclerite.
prs., prosternum.
prt., pronotum.
pt., posterior.
pt.t.a., posterior tentorial arms.
pt.t.p., posterior tentorial pit.
r., ridge.
rt., right.
S.1, *S.2*, *S.3*, ..*S.10*, sterna 1-10.
s., scape.
sa.sty., subanal style.
scl., scutellum.
sct., scutum.
sgn.r., subgenal ridge.
slv., salivarium.
spr., spiracle.
sp.s.1, *sp.s.*2, spinasternum first and second.
ss., suspensoria (sclerites associated at the base of hypopharynx).
ss.br.1. stomodaeal branch.
*ss.br.*2, mandibular branch.
st., stipes.
str. aps., sternal apophysis.
su.g., sutural groove of stipes.
t., tergum.
T. I, *T II*, *T. III*, ..*T.X*, terga first, second, and so on.
tar., tarsus.
tar. c., tarsal claw.
tb., tibia.
tb., tentorial bridge.
tb. sr., tibial spur.
t.f., tentorial foramen.
th., thorax.
tm., tormae.
tn., trochantin of leg.
tr., trochanter.

MORPHOLOGY OF THE PRIMITIVE TERMITE, *ANACANTHOTERMES MACROCEPHALUS* (DESNEUX) (ISOPTERA : HODOTERMITIDAE). PART 2. EXTERNAL MORPHOLOGY OF THE ALATE AND WORKER CASTES

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(With 3 Tables and 12 Text-figures)

CONTENTS

I—INTRODUCTION

This is the second paper of the series, the first having dealt with the external morphology of the soldier caste (Gupta, 1962).

Acknowledgements.—I am deeply grateful to Dr. M. L. Roonwal, Director, Zoological Survey of India, Calcutta, for suggesting the problem and for continuous guidance. My thanks are also due to Shri T. C. Mathew, Principal, Dungar College, Bikaner, for his interest and encouragement during the course of this work. I am also grateful to my colleague Dr. S. Venkatachary, for his valuable suggestions in the improvement of the text. I am also thankful to Shri R. K. Goyal who helped me in the preparation of the text-figures. I further wish to put on record my appreciation of the untiring zeal and patience of Shri Chiman Singh of Dungar College, Bikaner, in the collection of the material.

II—MATERIAL AND METHODS

Alates were collected in two lots at the time of swarming from the same locality as for the study of the soldier caste, *i.e.*, the outskirts of Bikaner city in Rajasthan. The swarming took place during a drizzle immediately following the first heavy shower of the rainy season in August 1955 and 1958. The insects were attracted to the strong light of a 'Petromax' lantern between 9-11 p.m. Inspite of my best efforts I failed to collect any alates during the years 1956 and 1957.

Worker forms were also collected from the same locality, while foraging or building the termite-hills.

The material was preserved in rectified spirit. For the study of the sclerites, the body was relaxed either by boiling the insects in a mixture of 30 per cent. alcohol and 5 per cent. glacial acetic acid, or boiling water and 5 per cent. glacial acetic acid, for a period of 20 minutes. For the study of individual parts, the insects were dissected out and the body parts cleared in a 5 per cent. aqueous solution of potassium hydroxide for one to three days. Permanent preparations in canada blasam were made by the usual method. Gage's method (1919), for staining chitin and also alcoholic eosin were used ; both the methods gave good results.

III—EXTERNAL MORPHOLOGY OF THE ALATE CASTE

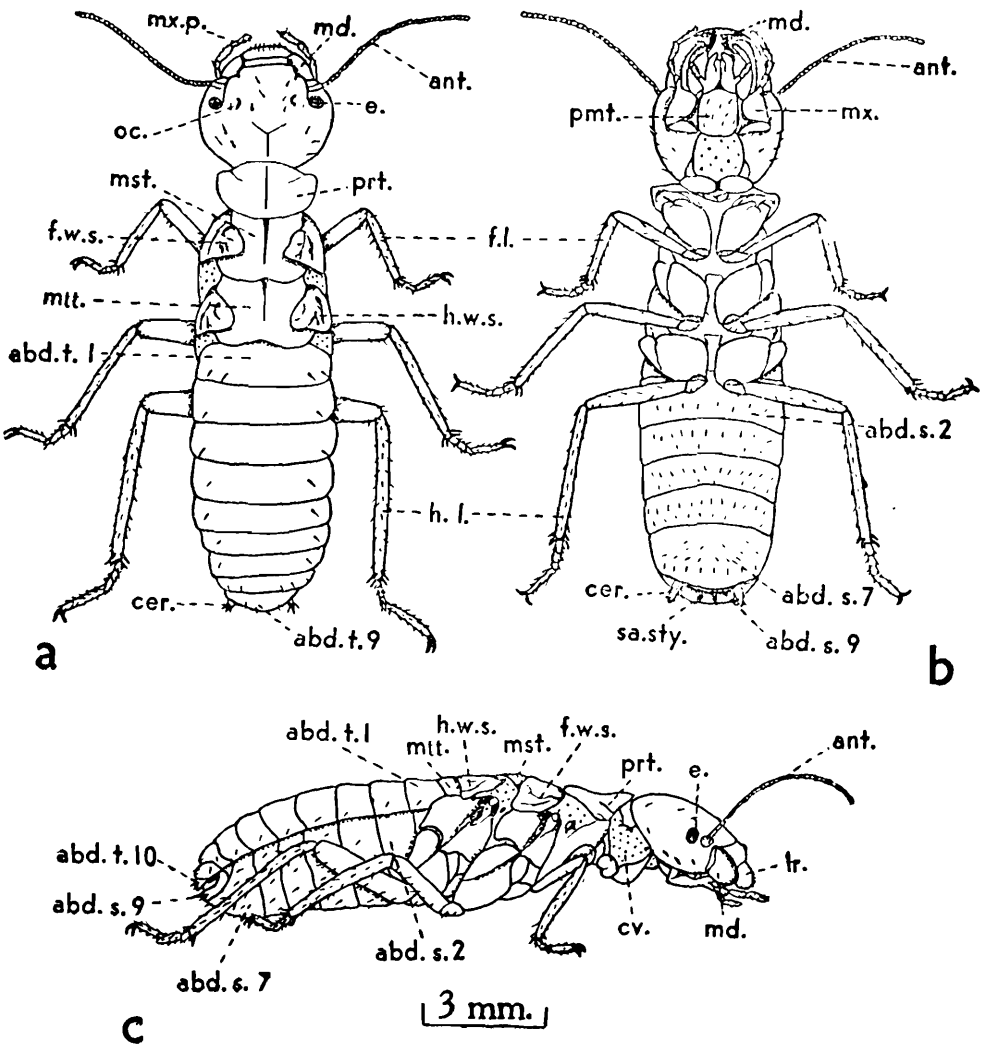
(a) *General*

The following account of the alates applies mainly to the females. The males are similar to the females in most respects, but wherever they differ, the differences are indicated.

Coloration.—The head in alates displays less pigmentation than in the oldier. It is pale brown except in the articular regions for mandibles, maxillae, etc., where it is dark brown. On the underside, the head is pale yellow. The thoracic tergites are strongly chitinised and dark brown, the abdominal tergites, due to differential pigmentation, present a banded appearance, with paler bands alternating with broad, transverse dark-brown band in each tergite. On the ventral side the entire body is yellowish white.

Setae.—The setae on the head are few but prominent. On the dorsal side of the body their number is insignificant except on the anterior margin of the pronotum. On the ventral side, the abdomen has longish setae which are more numerous in the middle of each sternite. The legs have long setae.

Size.—The body without wings measures about 13·8—14·6 mm. from the tip of the labrum (the mandibles lie covered under the labrum to the tip of the abdomen.



TEXT-FIG. 1.—*Anacanthotermes macrocephalus* (Desneux). Alate caste, female.

(*a*). Whole body of dealated adult, in dorsal view. (*b*). Ditto, in ventral view. (*c*). Ditto, in lateral view.

Sexes.—The males can be distinguished by the exposed eighth abdominal sternite, which, in females, lies under the seventh and is partly visible externally as two lateral plates lying apart. In a count of 1,226 individuals the males were found to comprise about 54 per cent. of the population (Table 1).

TABLE 1.—*Ratio of males and females among alates of* Anacanthotermes macrocephalus (*Desneux*) *in two random collections made on outskirts of Bikaner.*

Date of collections	Total number of individuals	Males		Females	
		Number	%	Number	%
20 August, 1956	40	22	55·0	18	45·0
1 August, 1958	1,186	635	53·5	551	46·5
Total and average	1,226	657	54·25	569	45·75

(b) *The head*

(Text-figs. 2 and 3)

The head, which is more or less round, is hypognathous, unlike the prognathous condition in the soldier, and is relatively smaller. It is bilaterally symmetrical, and has the orthopteroid type of mouth-parts. The posterior margin is partly covered by the pronotum as in the soldier caste. The mandibles, unlike those of the soldier, are largely covered by the labrum. As in the soldier, they are asymmetrical in respect of the teeth. In all the 50 insects examined, the left mandible partly crossed over the right one in the resting position.

The head-capsule measures as follows :—

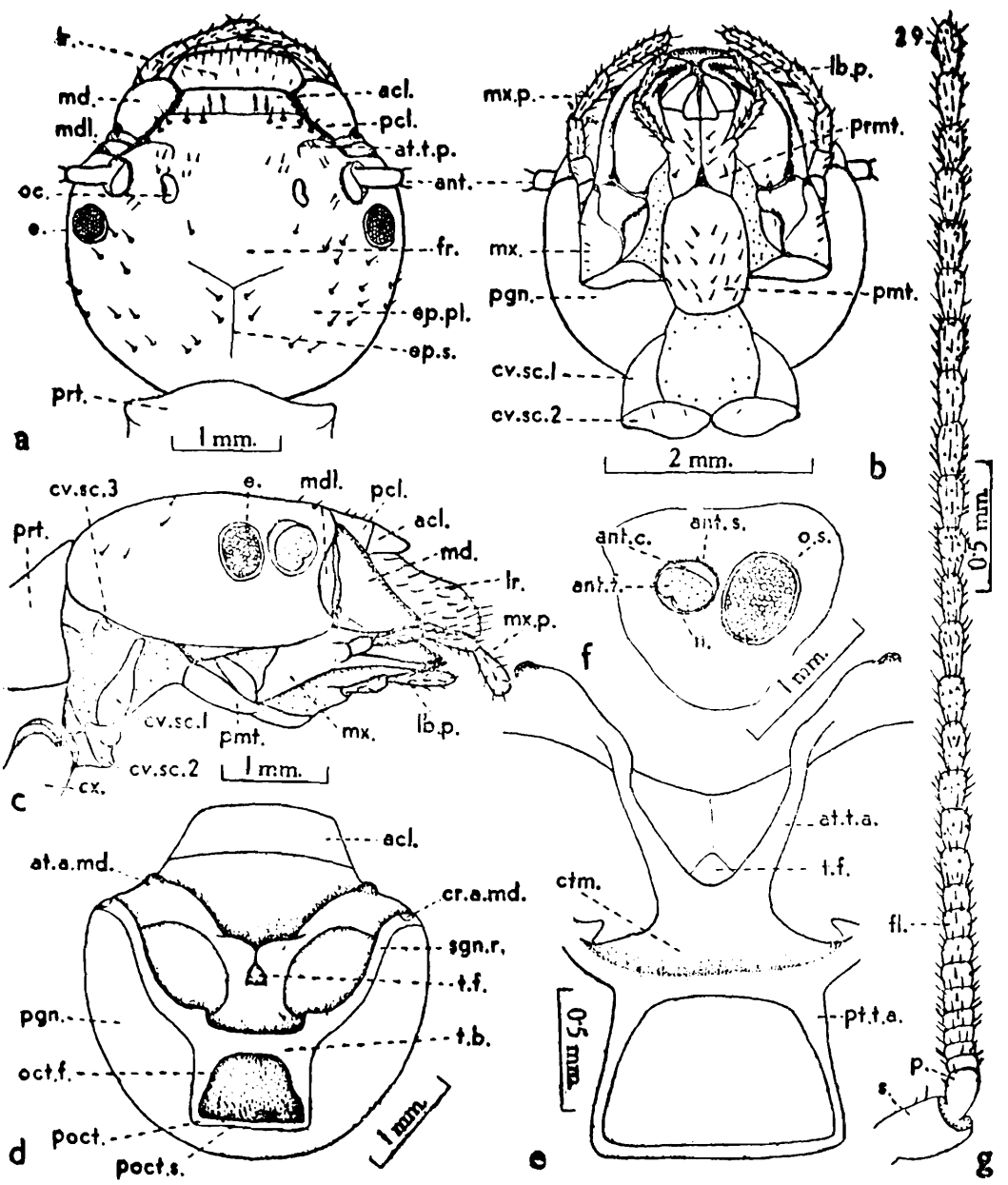
Length from the hind margin to the tip of the labrum .	3·5—3·8mm.
Length from the hind margin to the lateral base of the mandible	2·4—2·6mm.
Maximum height of the head . ..	1·3—1·4mm.
Maximum width of the head .	2·9—3·0mm.

