A NEW CARTON-BUILDING SPECIES OF ANT IN SOUTH INDIA

CREMATOGASTER DOHRNI ARTIFEX, MAYR.

BY

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(*With four plates*).

INTRODUCTION.

This remarkable species of arboreal ant was discovered by the writer for the first time in S. India in the Sirumalai hills in the vicinity of Dindigul town at an elevation varying from 2,500 ft. to 3,000 ft. While on a brief visit to those tracts with a party of Agricultural Students, early in January 1935, these insects attracted his attention by the huge globular dark brown nests, about the size of a foot-ball, attached to branches of various trees on either side of the track at a height of about eight to nine feet from the ground. Those spherical enclosures were conspicuous in appearance and were built round and embracing some fairly stout and healthy branches of certain trees. Besides the larger branches, several smaller ones passed right through the nests giving them additional support. The nests, which were full of ants at the time of collection, were singular both in the material used in construction and in their architecture; and the writer was naturally struck with admiration at the wonderful foresight and great ingenuity displayed in their construction.

The inhabitants of these curious nests are neither large nor attractive in appearance. The ant concerned is comparatively a very small one, ferrugineous in colour and varying in size from 3 to 5 mm.; but it is certainly one of the most skilful and talented of all the tribes. The head is somewhat larger and square and the thorax is provided at the hind part with a pair of prominent sharp spines. A slender nodulose waist or pedicel connects the flat triangular abdomen to the thorax. The abdomen itself is a shade darker than the rest of the body and is often held bent over and between the spines. The body has a thin covering of abundant fine silky pubescence. So far as is known there is no published record of this species in S. India and probably this is the first record of its occurrence in this country.

Since very little is known about this species of ant an attempt was made to make a thorough study of its biology and habits. With this end in view fresh nests were obtained from the same locality and were kept for observation and study for months together. Some experiments were also conducted to elucidate the natural history of the species concerned.

The Nest.

In South India the species is probably confined to the Sirumalai hills since no records of its capture from any other locality are to be found. The nests are fairly abundant in the wooded parts of those hills. They are very nearly globular enclosures built around branches. Generally the site chosen for their construction is at a point where one or more branches diverge. The main branch around which the nest is built does not necessarily run through the middle of it, and rarely exceeds $1\frac{1}{2}$ in. in diameter. Several smaller branches are often included in the formation of the nest and these vary in diameter from $\frac{1}{10}$ to very nearly $\frac{3}{4}$ of an inch. The supporting branches are all sound and healthy and bear good green foliage, and, therefore, no direct damage is apparently caused to that part of the branch where the nest is located.

Shape and colour.—The nests are generally globular, subspherical or ellipsoidal, but may vary from oblong to cylindrical in some exceptional cases (photographs). They are good, solid nests having the appearance and colour of decomposed and dried cow-dung. The general colour is dusky or dark brown with the hardness and consistency of crude card-board.

Size.—The largest nests are about the size of an ordinary foot-ball the maximum length and thickness noted being 12 and 9 in. respectively; but there is a considerable range of variation in size and in shape. The following measurements of half a dozen nests may furnish a good idea of the extent of this variation.

Shape	Length	Thickness
1. Largest size, more or less ovoid (Pl. I)	$11\frac{1}{2}$ inches	$9\frac{1}{4}$ inches
2. Elongate cylindrical, one end broadly rounded and the other less obtusely rounded	12 ,,	7 ,,
3. Ellipsoidal nest Fig. 2	$7\frac{1}{2}$,,	$5\frac{1}{2}$,,
4. Medium size—oblong	11 ,,	6 ,,
5. Small round—subspherical ...	6 ,,	5 ,,
6. Small size, slightly damaged ...	4 ,,	3 ,,

External Architecture.—The nest is made up of a multitude of thin rough, very often leaf-like sheets, composed of a material which has the appearance (as mentioned already) of dried cow-dung. The outer envelope is more or less uniform, but at irregular intervals on the surface there are numerous convex bulges in the form of irregular blisters. These blisters or projections, on careful examination were found to be eave-like extensions with small arched openings on their under surface. These openings are gateways for the ingress and egress of the ants; they are

