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THE NEST HABITS OF THE DIPLOPTEROUS WASP *POLYBIA OCCIDENTALIS* VARIETY *SCUTELLARIS* (WHITE) AS OBSERVED AT BARRO COLORADO, CANAL ZONE

BY HERBERT F. SCHWARZ

The wasps whose activities are recorded in this paper were first observed in the late afternoon of Nov. 8, 1930, on an ornamental shrub near the Laboratory at Barro Colorado Island by Dr. Frank E. Lutz, who directed my attention to them. The observations were terminated on Dec. 4, when I collected the nest and its inmates, with the kind assistance of Mr. E. I. Huntington. During this period of somewhat under a month, there were only a few days when the wasps did not receive at least an inspection, and a number of days out of the total were devoted largely or wholly to their study. I am indebted to Dr. Lutz and to Mr. Huntington for suggestions and other aid in the course of my observations and to Dr. J. Bequaert for his kindness in identifying the wasp.[1]

When first noticed, the wasps were assembled on several contiguous leaves of the shrub and there was as yet no evidence of a nest. Their actual number was not readily ascertainable, but, as no less than 130 wasps were collected from the nest on the final day and as the most mature part of the brood in the nest had at that time not yet pupated, it is a practical certainty that at least 130 wasps were present from the start. The nest was collected at 5:30 in the morning, before activities had begun, and it is my belief that approximately all of the inmates of the nest were secured.[2]

According to Donato, the caretaker of the Laboratory and an unusually keen-eyed observer of nature, the wasps had originally occupied a nest on a nearby shrub. There was indeed such a deserted nest only a few feet distant and this nest in its size as well as in its external and

[1]What is apparently an important contribution to the life-history of *Polybia occidentalis* var. *scutellaris* was published in 1896 by P. A. Schupp, S. J., in Natur und Offenbarung, XLII, pp. 143–151. The volume in question is, so far as I have been able to ascertain, not available in any public library in the United States. The observations of Schupp were made, I infer, on a South American colony of *scutellaris* that had reached a far greater stage of maturity than the one here described. From citations of Schupp's article in the papers of other authors—especially Wasmann—the habits of the two colonies would seem in some respects at least to be distinct.

[2]Bertoni (p. 120) collected a nest of *Polybia fastidiosuscula* de Saussure by night. The nest was devoid of brood and it was, therefore, inferred that the adults, to the number of 200, were the original founders of the nest (Bertoni, 1912, Museo Nac. de Hist. Natur. de Buenos Aires, (3) XV, pp. 97–146).

internal architecture, and in the number of its cells, approximated the nest subsequently built by the wasps herein described. I think almost without a doubt that the two nests were the work of the same species and in all probability of the same colony. There had been a raid of army ants on Nov. 8 all over the grounds of the Laboratory and possibly nest No. 1 had been ravaged by the ants and thereupon abandoned by the wasps. There were no evidences of brood in nest No. 1 when I examined it, and many of the cells of the comb were broken, suggesting possible violence.[1]

Nest No. 2 (the one to which this paper is devoted) was apparently begun on Nov. 9. On that day I noticed an incipient comb about three-quarters of an inch in diameter that had been attached to a twig of the shrub at a level of three or four feet from the ground. On setting out for a tramp on the morning of Nov. 10 I observed that the comb was still exposed and that it had at that time between 30 and 40 cells. On my return from the tramp that evening the nest was again examined. It had during the day been extended laterally and fastened for further support to the under side of two conveniently located leaves. The envelope had then been extended downward somewhat and curved under so as to form a covering below the comb. This under-curved extension was subsequently to be used as the ceiling of a second comb, but on the evening of Nov. 10 it was only about half completed, concealing about half of the cells of comb No. 1, and as yet devoid of cells of its own. Although only from 30 to 40 cells were noted on comb No. 1 on the morning of Nov. 10, there were counted 109 cells on this comb when the nest was opened on Dec. 4.

Further notable progress was made on Nov. 11. By 3 P.M. of that day not only had the cover been extended below comb No. 1 so that that comb was now enclosed, except for a nest-entrance 1¾ cm. in width by 9 mm. in height, but on the under side of the cover had been constructed the cells of comb No. 2. There were about 20 cells to a row and it was calculated (πr^2) that comb No. 2 contained about 300 cells. Actual count, made when the nest was opened on Dec. 4, revealed a total of 280 cells. Comb No. 2 was not composed of a flat alignment of cells but instead showed a marked yet symmetrical convexity.