But for the fact that the facial area is directed forwards, the mouth-parts and other appendages on the head are in the same relative position as in the soldier. As in the soldier, the fontenalle is absent.

The sutures are ill-defined or absent. The Y-shaped *epicranial suture* (*ep. s.*) is faintly visible. The *epicranial plates* (*ep. pl.*) are less extensive than in soldier. As in the soldier, the *clypeo-frontal* or *epistomal suture* is absent, and the *frons* (*fr.*) is thus not separated from the *clypeus* (*cl.*). The epicranial plates pass into the *genae* (*gn.*) and the *postgenae* (*pgn.*). The *occipital suture* is absent. The *gular sutures*, which are present in the soldier caste, are absent here.

The clypeo-frontal area is bounded anteriorly by the usual *clypeo-labral suture* (*lr. s.*). Unlike the soldier, the clypeus is divisible into an anterior membranous *anteclypeus* (*acl.*) and a darker *postclypeus* (*pcl.*) by an *intra-clypeal suture* (*i.cl.s.*) ; the anteclypeus is distinguishable by means of two longitudinal depressions into three regions—one median and two lateral—all of which bulge outwards. Of these, the median bulging is very prominent and accommodates the median elevation of the

labrum (*lr.*). The postclypeus can be said to be divided into right and left parts by a shallow, medio-longitudinal depression, but no distinct *median clypeal suture*, as found in *Odontotermes obesus*(Rambur)(Vishnoi, 1957), is visible. The *postoccipital suture* (*poct.s.*) encloses a *post-occiput arch* (*poct.*) bracing the *occipital foramen* (*oct.f.*) on three sides. The submarginal *subgenal suture* and its corresponding ridge (*sgn.r.*),



TEXT-FIG. 2.—*Anacanthotermes macrocephalus* (Desneux). Alate caste, female. (*a*). Head in dorsal view. (*b*). Head in ventral view. (*c*). Head, along with the cervix , in lateral view. (*d*). Head-capsule (appendages removed), in ventral view. (*e*). Tentorium in dorsal view. (*f*). Part of the cranium, showing left antennal and ocular sclerites. (*g*). Left antenna, showing 29 segments.

starts in front of the *posterior tentorial pit* (*pt.t.p.*), follows the same course as in the soldier and strengthens the ventro-lateral cranial wall for the articulation of the gnathal appendages. The *labium* (*lb.*) is attached directly to the neck membrane between its lateral attachments to the cranial margins just behind the posterior tentorial pits.

The *amennal* (*ant.s.*) and *ocular sutures* (*o.s.*) separate the antennal and ocular sclerites, as in the soldier.

The tentorium (Text-fig. 2 *d*, *e*).—It forms the endoskeleton of the head-capsule. In its essential structure it resembles that of the soldier and the differences are mentioned below :—

(i) The *posterior tentorial pits* (*pt.t.p.*) are not lengthened because of the hypognathous condition of the head. The *posterior tentorial arms* (*pt.t.a.*) are connected medially, forming a narrow transverse bar, the *tentorial bridge* (*t.b.*). Postero-laterally the posterior tentorial arms are produced backwards and become confluent with the postocciput arch to completely enclose the occipital foramen, (*oct.f.*),

(ii) The *corporotentorium* (*ctm.*) is comparatively smaller.

The labrum (Text-fig. 3*a*, *b* ; *lr.*).—The labrum is similar in form to, but slightly differs in structure from, that of the soldier. It measures about 0·98mm. in length and 1·33 mm. in width. In relation to the head-length, the alate labrum is larger than the soldier labrum. Its proximal articular margin shows a median elevation corresponding to the median elevation of the anteclypeus (*vide supra*). It further displays prominent convex curvature antero-posteriorly as well as from side to side, and its distal margin bears a marginal membranous area.

The under surface is lined by cuticle which, unlike the soldier, is not smooth. The labral palate is provided with two types of fine cuticular processes as in the alate forms of *Odontotermes obesus* (Rambur) (Vishnoi, 1956), *viz.*, (i) the small spine-like *aculei* (*lr.ac.*) covering practically the entire area except on the outer side; and (ii) two dentigerous stripes formed by numerous peg-like *denticles* (*lr.dt.*) arranged in antero-posterior rows, one on each side, between the imaginary median axis and the lateral border. The dentigerous stripes are also present in the soldier caste of this species. Imms (1919) did not mention such cuticular processes as the aculei in *Archotermopsis wroughtoni* Desneux though he mentioned " very minute closely set papillae ", probably corresponding to the dentigerous stripes referred to above.

At the basal angles are found, as in the soldier, two medially directed sclerites, the *tormae* (*tm.*) ; the right torma is larger than the left.

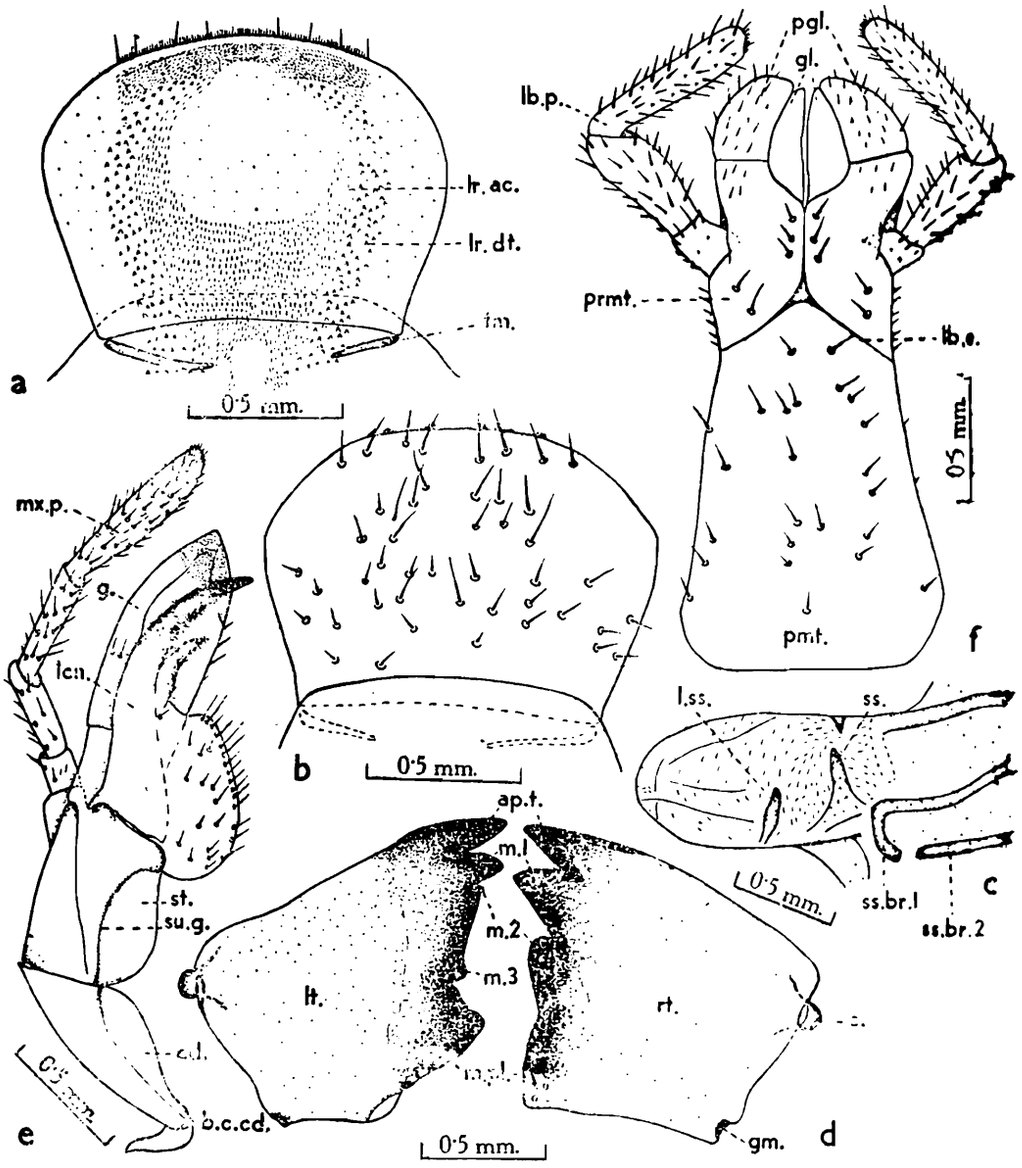
The hypopharynx (Text-fig. 3*c* ; *hyp.*).—The *hypopharynx* is seen in the same relative position and possesses the same structure and form as in the soldier.

The eyes and the head appendages (Text-figs. 2 and 3).—(i) The *compound eyes* (Text-fig. 2*f*; *e.*) : The eyes are larger than in soldiers and consist of a pair of prominent, bulging, dark, pigmented eyes, measuring about 0·53 mm. in the long diameter. They are placed slightly behind the antennal sockets. The facets are roughly hexagonal and number about 142. Each eye is surrounded by an *ocular suture* (*o.s.*) enclosing the *ocular sclerite* ; the internal ridge thus formed surrounds the eye.

In the same position where the ocelli lie in the soldier there are two pale spots (*oc.*), the nature of which requires further study.

(ii) *The antennae* (Text-fig. 2*f*, *g* ; *ant.*).—The antennae, which have 28-29 segments, measure about 4·75 mm. in length. In form, situation, structure, etc., they closely resemble those of the soldier except that the

antennal carinae (*ant.c.*) are less prominent. The number of segments in the two antennae, right and left, show less variation than in the soldier. A count in 50 male and 50 female alates (Tables 2 and 3 showed that 84 per cent. males and 92 per cent. females have an equal number of segments in both the antennae, of which 29-segmented antenna is found in 80 per cent. males and 48 per cent. females ; 16 per cent. males and 8 per cent.



TEXT-FIG. 3.—*Anacanthotermes macrocephalus* (Desneux). Alate caste. female.

(*a*). Labrum, in ventral view. (*b*). Labrum, in dorsal view. (*c*). Hypopharynx, in dorso-lateral view. (*d*). Left and right mandibles. (*e*). Right maxilla, in ventral view. (*f*). Labium, in ventral view.

females carry an unequal number of segments in the two antennae. However, wherever this bilateral asymmetry is found, the difference is of one segment only. In contrast to males, the 28-segmented antennae are more common in females (Table 3). The *scape* (*s.*), the *pedicel* (*p.*) and the first two flageller segments measure in length about 0·23, 0·19, 0·09 and 0·06 mm. respectively.

TABLE 2.—*Variation in the number of antennal segments of the right and left antennae of* 50 *individuals of each sex in alates of* Anacanthotermes macrocephalus (*Desneux*).

Item	Number of segments and frequency					
	Males			Females		
	Frequency	Left	Right	Frequency	Left	Right
(*a*) With one segment more in the left antenna.	5	29	28	1	29	28
	1	28	27	1	28	27
	Total 6 (12%)		—	Total 2 (4%)		—
(*b*) With one segment more in the right antenna.	2	23	29	*Nil*	28	29
	Nil	27	28	2	27	28
	Total 2 (4 %)		—	Total 2 (4 %)		—
(*c*) With equal number of segments in both antennae.	40	29	29	24	29	29
	1	28	28	19	28	28
	1	27	27	3	27	27
	Total 42 (84%)		—	Total 46 (92%)		—

TABLE 3.—*Frequency distribution of the number of antennal segments in* 50 *individuals of each sex in the alates of* Anacanthotermes macrocephalus (*Desneaux*).