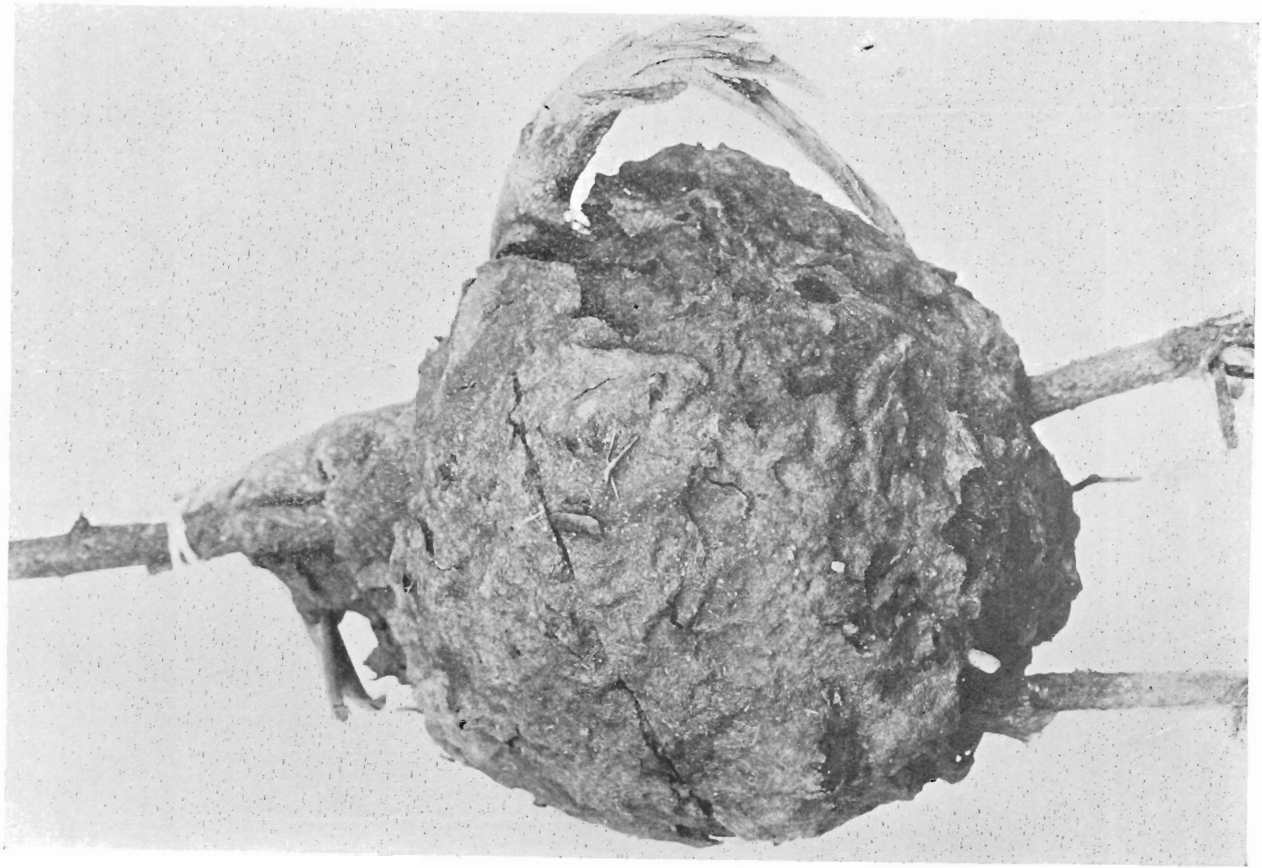

Fig. 1.—Carton nest of *Crematogaster dohrni artifex*, Mayr.

semicircular, but present no regularity in size or shape. They vary in size with a width and height ranging from 3 to 8 mm. and are big enough to allow the passage of half a dozen workers as also the winged sexual forms. The outer sheet or covering may not be entirely continuous and unbroken all round the spherical body of the nest. The upper portions may have a stronger and thicker covering due to the presence of more than one layer of convex sheets extending irregularly down the surface. The convex elevations and apertures are generally less numerous on the upper surfaces. This covering is nearly as efficient as the rest of the nest both in durability and hardness. On making a slight breach in the outer envelope, the interior of the nest is seen to present somewhat the appearance of a large sponge built out of several layers of leaf-like sheets. These convex sheets are arranged one over the other with interspaces enclosing a comb-like mass of passages and a labyrinth of covered ways leading in different directions. This arrangement may be compared to the irregular old-fashioned piling of heaps of tiles on the roofs of Indian houses.

Internal architecture.—A vertical or transverse section carefully cut through the nest by means of a fine small saw will reveal the nature of its internal structure (Photograph Fig. 3). The interior is seen crowded with irregular anastomosing galleries comprising small halls and corridors varying from 2 to 9 mm. in diameter. They lead in different directions and are formed by side walls and partitions built of the same material as the nest disposed in thin layers. Not infrequently a whole or portion of a dried leaf is taken advantage of to assist in making this labyrinth of chambers. Occasionally such leaves are covered or coated with this papery material. These galleries and chambers are the abodes of the members of the community and the nurseries of their brood wherein all functions and activities of the community are carried out. From an examination of a number of nests and their internal chambers it would appear that there are no separate specialised chambers for the different categories or castes of the colony. But this much can be ascertained, generally the eggs and young larvae are distributed more towards the inner recesses and the pupae and the teneral adults are located near the outer chambers, passages and halls. The winged males are also met with in chambers near the periphery of the nest. The queens and workers throng the interior of the entire nest. No specially enlarged cells or chambers, set apart for queens, were noticed. In these and other respects the mode of architecture and allocation of quarters differ from certain other groups of social insects like bees or termites.

Nest material.—The 'carton' manufactured by the ants for building their nests is a combination of several substances. A variety of raw material is used in the making. Wood scrapings, dust, fibre, leaf particles, scraps of bark, a little earth, and grains of sand all apparently go into its composition. The sharp mandibles and other mouth parts of the ants are the machinery employed in its manufacture. The raw material is chewed and

with the help of a secretion from the salivary glands worked up into a kind of paste; probably faecal and proctodial matter are also employed in the mixture. Thus is produced the woody composition, sufficiently hard and strong when dry, with which the nests are built. It is a hard compact material, which though somewhat brittle, yet retains some flexibility which it owes probably to the glandular secretions which enter into its composition. On the whole the 'carton' is more or less proof against rough weather. The nests withstand the rain though the outer layers become softened. That these nests are weatherproof was fully demonstrated by the nests experimentally grafted on to trees in the College grounds where they were exposed to the full force of the monsoon. The inhabitants equally survived the complete immersion of their nests in water.

The 'carton' has been subjected to a process of chemical analysis[1] and the following account may provide additional data as to its composition:—

1.	Moisture	10·00
	Dry basis	
2.	Loss on ignition—organic matter	81·20
3.	Insoluble mineral	2·77
4.	Soluble mineral matter by difference	16·03
	Total ...	100·00

Qualitative tests carried out with an hydrochloric acid extract indicated the presence of the following acids and bases among others:—

1. Phosphoric acid (P_2O_5.)
2. Sulphuric acid (SO_3).
3. Iron and Alumina ($Al_2O_3 + F_2O_3$).
4. Lime (CaO).
5. Potash (K_2O).

About 80·1 of the total dry matter of the nest consists of organic matter and it is probable that very nearly the whole of it is derived from plant materials such as leaves, twigs, bark etc. About 80·85 per cent. of the total mineral matter is acid soluble and the rest comprises insoluble sand. The fact that sand forms such a small fraction of the total mineral matter may suggest that the minerals are all derived from vegetable matter alone and no earth as such enters into the composition of the nest material. The material is strong, tough and hard and is insoluble in water.

The flakes comprising the material of the nest are hard, firm and strong though brittle. The material from which they are built appears to be impervious to water vapour or even to water. Two pieces of carton taken from a nest were placed in test tubes where one flake was brought into direct contact with the water and the other suspended above it so that the aqueous vapour might affect it. At the end of 24 hours there was no appreciable change in the weight of the flake suspended above the water while the flake brought into direct contact with the water showed a very slight loss. The experiment indicates a high degree of compactness and the absence of porosity in the carton despite its apparent thinness. The waterproof condition of the carton may arise from a coating of the glandular secretion applied by the ants over its surface and the secretion thus forms a cement-like coating which protects the nest during the continuous rains of the monsoon.

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[1] The writer is indebted to Mr. Varahalu, Assistant to the Agriculturai Chemist, for the chemical analysis and his thanks are herein recorded.

Tests with the following reagents on the flakes as also on powdered material were conducted:—

1. Dilute caustic potash—decinormal solution.
2. Dilute sulphuric acid—decinormal solution.
3. Water (hot and cold).
4. Sulphuric ether—decinormal solution.
5. Ethyl alcohol (98 per cent.).
6. Chloroform.
7. Carbon disulphide.
8. Acetone.
9. Benzol.
10. Nitrobenzene.
11. Pyridine.