[1]Brethes cites (p. 34) Dr. Rodriguez Gallego of Mercedes (Uruguay) to the effect that swarms of *scutellaris* that go forth toward the end of summer construct a provisional nest in which to pass the winter and abandon it when the fine season arrives (Brethes, J., 1903, Anales del Museo Nac. de Hist. Nat. de Buenos Aires, (3) II, pp. 15–39). Bertoni, too, states (p. 119) that nests of *scutellaris* up to 4 cm. in diameter occur at the beginning of winter, and that these nests are abandoned before procreation takes place (Bertoni, A. de W., 1912, Anales del Museo Nac. de Hist. Natur. de Buenos Aires, (3) XV, pp. 97–146). The observations at Barro Colorado were made toward the close of the rainy season but I can hardly believe that the abandonment of nest No. 1 is in this instance at least to be explained as a seasonal phenomenon, for the presence of cells seemed distinctly to indicate the expectation of a brood.

On Nov. 12 the wasps proceeded to extend the envelope. By 10 A.M. a slightly sloping roof had been projected on an average about half an inch beyond the circular cluster of cells, reminding me a little of the architecture employed in the houses of the Canal Zone to shield the dwellings from the rain. By 11:30 A.M. the envelope was being built not laterally and outwardly but downwardly and with an inslope, so as ultimately to cover comb No. 2. Building activities were being concentrated on that part of the envelope that was at the opposite extreme from

Fig. 1—Nest of *Polybia occidentalis* var. *scutellaris*, with its stalactite-like ornaments below. The leaf in contact with the nest and slightly above the portal was a menace, tending to shed gathered rain drops on the nest. The wasps subsequently removed the greater part of this leaf. Photograph by Dr. F. E. Lutz.

the nest-entrance, the envelope being extended gradually in the direction of the nest-entrance or the fore part of the nest. By 2 P.M. the envelope had been built forward under comb No. 2 and at that stage concealed about one-quarter of the comb.

The following day (Nov. 13) building operations were pursued actively throughout the morning but slackened as the day progressed and became virtually stagnant after 1:30 P.M. At the close of the operations on Nov. 13 the envelope was nearing completion. The outer entrance-hole (as distinguished from the inner one that gave access only

to comb No. 1) was at this time about an inch in width by a half an inch in height as contrasted with its final size, 11 mm. in width by 8 mm. in height.[1]

On the following morning (Nov. 14) the building activities were of a somewhat scattered character. Some of the wasps continued the task of reducing the size of the nest-entrance while here and there a wasp started to lay the foundations on the under side of the envelope of what was ultimately to develop into a series of six haphazardly placed, long, narrow stalactite-like ridges, measuring respectively 16 mm., 11 mm., 8 mm., 8 mm., 8 mm., 7 mm. These pendant ridges were architectural features lacking on the abandoned nest No. 1 and seemed the product of an exuberant desire to labor rather than a useful addition to the structure.

Building activities did not cease on Nov. 14. In fact, they continued almost right up to the time the nest was collected on Dec. 4. The last actual observed instance was on Dec. 2, but, judging from appearances, I believe that the wasps must have been at work also on the morning of Dec. 3. On neither the afternoon of Dec. 2 nor that of Dec. 3 was construction undertaken. As a general rule, indeed, the colony was more industrious in the mornings than in the afternoons, when activities usually grew dull or were suspended.

After Nov. 14 the wasps would occasionally lengthen the stalactites or narrow the nest-entrance, but their more serious efforts were applied to strengthening the supports of the nest. On Nov. 16 it was noted that a leaf, ordinarily concealed from view at the back of the nest, had been attached as a support. It is possible that this was accomplished on Nov. 15. Four other leaves had been employed as supports in the course of constructing the nest. Two of these were on the side remote from the entrance-hole, a third was on the under side of the envelope at the end where the nest-entrance was situated, and a fourth was somewhat back of the nest-entrance, on the upper part, or roof, of the nest. The two leaves on the side remote from the entrance-hole and that on the roof above were not papered over completely, but appeared, when the nest was subsequently opened, as green, window-like spaces framed by masonry. The leaves in these cases were, therefore, used not merely for support but as a substitute for the standard building material.

In its essentials, and ruling out of consideration the stalactite-like additions, the nest as finally collected was substantially constructed in

[1] R. von Ihering notes that the entrance-hole may show a great difference in size from nest to nest. He records (p. 256) a range of from 7 × 10 mm. to 5 × 7 cm. (Ihering, Rudolf von, 1904, Revista do Museu Paulista, VI, pp. 95–309).

five days (Nov. 9–Nov. 13). It had at that time a width of about 6 cm., a breadth of about 5 cm., and was just under 4 cm. in height. It consisted of two enclosed combs.