Number of antennal segments	Males				Females			
	Right		Left		Right		Left	
	Frequency	Approx. %	Frequency	Approx. %	Frequency	Approx. %	Frequency	Approx. %
29	42	84%	45	90%	24	48%	25	50%
28	6	12%	4	8%	22	44%	20	40%
27	2	4%	1	2%	4	8%	5	10%

(iii) *The mandibles* (Text-fig. 3*d*; *md.*).—The mandibles are meant for crushing and chewing, and are consequently modified and different from those of the soldiers. Each mandible is trapezoid in form and, as in the soldier, articulates with the cranium by a mid-dorsal *ginglymus* (*gm.*) and a ventro-lateral *condyle* (*c.*); it is worked in the transverse plane by the two apodemes—a smaller outer *abductor* and a larger inner *adductor*. The abductor is attached in a concavity situated just above the condyle, while the adductor is inserted into the large sinus immedia-

tely behind the *molar plate* (*m.pl.*). The distal part of the mandible is practically hidden from view, being covered by the labrum. The two mandibles, unlike the soldier, are subequal in length, though at base the right is slightly broader than the left. However, as in the soldier, the left mandible crosses over the right while in repose (*vide* above).

The two mandibles are asymmetrical in respect of the number of teeth. The right one possesses two *marginals* (*ml.* and 2) behind the *apical tooth* (*ap.t.*) and in front of the *molar plate* (*m.pl.*). The left mandible has three marginal teeth, of which only the first one is well marked and lies behind the apical tooth ; the second marginal is small ; the margin of the *incisor lobe* (*i.pl.*) following it is concave and forms a tooth-like projection, the third marginal (*m.*3), in front of the molar plate. The molar plate of the left mandible is wedge-shaped and, when seen from above, a blunt marginal tooth projects from the under surface. However, according to Ahmad (1950) it should not be mistaken for a marginal tooth.

(iv) *The first maxilla* (Text-fig. 3 *e*; *mx.*).—The maxillae are similar to those found in the soldier. The segments of the *maxillary palp* (*mx. p.*), beginning from the proximal segment, measure about 0·17, 0·21, 0.46, 0·54 and 0·71 mm. in length, respectively.

(v) *The labium* (Text-fig. 3*f*; *lb*).—It consists of the usual two segments, the *prementum* (*prmt.*) and the *postmentum* (*pmt.*), and resembles the labium of the soldier in its structure, position , and relation with the hypopharynx and with the neck membrane. The prementum is attached to the postmentum along the $\wedge$-shaped *labial suture* (*lb.s.*). The *ligula* is medially cleft anteriorly ; further, it has a strong longitudinal depression running up to the apex of the labial suture. In length the segments of the labial palp measure 0·19, 0·57 and 0 73mm., respectively. The postmentum, however, differs from that in the soldier in : (i) being less sclerotised ; (ii) not having the rounded basal angles produced in posteriorly directed arms ; (iii) the absence of the distal membranous part ; and (iv) the absence of the *gular sutures*, since the lateral margins are not connected with the cranial wall. Somewhat near the middle, the postmentum is transversely arched.

(c) *The neck*

(Text-figs. 2*c* & 4*a*)

The *cervix* (*cv.*) or neck with its lateral, ventral and dorsal sclerite, (*cv. sc.* 1, 2, 3) closely resemble those of the soldier and do not need a detailed description.

(d) *The thorax*

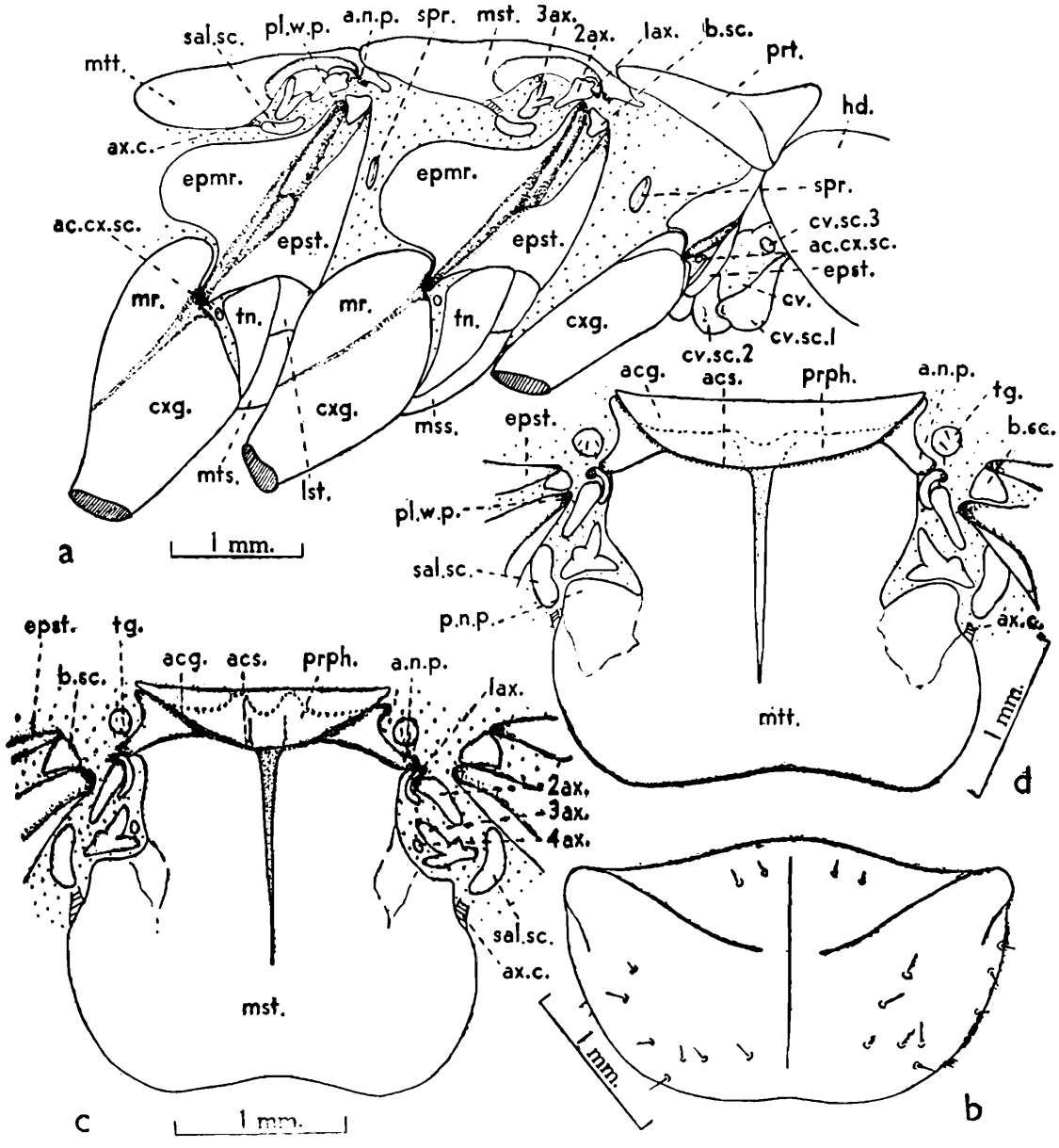
(Text-figs. 4 & 5*a*)

The thorax measures about 4·4 mm. in length and constitutes nearly one-third of the entire length of the insect. It consists of the usual three segments, the pro-, meso- and metathorax, of which the last two, which bear the wings, form the *pterothorax.*

The prothorax.—It is different from the pterothoracic segments both in form and structure. The *pronotum* (*prt.*) is the smallest of the three nota and measures about 1·5 mm. in length and 2·3mm. in breadth. It is saddle-shaped, with prominent, drawn out, antero-lateral spouts

and infolded margins as in the soldier ; only its anterior margin is weakly notched. The *sagittal suture* and *ridge* are distinct and the transverse apodemal inflexion is quite prominent. The anterior infolded margin forms a plate-like structure which becomes confluent with the neck membrane. The *pronotum* bears numerous small hairs.

The sternal sclerites (Text-fig. 5*a*) of the prothorax closely resemble those of the soldier, and the median carinate plate consists of the two fused *prosclerites* (*pro.sc.*) lying between the *episterna* (*epst.*) of the two



TEXT-FIG. 4.—*Anacanthotermes macrocephalus* (Desneux). Alate caste, female. (*a*). Cervix and thorax (wings removed), in lateral view. (*b*). Pronotum, in dorsal view. (*c*). Mesonotum with articular sclerites of the wing in dorsal view. (*d*). Metanotum with articular sclerites of the wing, in dorsal view.

sides. A very weakly pigmented oval plate, the prosternum (prs.), lies between the two coxae of the forelegs and further behind lies a medially placed, dark, pigmented, subcircular plate, the *first spinasternum* (*sp. s.* 1) (the intersternellum of Fuller, 1924), carrying internally a forwadly directed, rod-like structure. The pleuron of the prothorax is similar to that of the soldier caste and does not need a detailed description.

The pterothorax.—The pterothorax is composed of two segments—an anterior mesothorax and a posterior metathorax.

(i) *The tergites.*—The *meso-* (*mst.*) and *metanota* (*mtt.*) are subequal and similar. The *mesonotum* is a slightly arched plate divided in two regions—an anterior, narrow, waist-like *scutum* (*sct.*) and a posterior, slightly skirt-like *scutellum* (*scl.*). The scutum, as in the soldier, is traversed by a transverse submarginal *antecostal suture* (*acs.*) separating off a narrow band, the *acrotergite* (*acg.*) ; the corresponding internal ridge is directed downwards and forwards and displays a wing-shaped *prephragma* (*prph.*) with a pair of thin plate-like medio-lateral, triangular, *apodemal lobes* separated by a median notch, and a pair of lateral extensions (" yokes " of Fuller, 1924). There is no transverse suture to separate the *prescutum.*

The *scutellum* is not separated from the scutum by a transverse suture (the scuto-scutellar or Y-shaped suture of other wing-bearing insects nor is there any reversed notal suture. The scutellum, however, is elevated in the middle and depressed on either side to accommodate the wings when folded.

The sagittal suture is not seen externally. However, the ridge is very well developed and appears as a dark stripe through the notum. It is rather broadly joined in front to the *antecostal ridge* and posteriorly it gradually tapers to an end in the scutellar region. It does not reach the hinder border of the notum, nor does it subdivide into a short prong, as described by Fuller (1924) in *Hodotermes* spp. and other winged termites. This suture may not resemble the Y-shaped scuto-scutellar ridge regarded by Snodgrass (1935) as a fundamental ridge of the tergum in the winged insects, but Fuller (1924) believed that it is difficult to regard it as anything else. According to him it probably represents the two diverging ridges seen on the Blattid endonotum fused into one. However, since this ridge is more or less confined to the scutum, it should be regarded as the median ridge only.

The alar margin of the alinotum.—The lateral margins of the pterothoracic tergites, unlike the soldier, are specially modified in respect of the articular and flexor mechanisms of the wings.

The scutum presents antero-laterally a slightly backwardly directed stumpy process, the *anterior notal wing process* (*a.n.p.*) supporting the neck of the *first axillary sclerite* (1 *ax.*) of the wing base (*vide infra*). Immediately behind this the edges of the scutum become broadly emarginated and slightly incurved, giving the scutum a waist-like appearance. Further behind, the margin fans out to form the less chitinised *posterior notal wing process* (*p.n.p.*) which supports the third *axillary* (3 *ax.*).

The posterior border of the dorsum has rounded lateral angles and a broad, deep median notch. The margin is reflected under to form a reduplicated structure or ledge ; the thickened membranous ledge runs forward and outward on each side as the *axillary cord* (*ax. c.*) to the posterior wing articulation where it is applied to the outer edge of the third axillary and then folds sharply over into the edge of the basal membrane of the wing. As in other winged termites, a *postphragma* is not present.

The *metanotum* resembles the mesonotum in all essential respects. However, it differs from the latter in having a narrower acrotergite and a broader portion of the prephragma between the medio-lateral lobe and the lateral extension.

(ii) *The pleuron.*—The pleura of these segments do not differ fundamentally from those of the prothorax, and the differences that are met with are due to a degenerative tendency of the prothoracic pleura on the one hand and, on the other, to the special requirements of the wing-bearing condition in the pterothoracic pleura.