After continuous shaking, these were kept overnight. They were filtered subsequently and the residues left over after evaporating the filtrates showed the presence of (1) vegetable colouring matter, (2) fats and waxes. Of the numerous solvents tried, pyridine extracted the largest amount of these substances from the material. This was highly resinous and extremely sticky. While shaking with pyridine, the material gradually tended to disintegrate and soften. It lost its original firmness. No such changes were however observable in the case of the other solvents. This points to the fact that the cementing secretion of the material is pyridine soluble. Neither dilute sulphuric acid nor water, hot or cold, softened the material. It retained its firmness even after 48 hours of soaking. Caustic alkali caused (1) the swelling of the material and (2) the gradual dissolution of it.

Construction.—The actual process of nest construction has not been observed. The workers, after selecting a suitable building site on a branch, probably spread the paste-like material in thin layers and so gradually build up their globular nests. The labour involved appears formidable but the industry and co-operation of myriads of workers finally produce a structure which cannot but rouse our admiration. Together they collect the raw substances and by their combined industry produce the most efficient non-conducting building material which is proof against the elements, and with this product they build themselves an edifice which is both a fortress and a home—suited to all their requirements.

Trees infested.—These exclusive tree-dwellers seem to be partial to a few trees commonly occurring in these hills as may be gathered from the statement furnished below. Among these the *Valichai* tree appears to be a particular favourite as may be inferred from the number of nests occurring on it as also from the maximum size these attain.

Scientific name	Vernacular name	Locality	Remarks
Gardenia lucida Roxb.	Valichai ...	Serumalai ...	Nest fairly common on branches, largest sized
Aphania bifoliata Radlk.	Kookaimuthu ...	,,	Less common
Ochna squarrosa Linn.	Chilandi ...	,,	Occasionally found
Ixora parviflora Vahl.	Kurachushundu.	,,	

OTHER KNOWN CARTON-BUILDERS.

Suspended carton nests are known to be built, according to Wheeler, by many species of ants all over the world and these mainly belong to the genera *Camponotus*, *Polyrhachis*, *Azetica*, *Dolichoderes*, *Crematogaster*, *Macronischa*, *Myrmecaria* and *Tetramorium*. Among these the genus *Crematogaster* includes the largest number of carton-building species.

Name of species	Locality	Authority
C. ranavalonæ	Madagascar island	Forel.
C. tricolor	,,	,,
C. schencki	,,	,,
C. inconspicua	Africa	Mayr.
C. marginata		
C. stadelmanni		
C opaciceps		
C. hova		
C. peringueyi		Smith
C. montezumia		
C sulcata	Tropical America	Forel
C. ramulinida		
C. sholli		
C. lincolata		

In India the only species so far noted to be carton-builders are *C. kerbyi*, *C. rogenhoferi* and *C. ebeninus* referred to by Rothney, Wroughton and Mayr. The species of ant under discussion *C. artifex* has been recorded as a carton-builder in Siam and Singapore by Mayr. The writer has not come across any record of this species from S. India.

Crematogaster dohrni artifex, Mayr.

The species concerned is *Crematogaster* (*Acrocoelia*) *dohrni artifex* Mayr. It belongs to the sub-family *Myrmecinae*, tribe—*Crematogastrini*, genus—*Crematogaster*, sub-genus—*Acrocoelia*, species—*dohrni* Mayr., sub-species—*artifex* Mayr., *Verh. Zool.-Bot. G.E.S. Wien*, vol. xxviii, p. 682 (1878).

Distribution.—This appears to be the first record of its occurrence in S. India and probably in India. As stated already the species has been recorded by Mayr. as occurring in Siam and Singapore.

The genus *Crematogaster* is a large one and comprises a number of species which are distributed over the whole of the warmer parts of the entire world. They possess the most varied habits. Some five species have been noted by the writer in S. India as common—*C. rothneyi*, *C. contempta*, *C. subnuda*, *C. antherícina*. But all these are quite different from the species under discussion particularly in their life economy and nesting habits. The species *C. rothneyi* is a near ally of *C. artifex* in structure and size, but entirely different in its nesting habits. The former

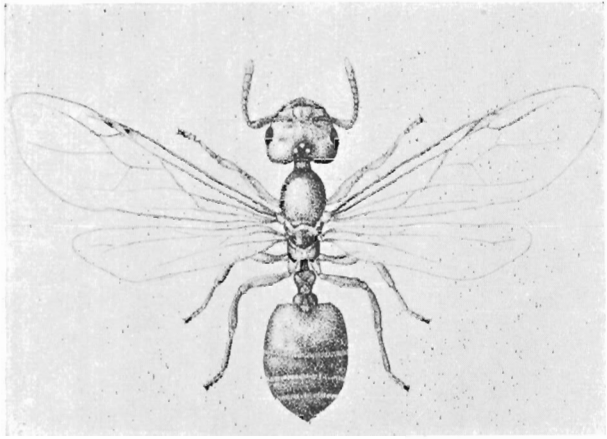

Fig. 1.—Queen.

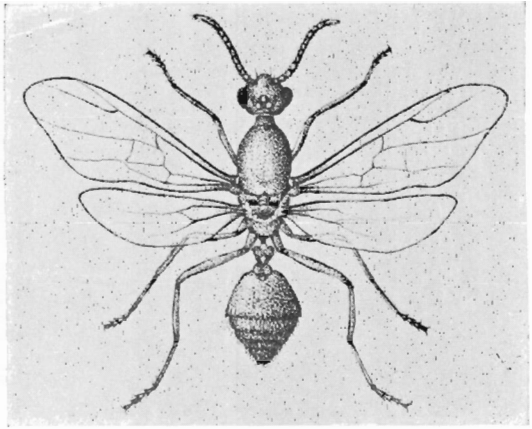

Fig. 2.—Male.

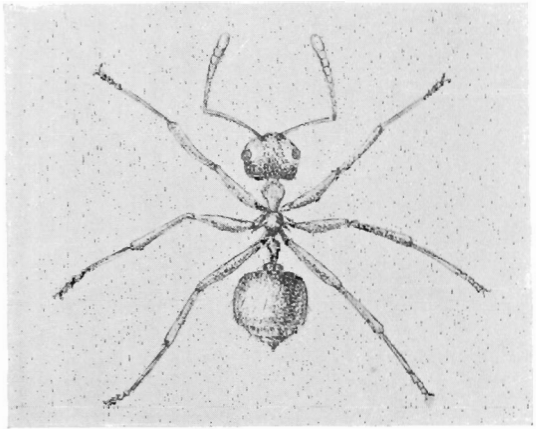

Fig. 3.—Worker major.