As in the soldier, the mesopleuron is divided by a deep prominent groove, the *pleural suture* (*pl. s.*), running from the base of the wing obliquely backward and downward separating the anterior plate, the *episternum* (*epst.*) from the posterior *epimeron* (*empr.*). Internally, it is produced into a massive apodeme, the *pleural ridge* (*pl. r.*), which is similar in structure to that of the soldier. Proximally, the suture and ridge end in a short, thick fulcral process called the *pleural wing process* (*pl. w. p.*) on which the *second axillary sclerite* (*2 ax.*) of the wing gyrates. Distally, the pleural suture ends in a broad *coxal condyle* (*cx. c.*), and appears to run over on the coxa without interruption.

The episternum (*epst.*) is a triangular sclerite lying in front of the pleural suture. It is bisected dorsally by a membrane-covered slit into an anterior vertical arm with chitinised apical thickening forming a more or less supplementary wing process to which are attached the ligamentous prealar portion of the wing and also the lateral attachment of the *tegula* (*tg.*). Behind the slit and in front of the pleural suture there is a narrow but deep slip of cuticle which slightly widens in the middle. There is no external indication by which the episternum can be divided into a dorsal *anepisternum* from the ventral *katepisternum.*

The epimeron.—The *epimeron* (*epmr.*) is a large, slightly convex plate behind the pleural suture. It is narrow towards the upper end, broad in the middle and again becomes abruptly narrower in the region of the coxal condyle, and is surrounded dorsally, posteriorly and ventrally by membranes.

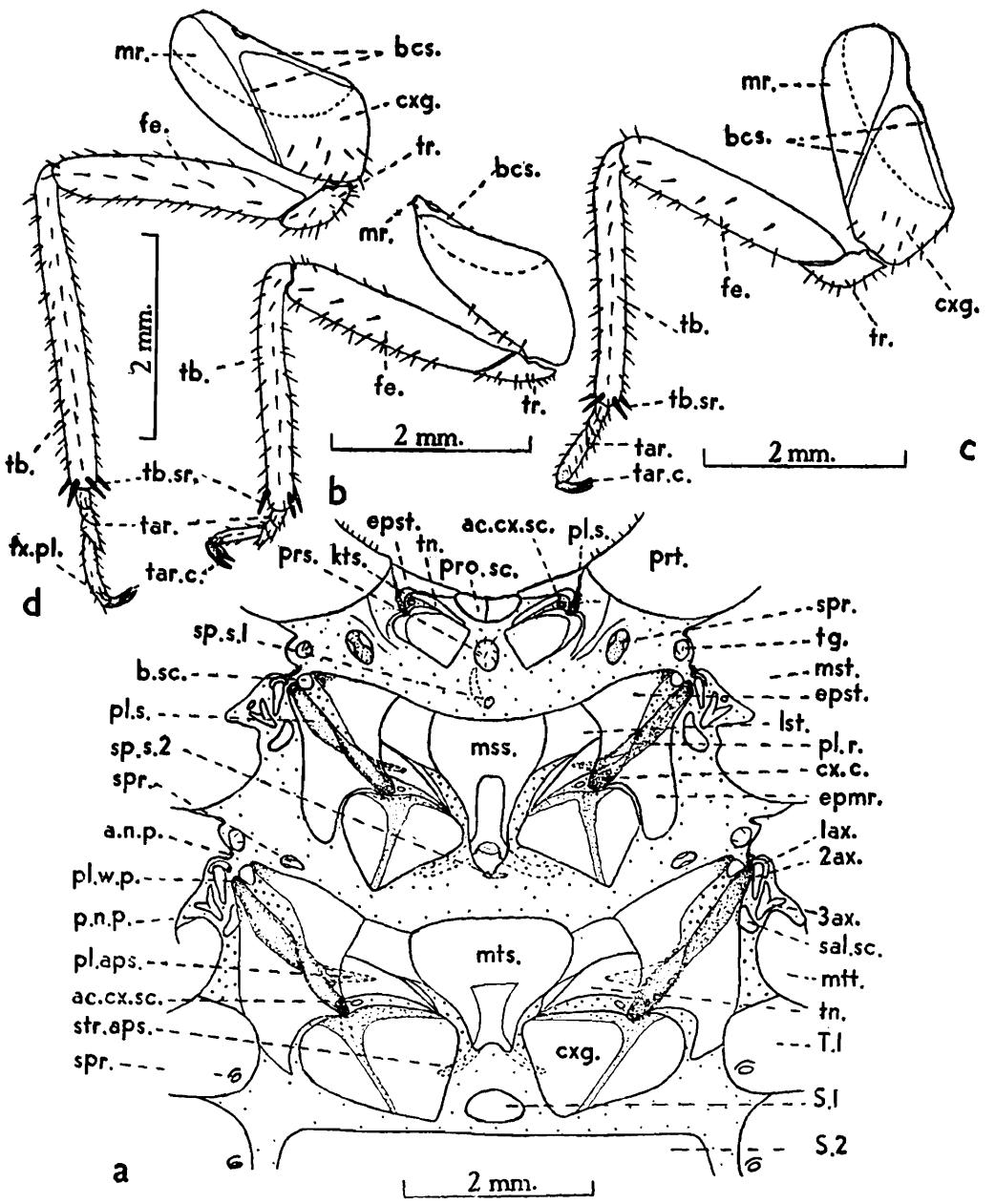
The trochantin.—The *trochantin* (*tn.*) is an elongate, triangular plate placed, as in the soldier, between the *laterosternite* (*lst.*) in front, the *katepisternum* (*kst.*) above, and the coxa behind. It is subequal in the meso- and metathorax but is relatively smaller in the prothorax. In the meso- and metathorax it is further seen to be divided by a ridge (forming an internal apodeme) into an anterior and a posterior triangular region.

The *metapleuron* resembles the mesopleuron in all essential details.

The epipleurites.—A pair of sclerites, called the *epipleurites*, one in front and the other behind the *pleural wing-process* (*pl. w. p.*), lies above the principal pleural sclerites. The anterior episternal epipleurite is called the *basalare* (*b. sc.*), and the posterior or epimeral one the *subalare* (*sal. sc.*) (or the "parapteron" of some authors). The basalare is a single, nodule-like, triangular sclerite which forms a bridge between the chitinous episternal wing-process and the pleural wing-process referred to above. The subalare is a crescent-shaped sclerite lying above the epimeron ; in its concavity the ventral arm of

the third axillary is hinged. Fuller (1924) regarded the chitinous tip of the anepisternum as the first parapteron, and the basalare and the subalare as the second and the third parapterons respectively.

The epipleurities of the metathorax also do not differ from those of the mesothorax. No such structures are present in the soldier.



TEXT-FIG. 5.—*Anacanthotermes macrocephalus* (Desneux). Alate caste, female.

(*a*). Ventral and lateral sclerites of the thorax with the tergites cut medially and spread on either side, in ventral view. (*b*). Right fore-leg, in ventral view. (*c*). Right middle-leg, in ventral view. (*d*). Right hind-leg, in ventral view.

(iii) *The sternal sclerites of the pterothorax.*—The sterna of the meso- and metathorax are subequal and do not differ from each other and from those of the soldier except in induration and pigmentation. The transverse sternal plate (*mss.*) is large and subtriangular, and lies flanked on either side by the subquadrate *laterosternite* (*lst.*) (the epimeral plate of Holmgren, 1909) which, with the episternum, forms the *precoxale*

(*pcx.*), as in the soldier. The backwardly directed slip is better chitinised, slightly flexed transversely and bears the *furca* (*str. aps.*) internally ; it is termed ' furcasternellum ' by Snodgrass (1935). The *second spinasternum* (*sp. s. 2*) is fused with the broad tip of the furcasternellum. The spinasternum of the *metasternum* (*mts.*) is absent as in the soldier, and the furcasternellum ends broadly. The chitinisation of the sternal plates is greater in the alates than in the soldier.

There is no *postcoxale* in any of the three thoracic segments and each of the three tergites, to some extent, overlaps the one which follows it.

There are two pairs of thoracic *spiracles* (*spr.* 1 and 2) situated, as in the soldier, as follows :—A pair each on the pleural membrane between the pro- and meso thorax and between the meso- and metathorax just in front of the episternum.

(e) *The thoracic legs*

(Text-figs.5*b*, *c* and *d*)

There are three pairs of subequal legs, which, in all essential respects, closely resemble those of the soldier. There is no *coxal suture* as reported in the winged forms of *Odontotermes obesus* (Rambur) (Kushwaha, 1960) and other termites (Fuller, 1924), though the coxae of the meso- and metathoracic legs are run obliquely by the *basicostal suture* (*bcs.*), which appears to be a continuation of the plerual suture (*vide supra*), dividing the coxa into an anterior *coxa genuina* (*cx. g.*) and a posterior *meron* (*mr.*). This suture has a prominent apodemal inflexion internally.

The other segments need no description ; the number of *tibial spurs* (*tb. sr.*) is as in the soldier, 3, 4, 4 in the fore- middle- and hind-legs, respectively.

(f) *The wings*

(Text-figs. 4 and 6)

1. *General.*—There are two pairs of subequal, pale-brown membranous wings extending, when folded, far beyond the end of the abdomen. While in repose, the left pair lies over the right. The anterior pair of wings is longer, but less broad than the posterior ones. The forewing with scale measures about 23 mm. long and 5·3 mm. broad, and the hindwing about 22 mm. and 6 mm., respectively. As in other Isoptera, the wings are deciduate and are, after the nuptial flight, shed off along a curved transverse suture near the base of the wing called the *humeral* or *basal suture* (*h.s.*). The proximal part, or the *wing stump*, or *scale* (*w.s.*) (scapular shield of Frogatt) remains permanently attached to the body.

Articulation of wings.—Each wing is attached to the body at its base by a membranous fold running from the *tegula* (*tg.*) in front to the *axillary cord* (*ax. c.*) behind. The wing-base is further strengthened by a group of sclerites called the *pteralia*, which includes the *tegula*,

the anterior *humeral plate*, the three *axillary sclerites* and two *median plates* in addition to the two *epipleurites*, and are described below.

1. *Tegula.*—This is a small lobe or scale-like sclerite lying at the anterior articular region of the wing just proximal to the humeral plate. It is larger in the forewing than in the hindwing, and bears a number of longish setae.

2. *Humeral plate.*—It is a small plate heavily chitinised and articulating with the basal portion of the *costa* (*C.*) (probably the costal sclerite of Comstock, 1918). It supports the ligamentous prealar portion of the wing. In the forewing it is triangular and spur-like ; in the hindwing it is represented by general chitinisation anteriorly to the base of the *subcosta* (*Sc.*).

3. *First axillary* (1 *ax.*).—It is the most anterior lateral wing-sclerite and lies along the margin of the scutum behind the *anterior notal wing-process* (*a.n.p.*), and is shaped like a gun trigger. Its anterior end is rounded and faces outwards, abutting against the anterior notal process of the meso- or metanotum on the one hand, and the base of the wing in the region of the subcosta on the other. In its middle it is strongly concave and receives the tip of the second axillary sclerite, while the tail end is again prominently curved outwards.

4. *The second axillary* (2 *ax.*).—It is a stout rod-like sclerite which is obliquely hinged at the anterior rounded end with the concavity of the first axillary. Its other terminal is broadly hinged over the forwardly directed arm of the third axillary, and its ventral surface near the middle fits over the fulcral wing-process of the pleuron (*pl. w. p.*).

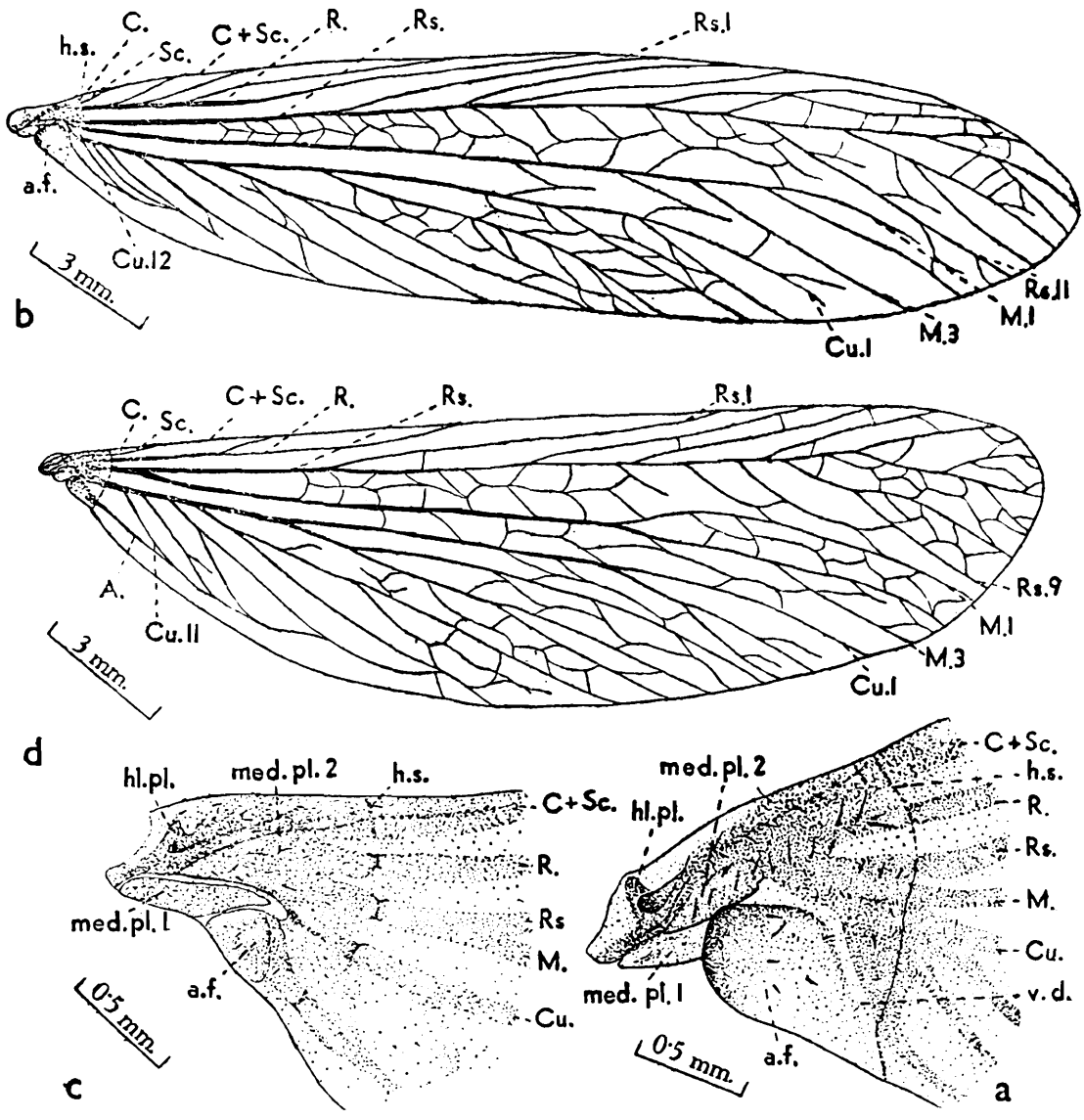
5. *The third axillary* (3 *ax.*).—It is the posteriormost axillary sclerite and lies between the *posterior notal process* (*p.n.p.*) and the second axillary. It is a complex sclerite and slightly differs in the meso- and metathroax. In the metathorax it is triradiate ; the outer ventral ray and the inner posterior ray lie against the postnotal process, with the ventral ray hinging in the concavity of the *subalare* (*sal. sc.*) and the other articulating with the condyle in the anal lobe of the wing. The forwardly directed process hinges with the second axillary and supports the membranous wing-base. The ventral arm is run over by the axillary cord which sharply reflects over to become continuous with the basal membrane of the wing.

6. A small sclerite lies between the apex of the third axillary and the anal lobe of the forewing, as found in other winged termites (Fuller, 1924).

7. *The median plates* (*med. pl.* 1 and 2).—These sclerites are, due to extensive chitinisation of the area, not easily separable. They lie in the median area of the wing-base and are separated by an oblique groove into a proximal plate and a distal plate. The former is more distinct and lies hinged to the third axillary. The distal plate, on account of heavy sclerotisation, cannot be delimited from the base of the veins (mediocubital) of this region. In addition to these sclerites, there are two epipleurites (Text-fig. 4) supporting the membranous base of the wing and have already been described.

2. *The fore-wing* (Text-fig. 6 *a* and *b*).—

The forewing-scale.—The forewing-scale (*f.w.s.*) is subtriangular, larger than the hindwing-scale and measures about 1·25 to 1·5 mm. in length along the median vein, the length being about 1/16th of the entire wing-length. It is delimited from the *lamina* (*la.*) by a *basal or humeral suture*(*h.s.*) (called line of fracture by Fuller, 1919). This suture runs as a definite groove just posterior to the *vena dividens* (*v.d.*) more or less at right angles to the posterior margin of the *anal lobe* (*a.f.*) till it crosses the *cubitus* (*cu.*) ; then it curves outwards to cross over the *median* (*M.*) and *radial sector*



TEXT-FIG. 6.—*Anacanthotermes macrocephalus* (Desneux). Alate caste, female. (*a*). Right forewing-scale, in dorsal view. (*b*). Right forewing, in dorsal view. (*c*). Right hindwing-scale, in dorsal view. (*d*). Right hindwing, in dorsal view.

(*Rs.*). Beyond this it is indistinct and becomes evident only by a constriction in the *radius* (*R.*). Further, it may appear as a faint line in the subcostal and costal regions.

Venation.—(i) *The costa* (*C.*).—Unlike *Mastotermes darwiniensis* Frogatt (Tillyard, 1931) and like *Archotermopsis wroughtoni* Desneux (Imms, 1919), a true *costal vein* emerges behind the humeral plate and runs

along the anterior border of the forewing. On its way to the humeral suture its course is marked by a row of 7-9 setae. It runs very close to the *subcosta* (*Sc.*) within the wing-scale.

(ii) *The subcosta* (*Sc.*).—The subcosta (postcosta of Fuller, 1919) is the second vein and forms the anterior articulation of the wing with the first axillary sclerite. It runs as a strongly chitinised ridge very close to the costa to slightly beyond the humeral suture. Then it separates, to run for a short course to merge again in the costa at about 1/6th of the entire wing-length. It remains unbranched throughout its course.

(iii) *The radius group.*—This vein consists of two stems (in *Archotermopsis wroughtoni* Desneux it has 3 stems, Imms, 1919). Since each of the two stems is multi-branched, it is difficult to name all of them. However, the first stem may be called the *radius* (*R.*) and the second the *radial sector* (*Rs.*). Their course is as follows : (a) *The radius.*—It originates behind the subcosta in the distal median plate and gives off 2-4 anterior branches outside the humeral suture to the costa before it finally merges into the latter at about the middle of anterior border of the wing. (b) *The radial sector.*—It also starts from the distal median plate and runs straight outwards till about 1/3rd of the wing-length before it gives off its first anterior branch to the costa. It gives off a variable number of anterior and posterior branches—3-6 anterior and 3-5 posterior branches. The anterior branches may further subdivide before they merge into the costa. Of the posterior branches, the proximal ones are usually atrophied and may anastomose among themselves or with the media. Three or four of the posterior branches may reach the posterior margin of the wing.

(iv) *The median vein* (*M.*).—The median vein (pseudomedia of Fuller, 1919) arises at the base of the radial sector in the wing-scale and remains closely approximated to the latter upto the humeral suture ; then it separates. The vein is hyaline and slender, as in *Archotermopsis wroughtoni* Desneux (Imms, 1919). It forks about the middle of the wing and each branch may further branch dichotomously before it reaches the posterior border, thus giving off a total of 3-6 branches.

(v) *The cubitus* (*Cu.*).—It starts immediately behind the median vein, but becomes a distinct entity only outside the humeral suture. It is a multi-branched vein, like the radius, and gives off 9-12 posterior branches. Of these, the proximal three may unite at their apices. The other branches may further branch dichotomously.

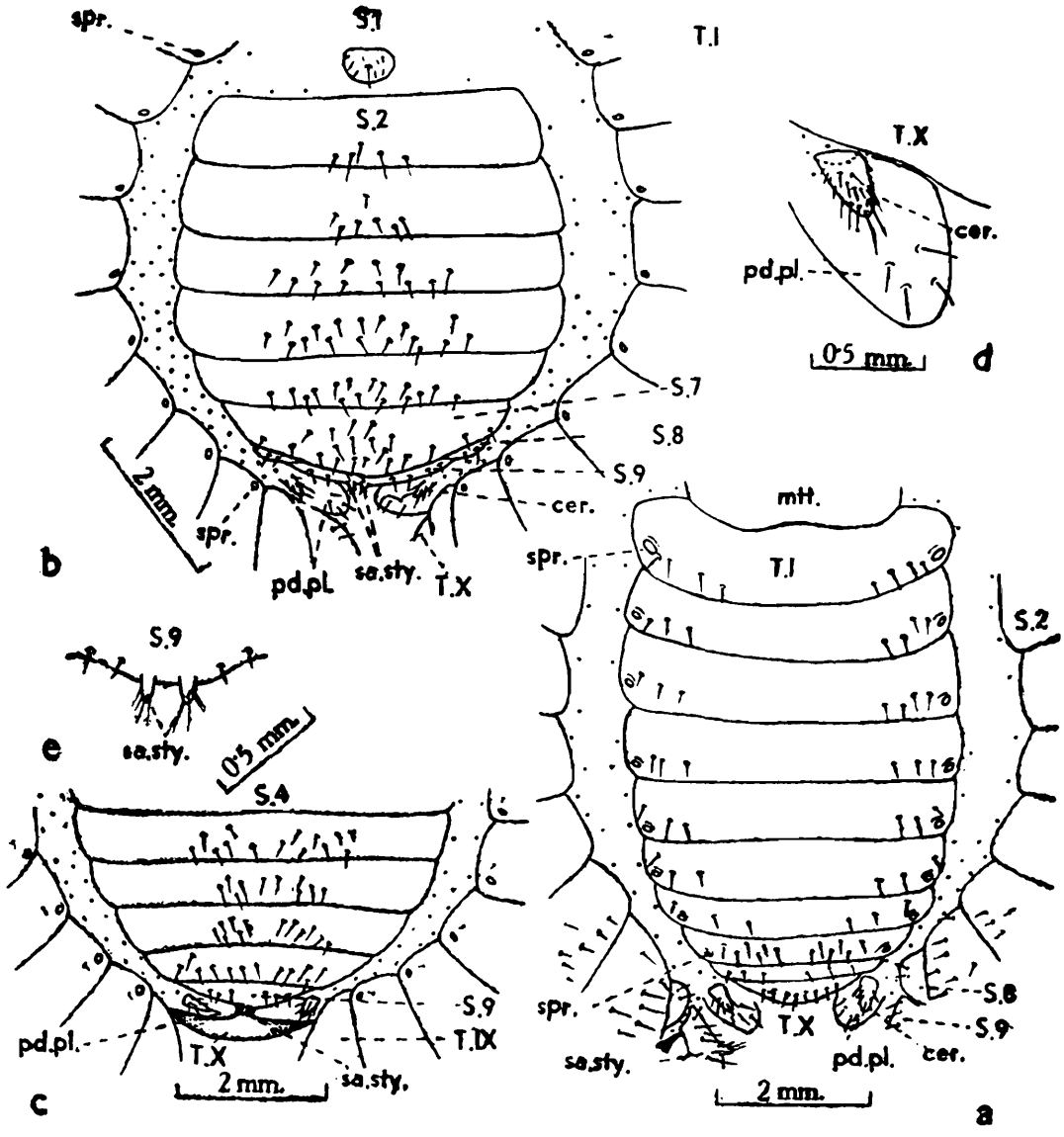
The vena dividens (*v.d.*).—It is in the form of an oblique groove separating the *anal lobe* (*a.f.*) from the costal. It runs from the base of the anal lobe to the posterior border within the wing-scale.

The anal lobe or clavus (*a.f.*) is a strongly arched plate as in Blattids. There are no anal veins in the forewing.

3. *The hind-wing* (Text-fig. 6*c* and *d*).—

The hindwing scale (*h.w.s.*).—Like the forewing scale it is also subtriangular but smaller in length, measuring about 1·1-1·2 mm. along the median vein, this being 1/18th to 1/20th of the entire wing-length. The humeral suture is not distinctly seen and can be imagined to run along the constrictions in the major veins such as the *anal* (*A.*), cubitus, radial sector and radius. There is no constriction in the costa and the subcosta.