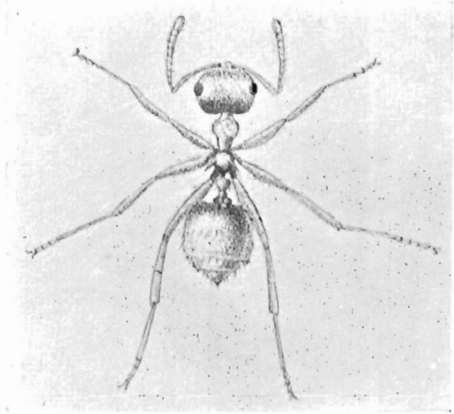

Fig. 4.—Worker minor.

Crematogaster dohrni artifex, Mayr.

occurs in houses, gardens, plants and in a variety of other situations; but the nests are always found in the soil or in crevices in the walls of buildings at a depth of 3 or 4 in.

Members of the Community.

There are three distinct types or castes of individuals in the colony: (1) the *females* or *queens*, (2) the *males*, and (3) the *workers* along with the immature forms, i.e., the larvae and pupae of each of these. The three adult castes differ much in size, structure and habits. The workers consist of two types—the worker major and the worker minor. The workers possess no noticeable difference either in structure or habits, but show a slight variation in regard to size.

The Queen (Pl. II, fig. 1).

There are two forms: the winged females and the dealated ones; but the latter are rather rare as the wings are retained during the greater part of their lives. The female is a well-developed robust individual and is comparatively much larger than the males or workers.

Length 8·5 mm. to 9·2 mm. with ovipositor extended; width in abdomen 2·5 mm. to 2·75 mm.; wing expanse 1·55 mm. to 1·62 mm. The general colour of the female is similar to that of worker, being dark yellowish brown with dorsal aspec of head and thorav fuscous. The ocelli are clear and transparent. The abdomen is large and massive and is deep dark brown towards apex. The ovipositor is just visible and not inconspicuous.

Head.—deep dull yellow—shining occiput—high—rounded slightly less broad than anterior margin. *Antennae.*—moderately thick covered with short soft hairs 11-jointed—scape gradually broadening towards end. *Flagellum.*—gradually thickened to apex with a distinct club of three terminal segments. *Eyes.*—dark, placed about middle on the sides of head. *Ocelli.*—distinct, transparent. *Mouth parts* (figure).—comparatively large. *Clypeus.*—broad with anterior margin very nearly straight. *Mandibles.*—thick and stout, shorter than those of ♀, possess 5 teeth not so pointed as in ☿—the apical one longer than rest folding closely into head with outer margins visible. *Maxillary and labial palps.*—shorter and often thinner than of ☿. *Thorax.*—Pronotum more or less depressed beneath large convex mesonotum which overhangs the prothorax anteriorly but not completely. *Metanotum.*—oblique with a pair of very short stout thick spines—just visible—tips of spines dark. *Pedicel.*—not long—first joint broadened with rounded spines, concave from side to side and anteriorly, transparent yellow, second joint dark yellow with a narrower squamiform node rounded above. *Abdomen.*—much larger than that of ☿. Sub-cordate darkening towards apex, ovipositor just visible. *Wings.*—hyaline, cells indicated by yellowish nervures.

The number of queens present in a healthy active normal colony may vary within considerable limits. The number is comparatively high even in normal times. As many as fifty-nine winged females have been recovered from a colony. Queens are continuously developed probably in all months of the year, as was seen from nests kept under observation for nearly eight months. But the highest emergence takes place in April. On emergence the queens frequently wandered out of the nest in search of food and fed on the honey or jaggery syrup provided for them. From several trials it was found that the reproductive

capacity of each female seems to be limited and is generally considerably less than in most of the other species. This notwithstanding, the community is one of the most populous. This has to be accounted for more by the multiplicity of queens than the individual rate of oviposition. Under artificial conditions, the winged female on emergence or after did not exhibit any great tendency to flight. In nature this may be different. But it is inferred from their habits in captivity, that the marriage flight itself takes place within the vicinity of the nest, and the majority of queens probably return after fecundation to the parent nest. That fertilisation can take place outside the nest is made clear from the fact that such females have been seen to produce fertile eggs. The winged females attended by workers frequently emerge from the nests during cool morning hours and also in the evenings. This tendency was markedly observed in certain cages in the laboratory in which the exits were not well secured thus permitting one or two queens accompanied by workers to escape and wander about. Like the workers the queens are impatient of drought and move from one side of the cage to another or to a wet sponge for the sake of moisture.

Food.—A queen can attend to her toilet without the assistance of the workers but rarely seeks her own food when in their company. When solitary she has been observed partaking of liquid food in the shape of honey or sugar syrup, as also to attack and catch a soft-bodied quiet termite nymph. When in the company of workers a queen is fed by her attendants, the process of feeding is effected by a mutual application of the mouth parts. She exhibits another striking tendency. She apparently is fond of proctodial matter exuded by the workers. She forcibly holds the gaster of a worker with her front legs and applies her mouth parts to the tip, the while gently stroking the abdomen with her antennae tickling the creature to induce the flow of the liquid coming out of the anus. This is rather a common proceeding among ants and in the present instance appears to be a modification of the habit of milking 'ant cattle'.

Behaviour.—Though several queens were kept together in separate cages or in slices of nests with and without a retinue of workers there was a complete absence of any hostility. They lived together in peace and amity, often congregating together huddled up in a family circle. Even queens from different nests were not antagonistic. But it was frequently observed that workers of a particular nest never tolerated the presence of an alien queen. Such intruding queens were mercilessly attacked and killed.

Fecundity.—In the queens fecundity appears to be comparatively low. To test their egg-laying capacity several queens were isolated in artificial cages, with or without workers. They were provided with sufficient moisture and food in the shape of honey or sugar syrup. Eggs were never laid till after six or seven days after emergence. The maximum number laid by a single queen per day never exceeded 3 or 4. In about a dozen observed cases the total number of eggs laid by a single individual never

exceeded 21. A few queens were dissected under a binocular microscope seven days after emergence to gain some idea of individual egg-laying capacity. The number of eggs in various stages of development in the ovaries was found to be fairly constant for three individuals so tested. It varied from 42 to 46 averaging 44. When unattended by workers the queens collected eggs if scattered and shifted them from place to place often under or over a wet sponge; but such eggs fail to hatch in the absence of workers.