Venation.—The *costa* and the *subcosta* take their origin in the wing-scale as in the forewing, and remain closely approximated in the wing-scale. Outside the humeral suture the subcosta gets separated for a short distance and remains unbranched. The *radius* (*R.*) gives off 2-3 anterior branches to the costa. The *radial sector* (*Rs.*) gives off 4-6 anterior and 3-5 posterior braches ; some more basal posterior branches atrophy and anastomose among themselves or with the median. Unlike the forewing, the *median* (*M.*) takes its origin from the radial sector outside



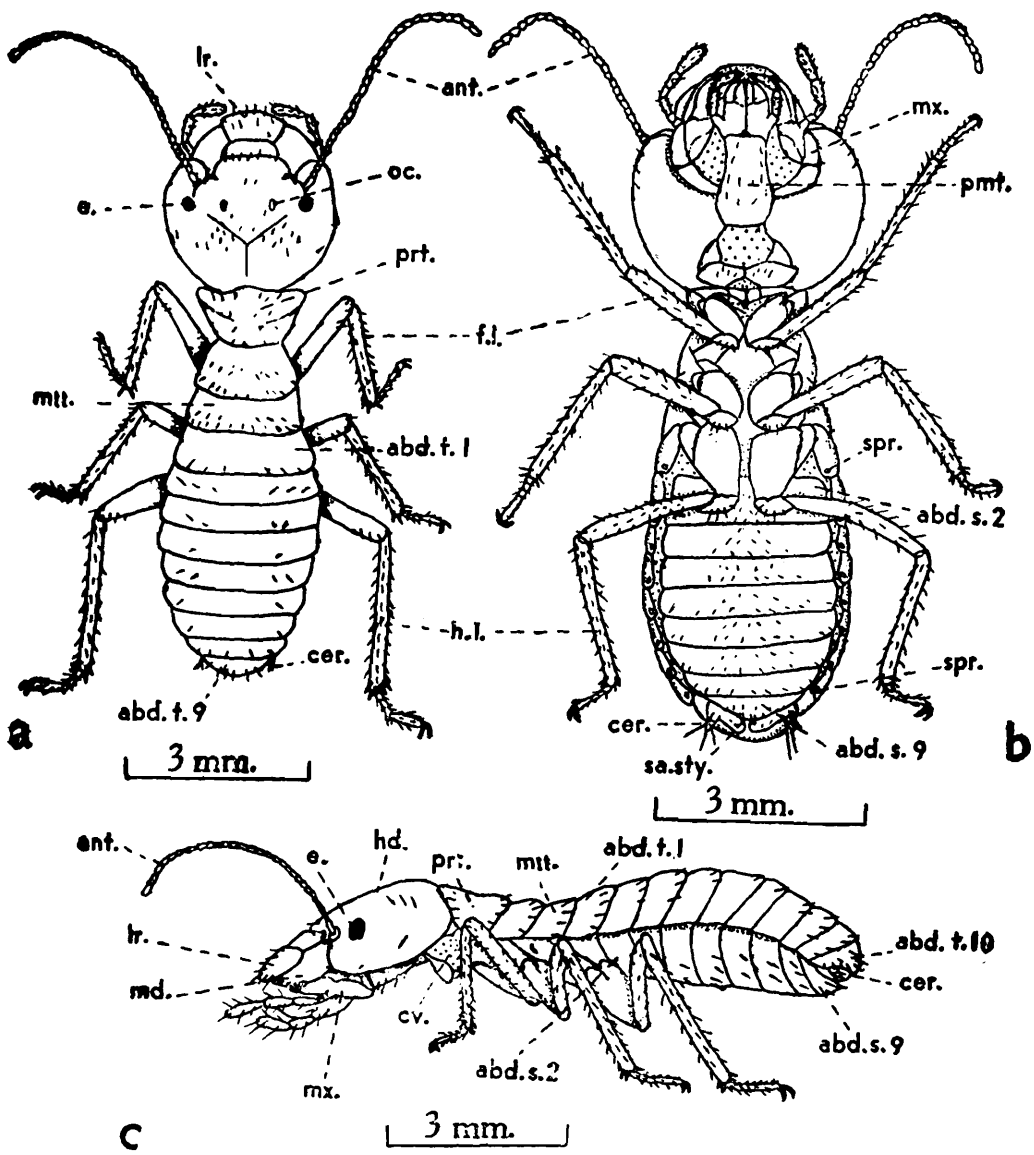
TEXT-FIG. 7.—*Anacanthotermes macrocephalus* (Desneux). Alate caste.
(*a*). Tergites of the abdomen of a female with sternites cut medially and spread on either side, in dorsal view. (*b*). Abdominal sternites of a female with the tergites cut medially and spread on either side, in ventral view. (*c*). Posterior abdominal sternites of a male with tergites cut medially and spread on either side, in ventral view. (*d*). Cercus of a female. (*e*). Subanal styles of a female.

the humeral suture. After running for about 2/3rds in length it gives off 2-3 branches which may again subdivide. Basally along its course it gives off a number of anterior branches which anastomose with the proximal posterior branches of the radial sector. The *cubitus* (*Cu.*) gives off 9-12 branches, all running to the posterior border of the wing ; each of the branches may further subdivide. Of these, the first 3 or 4 atrophy and anastomose amongst themselves.

The *vena dividens* (*v.d.*) is an insignificant anal furrow and does not reach the posterior border of the wing-scale. The length of the area is nearly half of that of the forewing. The *anal vein* (*A.*) comes out of the anal lobe as a prolongation of the latter, enters the lamina and fuses with the posterior basal branches of the cubitus.

(g) *The abdomen*
(Text-fig. 7)

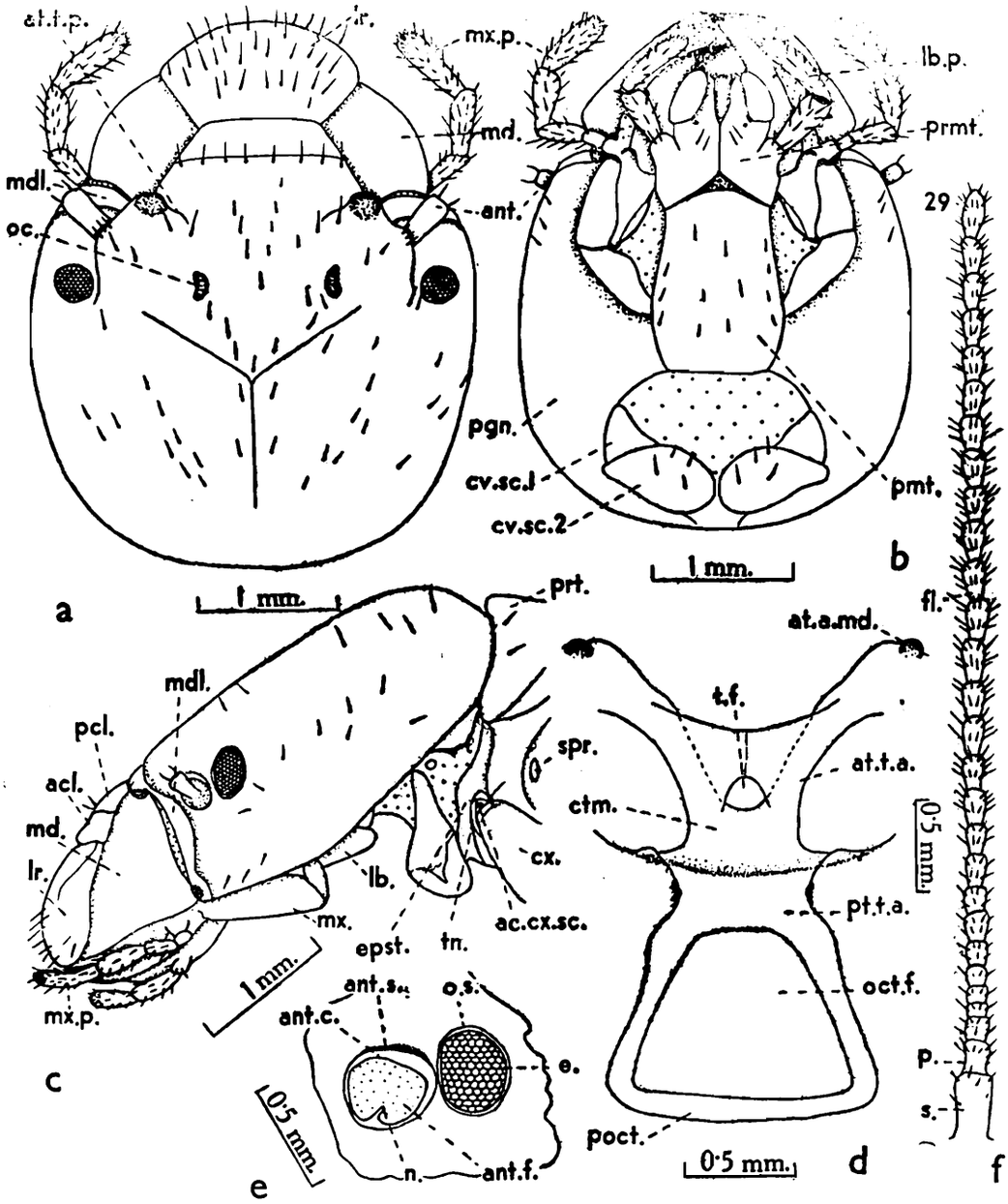
The abdomen has ten segments which have the same arrangement of tergites and sternites as in the soldier. It is broadly united with the thorax



TEXT-FIG. 8.—*Anacanthotermes macrocephalus* (Desneux). Worker caste. (*a*). Whole body in dorsal view. (*b*). Ditto, in ventral view. (*c*). Ditto, in lateral view.

and measures in males 6·0—6·3 mm. in length and 3·3—3·7 mm. in width, and in females 6·0—6·7 mm. and 3·2—3·5 mm., respectively. The tergal plates show comparatively uniform chitinisation. The second sternite has a median longitudinal flexure as in the soldier. In females the arrangement of sternites is different from the males. The VII sternite (the *hypogynium* or the *genital plate*) is greatly enlarged so as to cover the VIII and greater part of the IX sternite. The VIII sternite or the

paragenital plates, partly visible laterally, are divided into two plates lying apart from each other. In males, the VII sternite is not enlarged. The VIII sternite is entire, and, together with the IX sternite, lies exposed. In both the sexes the IX sternite bears a pair of unsegmented. setose and submarginal *subanal styles* (*sa. sty.*) and the X sternite is divided laterally into two lobes, the *paraprocts*. At their basal membrane the latter carry one pair of unsegmented *cerci* which bear longish setae.



TEXT-FIG. 9.—*Anacanthotermes macrocephalus* (Desneux). Worker caste. (*a*). Head, in dorsal view. (*b*). Head, in ventral view. (*c*). Head along with cervvix, in lateral view. (*d*). Tentorium, in dorsal view. (*e*). Part of cranium, showing left antennal and ocular sclerites. (*f*). Right antenna, showing 29 segments.