Founding new colonies.—It may have been apparent from the description of the nests and the elaboration of the material for their construction that the queens, though large-sized, may not by themselves be able to establish new colonies. The ordinary mode of founding a nest is probably by a process similar to 'swarming' in the case of honey bees, i.e., a certain contingent of workers headed by a queen or a number of queens may leave the parent colony and emigrate to new and suitable places to establish a separate colony. That this may be the usual method is strongly suggested by the continual marchings of an army of workers presided over by two or three queens after escaping through cloth coverings from artificial cages in the laboratory.

Longevity.—The longevity of the queens in isolation or in company with workers was tested in several cases. In each instance a plentiful supply of food in the shape of termites or maggots and honey or sugar syrup was provided. The maximum life span under these conditions never exceeded 58 days in April (9th April 1935 to 5th June 1935). The queens generally retain wings either throughout life or at least for 30 to 35 days. In rare cases the wings were pulled off by workers earlier.

Males (Pl. II, fig. 2).

These are feeble insects, slender, delicate and winged. They are much smaller than the workers. Length 3·5-3·75 mm.; width 1·0 mm. across thorax (the broadest part of body).

The whole body is covered with smooth erect hairs. The general colour is dull yellowish brown. Head smaller and a shade darker than thorax, with large and prominent eyes placed high on sides of head. Ocelli clear and transparent. *Antennae* 12-jointed; scape very short. *Flagellum* without club, the last joint much longer than the rest, first joint rounded in form (globose). *Mouth parts* (fig.) delicate. *Mandibles* slightly rounded below—conical—and more or less tapering. *Apex* with a minute cleft. *Maxillae* and *labium* comparatively larger. *Thorax* very similar to ♀ but completely devoid of spines and legs are very delicate. *Pedicel* more or less similar to ♀, second joint transversely oval. *Abdomen* of a deeper yellow brown, abdominal tip not pointed as in ♀. Genitalia present and visible and well defined (fig.) consisting of the usual parts. *Wings* hyaline but not as glassy as in ♀. Nervures yellowish.

The males on emergence are not active. They are often dragged about and harassed by the workers, who sometimes forcibly pull off the wings and carry them about between their mandibles. The males are often attacked by ectoparasites in the form of small mites.

Longevity.—The males are shortlived and have not been observed to imbibe any food. Maximum period of life observed in cages is 11 days.

Workers (Pl. II, figs. 3 & 4).

Description.—The workers are of two types, worker major and worker minor. These are structurally more or less identical with slight differences in size of head, thorax, antennae but the main difference is only in size.

☿ major 4·10-5·11 mm.; ☿ minor 3·25-3·82 mm.

The larger workers are at least twice as numerous as the smaller ones. Both the forms are equally active and industrious sharing and attending to the duties of the colony.

The worker is a dark reddish brown insect with the abdomen varying from dark to dark brown. The body is very nearly covered with whitish hairs fairly long. The head is approximately square in shape with an indistinct trace of fine longitudinal striations.

Mouth parts.—Mandible long with five sharp teeth; maxillary and labial palps somewhat longer than those of ♀♀ or ♂♂. The worker major has a slightly broader head than the minor. Antennae distinctly clubbed at the tip. Eyes placed at sides of head. *Thorax.*—The metanotum is rather broad with long pointed divergent spines directed backwards. Abdomen flat and broad with the sting conspicuous. Stylets sharp tapering and very fine at the tip.

Longevity.—Workers are comparatively shortlived. They lived on an average for about 5 to 6 weeks in captivity. The maximum period noted in isolated cages was about 7 weeks.

Immature Stages and Larval Anatomy.

Oviposition.—Several queens were isolated in cages for recording their egg-laying capacity with and without workers. Eggs were laid by queens even when unattended by workers. Hence it is inferred that no special oviposition stimulus is derived from the presence of workers; but the eggs invariably fail to hatch in their absence. The queen takes some care of the eggs but even then they get mouldy. Eggs were laid singly, and were glued on to glass surfaces, corks or even cloth plugs. The number laid by an individual per day is generally 3, but occasionally 4 may be found. Egg-laying was never observed earlier than at least 7 days after emergence. The maximum number laid never exceeded 21 by any single individual in artificial cages; but it varied from 18 to 21 in the month of April for 11 individuals under observation. The queen continues to lay eggs for 6 or 7 days with irregular breaks.

The egg.—It is nearly white in colour, elliptical, slightly thickened in the middle; ends obtuse rounded, one end a shade narrower. The surface is lustrous indistinctly shagreened under high-power microscope. Chorion—elastic with no markings other than a longitudinal white streak (Pl. III, fig. 1).

Length 0·46-0·52 mm. average being 0·47 mm. for 40 specimens. Average thickness in middle region 0·27 mm.; broad rounded end 0·27 mm.; other end 0·255 mm.

Incubation period.—The incubation periods of the eggs in artificial cages with queens and workers were noted for quite a large number during April and May 1935. The incubation period varies considerably if the cages are not provided with sufficient moisture to make conditions of incubation entirely favourable; but

Egg

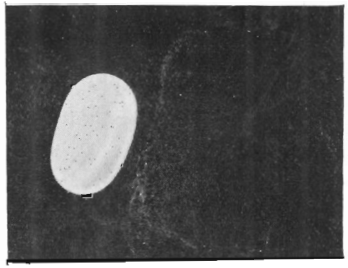

Fig. 1.—Egg.

Pupae

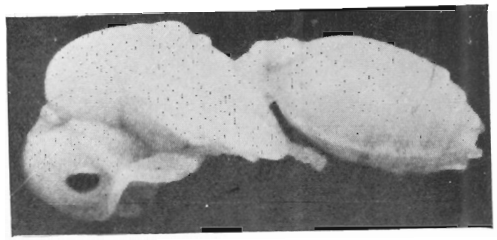

Fig. 4.—Queen Pupa.

Larvae

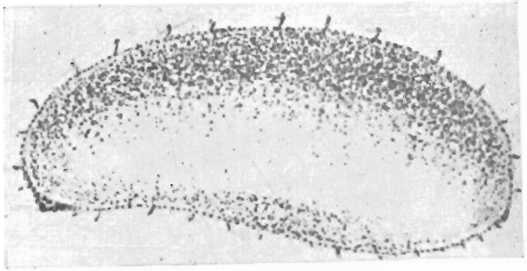

Fig. 2.—Queen larva (fullgrown).

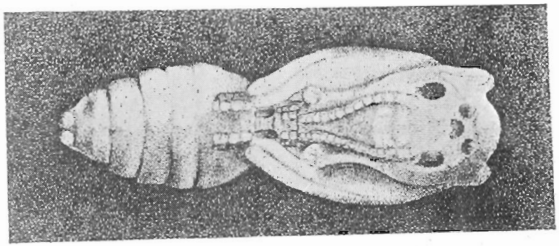

Fig. 5.—Male Pupa.

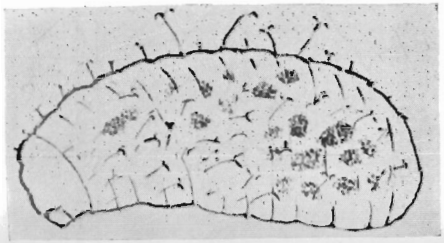

Fig. 3.—Worker larva (fullgrown).

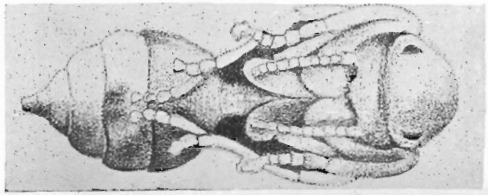

Fig. 6.—Worker Pupa.

it is generally short, about four or five days. The eggs seem to show a state of growth just before hatching. Towards the beginning of the third or the fourth day colour slightly fades, but not very perceptibly. The egg now assumes a dull creamy tinge and the larvae may be discernible through the thin chorion under the microscope.

Larva.—Upon hatching the larva is hardly larger than the egg and remains curved for a short while. It closely resembles the larvae of other species of the genus and has much in common with the grubs of the family. As is usual with the family, the grubs are soft apodous, vermiform, glassy covered by a transparent membrane having a small conical projection marking the narrower anterior end and slightly broader approximately straight hind end. The usual 13 segments are not clearly marked at this stage. Like other larvae they are incapable of exertion. They possess a sparse covering of small rigid hairs projecting from minute tubercles or elevations on the integument, which are helpful for providing easy transport. Some of these hairs show a tendency to be tipped or incipiently forked (Pl. III, fig. 3).

The young larvae are fed by the workers on liquid disgorged food and the diet of the older ones probably includes bits of solid substances in addition. In cages provided only with vegetable food, grain, syrup, etc., the development of the larvae appeared to be slow and delayed. The quantity and the quality of the food effect changes and produce irregular growth in the larvae. After the fourth or fifth day it is easy to tell a queen grub from a worker one by the size and growth (Pl. III, fig. 2).

The older worker larva.—Length 1.05 mm.; width 0.64 mm. These worker grubs at this stage are covered with different kinds of hairs which can be classified under five distinct kinds. Some hairs are simple. Others are tipped; still others are forked. The majority are furcate or tipped with a double hook so that they look like miniature anchors. A few are imperfectly anchor-shaped. The hairs are about 1/20th of the width of the larvae.

The full-grown worker larva possesses only a few scattered hairs. Length 2.60-2.75 mm.; width 1.0 mm.

The queen larva.—The full-grown queen larva is much stouter and longer in size and is dull creamy white in colour. It is almost smooth save for sparse minute hairs. Length 4.9-5.2 mm.; width 2.2-2.5 mm. The mass of meconium is only indistinctly visible in these grubs (Pl. III, fig. 2).

The grubs of males have not been identified as such by the writer.

Pupa.—When full grown the larva discharges as usual the meconium and passes on to semi-pupa stage. Unlike the larvae of *Camponotus* these grubs transform themselves into pupae without a cocoon. The pupae are naked and in this stage the various castes including worker major and minor are easily distinguished by size, appearance and colour.

The queen pupae (Pl. III, fig. 4) are dull creamy white in colour and are comparatively in size. Length 7.1-7.4 mm.; width 2.1-2.3 mm.

The male pupae (Pl. III, fig. 5) are a little shorter than those of the workers; but more robust at the thorax with developing wings. They are easily distinguished from worker pupae not only by colour, size and the presence of wings; but also by the distinct visibility of three ocelli and pinkish eyes. Length 2.9-3.2 mm.; width 1.21-1.35 mm.

The worker pupae (Pl. III, fig. 6) are dull dirty white, sometimes greyish white to slight brown in colour. Length 3.6-3.75 mm.; width 1.1-1.20 mm.

The worker, queen and male pupae are in the earliest stage whitish in colour and devoid of any markings except the reddish eye spots. As they develop they assume a shade of brownish yellow which gradually deepens. They are devoid of any cocoon and the thin fragile pupal skins are shed when the callow emerges. These pupal skins are seen to be easily disposed of by workers, probably devoured.

The Callows.—The callows or newly-hatched workers are yellowish white which changes to medium brownish yellow and soon after to brown or dark brown. They take a little over two days to assume the adult colouration. The helpless callows are not entirely idle during the period. They are not strong enough to undertake the labours of foraging or defence; but the instinctive obsession of nurture of the brood is displayed by them. Some time after emergence, they have been seen to shift the eggs and larvae as also to constantly lick them with their soft mouth parts.

Length of Life Cycle and Developmental Periods.

The total period of the life cycle varies very much not only in the different castes but also in the same caste according to conditions of temperature, humidity and food supply. Several experiments in artificial cages were conducted to gauge the period of the egg, larval and pupal stages and a regular and systematic observation of about six complete nests was continued in the laboratory for nearly eight months. From four to five broods were reared in the nests beginning from the middle of January. The one essential condition was to keep one or several queens and a number of workers along with the eggs and larvae as otherwise the eggs fail to hatch and the larvae do not mature. Another factor equally important is to provide as nearly natural conditions as possible including the quality and the quantity of food supplied. Several separate trials of isolation of a known number of workers with a queen or two introduced in a small slice of an empty and cleaned nest were carried out and the total minimum period for the emergence of a fresh brood of workers was noted. Since the development period of the larvae is difficult to determine separately, the length of egg stage and pupal stage were separately worked out. In one case eggs were laid on 16th April 1935 and the first emergence of callows was noted on 24th May 1935 and continued up to 26th

June 1935. Thus the period varied in April and May from 38 days to 71 days.

Egg period noted—4 to 5 days.
Pupal period—10 to 21 days.
Larval period—24 to 47 days.

The minimum pupal period of queens has been noted to be 10 to 11 days; but it is almost certain from observation in nests kept in the laboratory that the length of the life cycle is much shorter in nature. It may be even a little less than a month.

Seasonal Variation and Swarming Period.

The study and observations of these ants were confined to a period of nearly eight months commencing from January 1935; and hence the account of their seasonal activity is restricted to results obtained during this limited period.