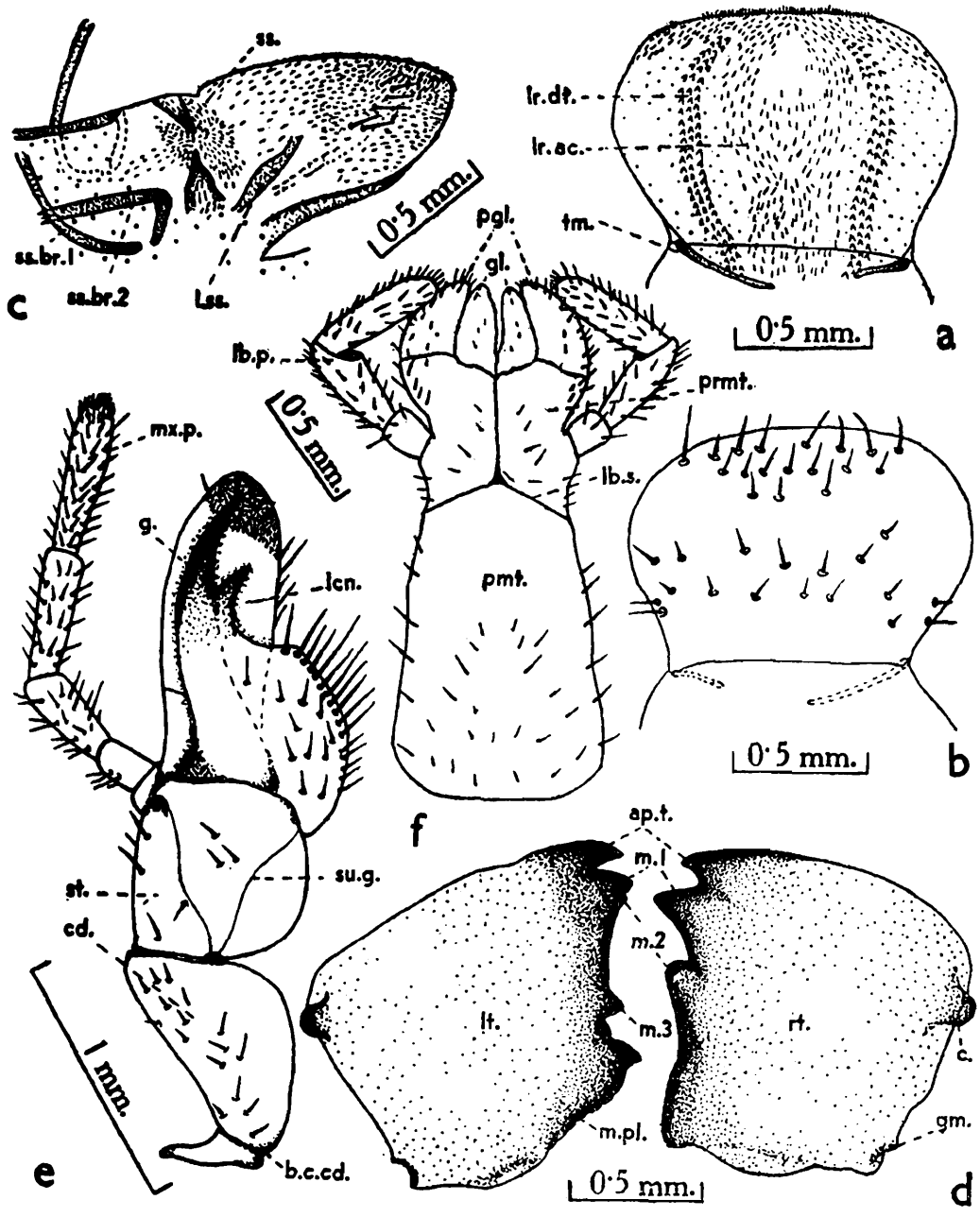
IV—EXTERNAL MORPHOLOGY OF THE WORKER CASTE

(a) *General*

Pigmentation is the poorest in this worker caste. The head is paler than in the alate. The *pronotum* is better chitinised than other thoracic

and abdominal tergites which are dirty white and translucent and appear slaty grey, on account of the contents of the alimentary canal being visible. On the ventral side the same condition occurs.

The setae are more numerous and longer than in the alates. The body length varies from 6·5-10·2 mm., and the sexes, if existent, are indistinguishable externally.



TEXT-FIG. 10.—*Anacanthotermes macrocephalus* (Desneux). Worker caste.

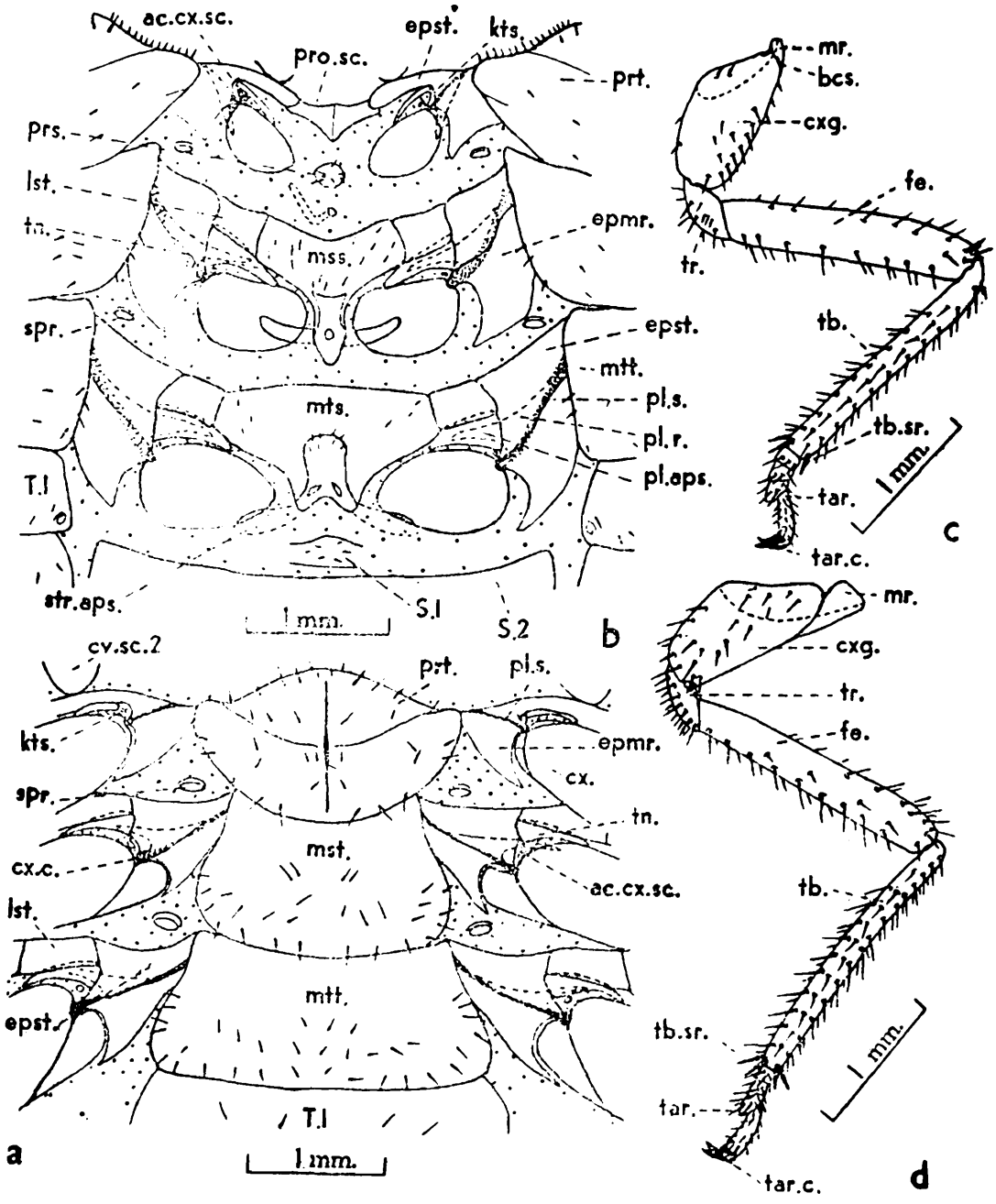
(*a*). Labrum, in ventral view. (*b*). Labrum, in dorsal view. (*c*). hypopharynx, in dorso-lateral view. (*d*). Left and right mandibles. (*e*). Right maxilla, in ventral view. (*f*). Labium, in ventral view.

(b) *The head-capsule and appendages*

(Text-figs. 8, 9 & 10)

In form, size, relation to the long axis of the body, the cranial sutures, the cranial areas, the attachment of various appendages such as the antennae, labrum, mandibles, maxillae, labium, hypopharynx, etc., and

in other structures like the tentorium, eyes, ocelli, etc., the workers, very closely resemble the alates. The mandibles in workers do not cross over each other but lie apposed, the left one being a little dorsal to the right. The antennae have 25-30 segments. Each of the two compound eyes has about 100 facets and the ocelli-like spots are seen in the same position as in the soldier and alate forms.



TEXT-FIG. 11.—*Anacanthotermes macrocephalus* (Desneux). Worker caste.

(*a*). Dorsal and lateral sclerites of the thorax with the sternites cut medially and spread on either side, in dorsal view. (*b*). Ventral and lateral sclerites of the thorax with tergites cut medially and spread on either side, in ventral view. (*c*). Left fore-leg in ventral view. (*d*). Left middle-leg in ventral view.

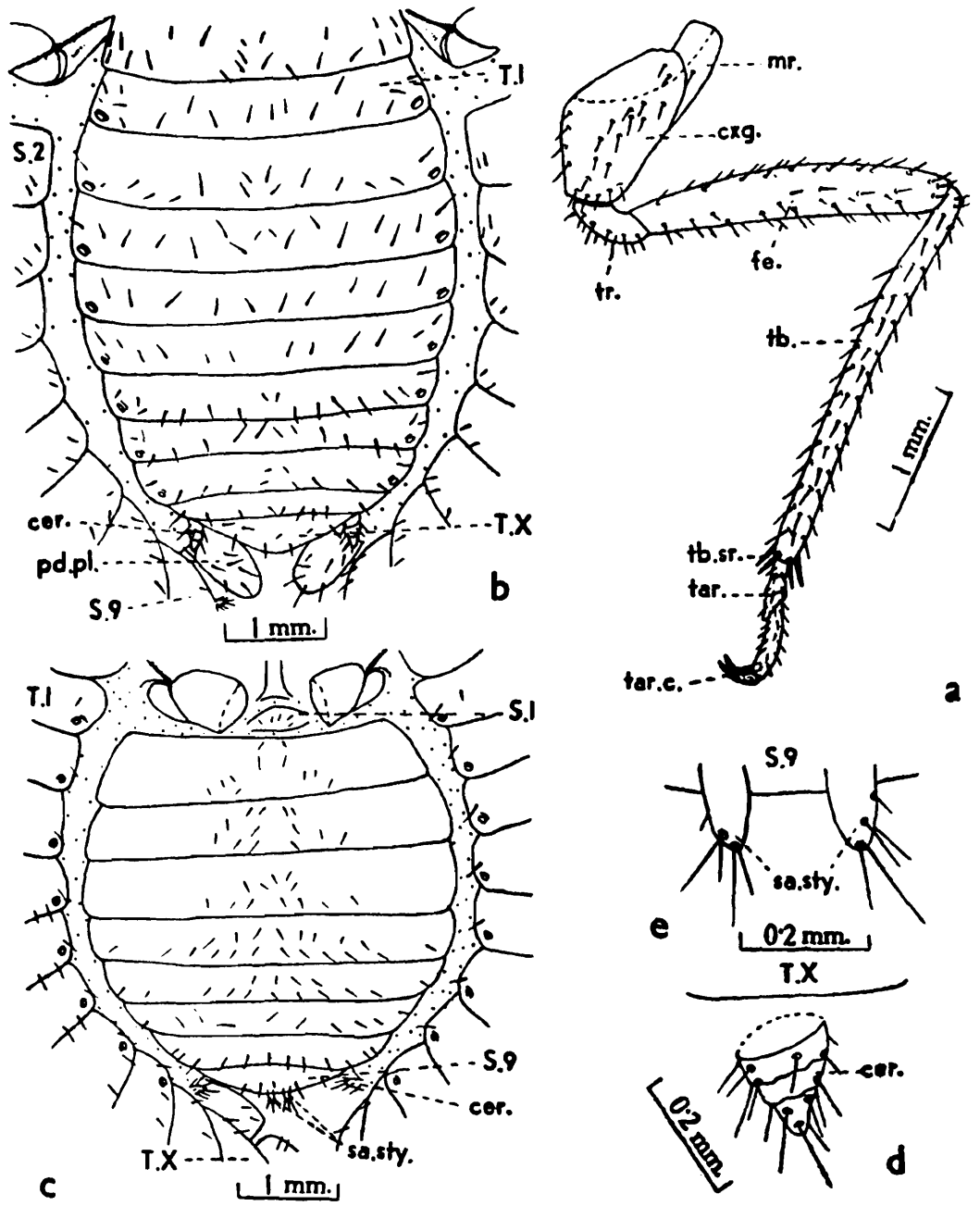
(c) *The neck*

In all essential respects, the neck resembles that of the soldier, and a detailed description is unnecessary.

(d) *The thorax and the abdomen*

(Text-figs. 11 & 12)

The thorax and the abdomen, in respect of tergites, sternites, legs, spiracles, and subanal styles, closely resemble those of the soldier. The *cerci* (Text-fig. 12*d*) here are 3-segmented, unlike those in the alate and soldier castes.



TEXT-FIG. 12.—*Anacanthotermes macrocephalus* (Desneux). Worker caste. (*a*). Left hind-leg, in ventral view. (*b*). Abdominal tergites with ventral sclerites cut medially and spread on either side, in dorsal view. (*c*). Abdominal sternites with dorsal sclerites cut medially and spread on either side, in ventral view. (*d*). Cercus. (*e*). Subanal styles.