The colonies were noted to be most populous from March to May when the sexual winged forms as well as the workers are found in incalculable numbers. It may be inferred from the presence of a varying number of queens or females at all times, that the females are probably developed in small numbers all through the various seasons of the year as also the worker individuals. From about the middle of March small numbers of winged males begin to emerge and by about the middle of the next month thousands of males are produced. Thereafter there is a slow and gradual decline in numbers till about the beginning of May. From this period males are seen only rarely and in small numbers. Towards the end of March the numbers of winged females begin to show an increase attaining a maximum by about the middle of April. They continue to emerge for about a week. This period, i.e., the end of April appears to mark the peak of emergence and hence the real swarming season and the period of marriage flights are confined largely to this part of the year. From the beginning of May till early June the number of queens produced gradually decreases. Soon after the appearance of queens the production of workers is hastened and the largest numbers are found in May and the beginning of June. After the middle of June the numbers undergo a gradual diminution so that only the normal activities are continued. By about the end of July considerable numbers die and the colony has a precarious existence under artificial conditions. It has been seen that the males put in their appearance early in the field, i.e., about two weeks before the swarming of queens. It is inferred that the queens naturally require a longer period of development than males.

Sex Ratio.

It is difficult to estimate the sex ratio with any accuracy as the winged sexual forms continue to emerge day after day during the swarming season and long after. In order to arrive at some idea of the proportion of the sexes a few swarms of males and females that emerged out of the nests on particular days in the

zenith of the swarming season were collected and a few such computations were actually made. The percentage of winged females varied slightly, but was never seen to exceed 3 per cent. of the emerged sexual forms.

Habits in General.

These ants are markedly carnivorous and depend mainly on animal food for their sustenance though they exhibit a partiality for any sweet liquid such as honey or syrup. They were reared for months in the laboratory on a supply of termites or soft fleshy maggots, hairless caterpillars, the flesh diet being varied with an occasional provision of jaggery syrup or honey. Soft bodied insects like termites are their main prey though they will attack small beetles and flies. Their chief weapons of attack are their sharp mandibles. It is said on excellent authority that the sting is rarely used by ants of this genus but the writer's experience to the contrary is based on long and continuous observation in the laboratory. The ants attacked insects introduced into their cages with their sharp and powerful mandibles but if resistance was offered the sting was freely used. The sting is thrust direct into the body of the victim by turning the tip of the mobile gaster or the ant in the accustomed manner elevates its abdomen above its back or head and squirts the acid into the wound made by its mandibles. Occasionally in the scuffle a turbulent termite would get hold of an ant by a leg or an antenna. In its efforts to free itself the ant would bring its sting repeatedly into play, sometimes it was helped by a passing comrade who coming to the rescue equally used its sting as the more effective weapon of attack. In the process of stinging the stylets pierce the soft body of the victim and a minute drop of frothy liquid is injected into the wound. The writer has had personal and intimate experience of the methods of these ants in attack, particularly when collecting their nests from the trees, when the ants dropped like rain upon him, entered his clothing and brought their stings and mandibles into continuous and painful use.

The ants carry their victims into their nest holding them between their mandibles. Foraging parties of workers will bring in live and dead insects of various kinds. They feed on all kinds of animal matter, including the dead of their own species, evincing a trait of cannibalism which is apparent in the spoils conveyed by the workers to their nests. Occasionally a few workers join hands in transporting a particularly heavy object to the nest. Such team work is rare in this species; but in one instance the captives in our laboratory gave a marvellous example of co-operation and team work. Their objective in this instance was some powdered jaggery heaped on a high glass cube in the proximity of the nest. Some of the workers succeeded in climbing the smooth walls of the cube, while the rest crowded round the bottom. The workers at the summit of the cube attacked the pile of sweet stuff, each ant taking a particle between its mandibles, carried it to the edge of the cube and now, instead of descending with their burdens down the slippery surface of the cube, the ants

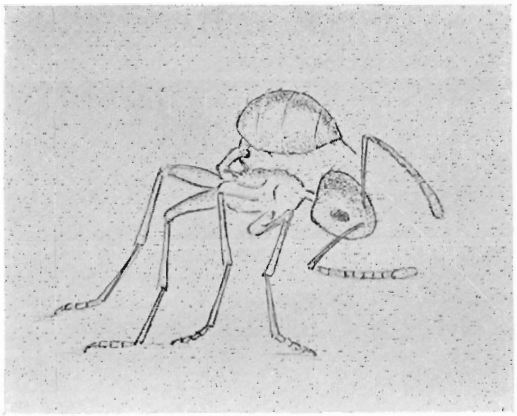

Fig. 1.—Worker ant with bent abdomen.

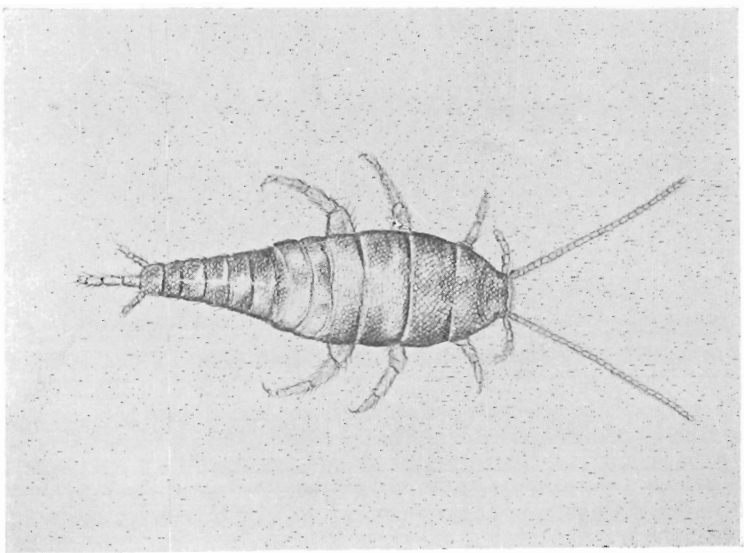

Fig. 2.—*Lepisma subnigrina colygii* in nest of *Crematogaster d. artifex.*

dropped the particles over the edge, then cleaning its antennae and mandibles each ant went back to the pile for more. They kept steadily at their labour till the pile of food was cleared and every particle of it dropped over the edge. The legion of workers below were not idle. They picked up the particles as they were dropped by the workers above and carried them in a continuous stream to the nest.