V—SUMMARY

1. The external morphology of the alate and the worker castes of *Anacanthotermes macrocephalus* (Desneux) is described.

2. The head in both the castes is hypognathous and the mouth-parts are in the same relative position as in the soldier. The sutures are ill-defined or absent. Unlike the soldier caste, the gular suture is absent and the intraclypeal suture is present.

3. The somewhat asymmetrical mandibles are modified for crushing and chewing. In both castes the labrum is comparatively larger than in soldiers and on the under surface possesses two types of cuticular processes, *viz.*, (i) peg-like denticles arranged in two longitudinal stripes ; and (ii) spine-like aculei. The maxillae and labium differ from those of the soldier in minor details. A pair of compound eyes and a pair of rudimentary ocelli-like spots are present as in the soldier. The fontanelle is absent. The moniliform antennae have 28-29 segments in the alates and 25-30 segments in the worker caste. The tentorial bridge of the tentorium is represented by a narrow transverse bar in both the castes.

4. The neck in both the alates and workers resembles that in the soldiers.

5. The prothoracic sclerites in both the alates and workers very closely resemble those in the soldiers.

6. In the alates the meso- and metathoracic segments constitute the pterothorax. The sclerites in these two segments differ markedly from those in the soldiers and workers in both number and structure ; this is on account of the presence of the two pairs of wings and their articulation with the body. There are two pairs of epipleurites (parapteron of some authors) and three pairs of axillary sclerites. There is a small additional sclerite between the third axillary and the anal lobe of the forewing.

7. The pro-, meso-, and metathoracic sclerites in the worker caste closely resemble those of the soldier.

8. The two pairs of wings are subequal and deciduate. The venation in the fore- and hindwings is slightly variable. In the forewing, the costa is marginal, the subcosta is unbranched and closely approximated to the costa ; the "radial vein" has two stems, the radius and the radial sector, each stem being multibranched ; the median vein, arising from the second stem of the radial inside the humeral suture, has three or more branches ; the cubital vein is multibranched, with 9-12 branches. However, the forewing differs from the hindwing in having (i) a larger wing-scale, (ii) a distinct spur-like humeral plate, (iii) a larger anal lobe, (iv) a very distinct *vena dividens*, and (v) a more clearly demarcated humeral suture. It further differs from the hindwing in the absence of anal vein which in the latter anastomoses with the proximal branches of the cubitus.

9. The three pairs of thoracic legs resemble those of the soldier in both the castes.

10. The abdomen in both the castes has ten segments and a pair of setose unsegmented styles, as in the soldiers. The cerci in workers are 3-segmented, unlike those in the alates and soldiers where they are unsegmented.

11. The sexes are distinguishable externally in alates only. In alates the VII sternite is larger in females and covers the VIII sternite and partly the IX sternite. The VIII sternite is divided into two plates, lying apart. In males the VIII sternite is entire and exposed.

12. In the worker caste the number of tergites and sternites is the same as in the soldier.

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VII—ABBREVIATIONS USED IN THE TEXT-FIGURES

A., anal vein of wing.

abd., abdomen.

abd. s. 1, abd. s. 2, etc., abdominal sternites.

abd. t. 1, abd. t.2 , etc., abdominal tergites.

ac. cx. sc., accessory coxal sclerite.

acg., acrotergite.

acl., anteclypeus.

acs., antecostal suture.

a.f., anal field of wing.

a. n. p., anterior notal process of meso- and metanotum.

ant., antenna.

ant. c., antennal carinae.

ant. f., antennal foveolae.

ant. s., antennal suture.

ap. t., apical tooth of the mandible.

aps., apophysis (of any body-part).

at., anterior.

at. a. md., anterior articulation of the mandible.

at. t. a., anterior tentorial arm.

at. t. p., anterior tentorial pit.

1 ax., 2 ax., 3 ax., 4 ax., first, second third and fourth axillary sclerite of wing joint.

ax. c., axillary cord of meso- and metanotum.

b. c. cd., basal condyle of the cardo.

bcs., basicostal suture of coxa.

b. sc., basalar sclerite of wing joint.

C., costal vein of wing.

c., condyle of mandible.

cd., cardo.

cer., cercus.

cl., clypeus.

cr. a. md., cranial articulation of the mandible.

C+Sc., Costal subcostal vein.

ctm., corporotentorium.

Cu., cubital vein of wing.

Cu. 1, Cu. 2, etc., branches of the cubital vein of wing.

cv., cervix.

cv.sc. 1, first or anterior cervical sclerite.

cv.sc. 2, second or posterior cervical sclerite.

cv.sc. 3, third or dorsal cervical sclerite.

cx., coxa.

cx. c., coxal condyle.

cxg., coxa genuina.

cx. pr., coxal process.

e., eye.

epmr., epimeron.

ep. pl., epicranial plate.

ep. s., epircanial suture.

epst., episternum.

fe., femur

fl., flagellum of antenna.

f. l., foreleg.

fr., frons.

f. w., fore wing.

f. w. s, fore-wing scale.

fx. pl., flexor plate (between claws and distitarsus).

g., galea.

gl., glossa.

gm., ginglymus.

gn., genae.

hd., head.

hd. c., head-capsule.

hl. pl., humeral plate of wing joint.

h. s., humeral suture of wing joint.

h. w., hind wing.

h. w. s., hind-wing scale.

hyp., hypopharynx.

i. cl. s., intra-clypeal suture.

i. pl., incisor lobe of the mandible.

kts., katepisternum.

la., lamina of wing.

lb., labium.

lb. p., labial palp.

lb. s., labial suture.

lcn., lacinia.

lgl., ligula.

lr., labrum.

lr. ac., labral aculei.

lr. dt., labral denticles.

lr. s., labral suture.

lss., lateral sclerite of hypopharynx.

lst., latero-sternite.

lt., left.

M., median vein.

M. 1, M. 2, etc., branches of the median vein of wing.

m. 1, m. 2, m. 3, marginal teeth of the mandible.

md., mandible.

mdl., mandibularia (or trochantin of mandible).

m. pl., molar plate of mandible.

med. pl. 1, proximal median plate of wing joint.

med. pl. 2, distal median plate of wing joint.

mr., meron.

mss., mesosternum.

mst., mesonotum.

mts., metasternum.

mtt, metanotum.

mx., maxilla.

mx. p., maxillary palp.

oc., ocellus.

oct., occiput.

oct. f., occipital foramen.

o. s., ocular suture.

p., pedicel of antenna.

pcl., postclypeus.

pcx., precoxale.

pd. pl., podical plates.

pgl., paraglossa.

pgn., postgenae.

pl. r., pleural ridge.

pl. s., pleural suture

pl. aps., pleural apophysis.

pl. w. p. pleural wing process.

pmt., postmentum.

p. n. p., posterior notal wing process.

poct., postocciput.

poct. s., postoccipital suture.

prmt., prementum.

pro. sc., prosclerite.

prph., prephragma.

prs., prosternum.

prt., pronotum.

pt., posterior.

pt. t. a., posterior tentorial arm.

pt. t. p., posterior tentorial pit.

R., radius vein of wing.

r., ridge.

Rs., radial sector vein of wing.

Rs. 1, Rs. 2, etc., branches of the radial sector vein of wing.

rt., right.

S. 1, S. 2, S. 3, etc., sterna 1-10.

s., scape.

sal. sc., subalar sclerite.

sa. sty., subanal styles.

Sc., subcostal vein of wing.

scl., scutellum.

sct., scutum.

sgn. r., subgenal ridge.

sp., spine.

sp. s. 1, sp. s. 2, first and second spina-sternum.

spr., spiracle.

ss., suspensoria (sclerites associated at the base of hypopharynx).

st., stipes.

str. aps., sternal apophysis.

su. g., sutural groove of stipes.

T., tergum.

T. I, T II, .T. X, terga first, second, and so on up to tenth.

tar., tarsus.

tar. c., tarsal claw.

tb., tibia.

t. b., tentorial bridge.

tb. sr., tibial spur.

t. f., tentorial foramen.

tg., tegula.

th., thorax.

tm., torma.

tn., trochantin of leg.

tr., trochanter.

v. d., vena dividens.

w. s., wing scale.

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I. Invertebrate Division

(Superintending Zoologist — Dr. B. S. Chauhan)

1. **Protozoology Section**	Zoologist : Shri K. K. Mahajan	Shri K. K. Mahajan (Officer-in-Charge)
2. **Helminthology Section**	Zoologist : Dr. P. D. Gupta Asstt. Zoologist : Shri S. Biswas*	Dr. P. D. Gupta (Officer-in-Charge)
3. **General Non-Chordata Section**	Zoologist : Vacant Asstt. Zoologist : Shri T. D. Soota	Shri K. S. Pradhan (Officer-in-Charge)
4. **Crustacea Section**	Zoologist : Shri G. Ramakrishna	Shri G. Ramakrishna (Officer-in-Charge)
5. **Mollusca Section**	Zoologist : Dr. H. C. Ray Asstt. Zoologist : Shri A. S. Rajagopalaiengar	Dr. H. C. Ray (Officer-in-Charge)

II. Entomology Division

(Superintending Zoologist — Vacant)

1. **Insect Section** .	Zoologist : Shri K. S. Pradhan Zoologist : Vacant Asstt. Zoologist : Shri G. Mathai Asstt. Zoologist : Shri T. G. Vazirani Asstt. Zoologist (2) : Vacant	Dr. A. P. Kapur (Officer-in-Charge)
2. **Arachnida Section**	Zoologist : Shri B. K. Tikader	
3. **Termite Research Unit**	Jr. Research Officer : Shri Om Bahadur Chhotani	

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* Indicates officers transferred to Regional Stations.

III. Lower Chordata Division

(Superintending Zoologist Vacant)

1. **Marine Fish Section**	Zoologist : Dr. A. G. K. Menon	Dr. A. G. K. Menon (Officer-in-Charge)
2. **Freshwater Fish Section**	Zoologist : Dr. K. C. Jayarama-krishnan	Dr. K. C. Jayarama-krishnan (Officer-in-Charge)
3. **Protochordata and Amphibia Section**	Zoologist : Km. M. B. Kripalani	Km. M. B. Kripalani (Officer-in-Charge)

IV. Higher Chordata Division

(Superintending Zoologist Dr. K. K. Tiwari)

1. **Reptilia Section**	Zoologist : Shri M. N. Acharji	Shri M. N. Acharji (Officer-in-Charge)
2. **Birds Section**	Zoologist : Dr. B. Biswas	Dr. B. Biswas (Officer-in-Charge)
3. **Mammals and Osteology Section**	Zoologist : Vacant Asstt. Zoologist : Vacant	
4. **Prehistoric Zoology Section**	Vertebrate Zoologist : Shri Bhola Nath	Shri Bhola Nath (Officer-in-Charge)

V. Other Scientific and Technical Branches

1. **Taxidermy and Museum Section**	Curator : Shri B. S. Lamba Asstt. Curator : Shri A. K. Mukherjee* Shri Syed Mohammed Ali	Shri B. S. Lamba (Officer-in-Charge)
2. **Marine Survey Unit**	Zoologist : Dr. A. Daniel Asstt. Zoologist : Vacant	Dr. A. Daniel (Officer-in-Charge)
3. **Animal Population Studies Unit**	Zoologist : Vacant Asstt. Zoologist : Vacant	
4. **Documentation Unit**	Documentation Officer : Vacant	

* Indicates officers transferred to Regional Stations.

VI. Regional Stations of the Zoological Survey of India

1. Eastern Regional Station, Z.S.I., Shillong . .	Zoologist : Dr. K. Reddiah	Dr. K Reddiah (Officer-in-Charge)
2. Western Regional Station, Z.S.I., Poona . .	Zoologist : Shri B. K. Tikader	Shri B. K. Tikader (Officer-in-Charge)
3. Central Regional Station, Z.S.I., Jabalpur . .	Zoologist : Shri H. Khajuria	Shri H. Khajuria (Officer-in-Charge)
4. Northern Regional Station, Z.S.I., Dehra Dun . .	Zoologist : Vacant Asstt. Curator : Shri A. K. Mukherje	Shri A.K. Mukherjee (Officer-in-Charge)
5. Desert and Gangetic Plains Regional Station, Z.S.I., Jodhpur . . .	Zoologist : Vacant Asstt. Zoologist : Shri S. Biswas	Shri S. Biswas (Officer-in-Charge)