The partiality of this species for honey and syrup or sugary liquid has already been commented upon. An ounce or two of jaggery syrup or honey solution kept inside their cages was consumed in the short space of an hour. In the act of feeding they presented a beautiful sight, arranging themselves in a regular row round the brim of the shallow vessel, drinking with their mouth parts dipped into the liquid. When satiated they remained motionless and inactive. In addition, these ants like some other species imbibe 'honeydew' from various Aphids and Coccids. This pastoral habit of 'milking' different kinds of Homoptera for the supply of 'honeydew' is not as strongly developed in these as in some other ants. But when available the syrupy fluid given out by these insects is eagerly sought after, as was observed when the ants' nests were placed on trees infested with coccids or when the ants were supplied with leaves or twigs covered with these minute insects. In rapid movement particularly when excited or alarmed the workers hold the abdomen curved over the back (Pl. IV, fig. 1). It is a trait characteristic of the genus, though a closely allied species, *C. rothmeyi*, the commonest of the fraternity in South India seldom displays this peculiar gait. The action of holding the mobile gaster bent over the back is probably a defensive device—in this position the sting is held like a lance in rest ready for action—it is a warning of prompt attack. When disturbed, the workers swarm out of the nests in thousands and their movements *en masse* produce a characteristic rustling sound like the patter of light rain on dead leaves.

Their relations among themselves and with others of alien colonies.—The workers of the same colony do not show any great tendency to team work and co-operation except perhaps in the process of nesting and occasionally in the face of a common enemy when they seem to act together. In the course of their normal activities they often meet one another in their marches and have been observed to exchange greetings by antennal wavings and strokes. Sometimes two individuals will stand with their mouth parts interlocked for about half a minute to exchange food. One noticeable feature is their occasional behaviour towards the frail, helpless winged males. These latter were often dragged, pulled out, mangled and thrown out from the nests.

Hostility among workers of different nests.—Great antagonism is exhibited by workers of different nests. About half a dozen nests were kept under observation in the laboratory at a distance of two to three feet from one another. Not infrequently batches of workers escaped from cages through holes bitten through the thick cloth covering. They marched on the table in groups and

naturally encountered similar battalions from neighbouring nests. On such occasions great battles ensued between the parties and clusters of struggling ants interlocked in mutual assault and piles of dead were seen between the cages on the table. The workers do not of course possess any striking odour, but what little odour they emitted was certainly disagreeable.

Battle with black ants.—In order to find out whether it would be possible to establish these ants on trees in the plains as also to study their habits outdoors a few nests obtained from the hills were kept under observation attached to branches of suitable trees on the college premises. One such was grafted on to a branch of a *Peltophorum* tree and another to a *Neem* tree. Within a few hours after introduction the ants began to stream out along branches in small numbers. In the cool of the morning or evening particularly, large swarms of workers sallied forth in continuous streams along different branches and, as the sun grew hotter, returned with spoils of diverse kinds to the nest. Except during the hottest part of the day they were busy with their normal duties such as foraging, milking ant cattle, etc. But soon they were faced with a formidable enemy in the shape of the common black ant (*Camponotus compressus*). The soldiers and workers of the giant ants began to attack them all along their routes and attempted to storm their fortress after their retreat into the nests. The black ants possess the advantage of bodily size and strength and a more powerful armature of mandibles; but they were more cumbrous and certainly less agile in movement. Any unwary crematogaster caught between the great mandibles of a black ant was immediately killed. The smaller ants valiantly defended their nests against the intruding enemy; but despite the courageous defence they put up theirs was a losing fight. They were no match for the giants in single hand to hand fighting. But they soon developed different tactics and attacked their antagonists by rushing out of the nest biting a leg or antenna and immediately retreating into the nest. As many as twenty or thirty ants would engage in this hit and run battle against one of the giants, who knew not how to defend himself. Thus by their agility and the weight of their numbers they were able to stem the attack. Thus they defended their nests for days. The battle field round the nest and branches and on the ground below was strewn with many dead and dying black ants literally covered with numerous dead and dying crematogasters firmly clinging to legs, antennae and other parts. The colonies continued to flourish for about a fortnight. They were apparently not much affected by the weather. The nests withstood some heavy April showers except that the outer portions were slightly softened. But the colonies soon dwindled, probably on account of climatic changes, but chiefly as the result of an increase in the number of the black ants—too strong an adversary for these small ants to resist indefinitely. Ultimately one of the colonies was wiped out, and the other removed to the laboratory for observation.

Provisions in the Colony.—These ants do not keep any store of provisions in the nest. They appear to depend upon their daily labour for sustenance. Large quantities of the remains of termites and other used up food, mutilated wings, empty head capsules are sometimes found in the superficial compartments of their abodes. These are regularly cleared by workers from the nests. These ants have not been observed to keep any 'ant cattle' inside their habitations.

Guests in the Colony.—In almost all nests a good number of small dark-coloured Lepismids (Pl. IV, fig. 2) were commonly found. No other living creatures were noted associated with or living inside these curious nests. These small Lepismids were never seen in close communion with their hosts. They were observed gliding furtively through the galleries of the nests. The nature of their food or their precise relationship with their hosts have not been ascertained. The Lepismid is a dark insect with a broad thorax and tapering abdomen. *Size.*—Length 4.0 mm.; width at thorax 1.3 mm. They are very agile in their movements and highly elusive and therefore escape being caught. The specimens probably obtain their food from small droplets of sweetish liquids spilt during exchange of food by the ants. In their general appearance they have a close resemblance to the Lepisimid Atelura (Lepismina) recorded by Janet. The specimens have been identified by Dr. Silvestri as *Lepisma subnigrina* Silv. *cotygii.*[1] Are they Myrmecocleptics?

Census of the Community

The strength of the ant colony must greatly vary according to the supply of food. The colonies examined were invariably very populous. In order to obtain an idea of the population of a nest and to discover also the ratio of different castes, a nest from the branch of a tree was removed intact and enclosed with all its occupants in a long-cloth bag. The nest in question was a comparatively small one 7½ in. by 5½ in. in size. The entire nest in the bag was put in a closed glass jar and chloroform introduced. After a time it was found that the occupants of the innermost recesses were not killed. The nest was now cut up by a fine saw into four slices and its occupants were again chloroformed. The contents of the nest were later on emptied carefully and weighed and the numbers of individuals in sample weights were actually counted and the results are presented as below:—

Worker major including callows ...	39,082
Worker minor including callows ...	13,192
Males winged	4,614
Females winged	59
Female pupae	816
Female larvae large size	634
Eggs	37
Smallest larvae probably of ♀ and ♂ ...	2,744
Pupae of ♀ and ♂	1,100

[1] My thanks are due to Dr. Silvestri for the identification of the specimen.

Conclusion.

In the foregoing paragraphs an attempt has been made to present the life-economy, structure, life-history, relations, nesting architecture etc., of these wonderful ants. Their natural history on the whole constitutes one of the most fascinating and instructive chapters particularly in respect of animal instinct and ingenuity.

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