Had the wasps been given further opportunity, I think it likely that from time to time other combs would have been added but the relatively frail support from which the nest was hung seemed in this case to set a limit to indefinite expansion, and it is doubtful whether the nest would ever have attained a size comparable with the nest from which the type material of *scutellaris* was derived,[1] namely, 21 inches × 17 inches × 11 inches,[2] or with the even more prodigious nests mentioned by Lucas.[3] One of these, of unrecorded locality, was 72 cm. in length and had a circumference of 1 m., 20 cm.; the other, from the department of Facuarembo, belonging to Uruguay, measured 75 cm. in height and had a width of 45 to 50 cm. The latter nest, according to the natives of the region, was the work of from twenty-five to thirty years![4]

There is another reason, however, for believing that the size of the Panamanian nests may be relatively small. Ducke,[5] in commenting on *Polybia occidentalis* and its varieties, notes that nests in regions remote from the equator are apt to be characterized by larger size. Inversely those relatively near the equator might be expected to be small.

> Without doubt, in regions more remote from the equator, this wasp has acquired the habit of building very large nests, which are more resistant to the effect of winter; this tendency may be observed in the case of several species of American wasps. It would be very interesting to know the nidification of the form previously mentioned from Guiana which has the colors of *scutellaris;* it is probable that under the climatic conditions of this land the nidification is not distinguished in any way from that of *occidentalis* s. str. Nests as extraordinary as those of *scutellaris* from southern Brazil would have difficulty in escaping collectors in a region like French Guiana, which for the vespids is one of the best known regions of the American continent!

It is further to be noted that, astonishingly rapid as construction seemed to be during the first few days, when two combs were completed, there was no expansion of the Barro Colorado nest subsequently. In contrast, H. von Ihering indicates that in Brazil colonies of *scutellaris* erect in two or three weeks nests consisting of from four to five combs,[6] and a nest begun on May 20 that R. von Ihering collected on July 11 had at that time seven combs.[7]

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[1]White, A., 1841, Annals and Mag. Natur. Hist., VII, pp. 322, Pl. IV, figs. 1–7.
[2]White, A., 1843, Annals and Mag. Natur. Hist., XII, pp. 268–270 and 322.
[3]Lucas, H., 1867, Ann. Soc. ent. de France, (4) VII, pp. 365–368; 1885, *op. cit.*, (6) V, p. liv.
[4]Hardly less impressive than these nests is another mentioned by Lucas. The nest in question (from the environment of Montevideo) was 54 cm. in length and 1 m., 35 cm. in circumference. R. von Ihering gives as the maximum size of those nests of *scutellaris* that had come to his attention one measuring 55 cm. by 35 cm. (Ihering, R. von, 1904, Revista do Museu Paulista, VI, pp. 95–309).
[5]Ducke, A., 1910, Ann. Histor.-Natur. Musei Nation. Hungarici, VIII, pp. 449–544.
[6]Ihering, H. von., 1896, Zool. Anzeiger, XIX, pp. 449–453.
[7]Ihering, R. von., 1903, Zool. Anzeiger, XXVII, p. 115.

Even more remarkable than differences of size are, however, differences in the architecture of the nests of *scutellaris*. At first glance the nest from Barro Colorado, with its, for the most part, smooth and unornamented exterior, seems so different from the nest of spiny surface figured by White that one would hesitate to associate the two. Yet both types are the achievement apparently of the same wasp. While in southern Brazil and Argentina the spine-studded type of nest is the prevalent one, in Rio de Janeiro, Minas Geraes, and São Paulo nests devoid of spines predominate.[1] In Puerto Bertoni, Paraguay, and in all the region exclusive of the forest of the Alto Paraná as far as Yaguarasapá the smooth type of nest occurs according to Bertoni (p. 119), whereas six leagues to the interior from Puerto Bertoni the spiny type of architecture begins to manifest itself and this type predominates in the entire region contiguous to the open country.[2]

In addition to these rather striking variations in the architecture of the nest, Ducke indicates (p. 497) that there is also instability in the coloration of the insect: "The most remarkable of all the races of *occidentalis* is *scutellaris* White, entirely black with the scutellum intensely yellow; . . . . in the case of this insect as in the case of its nests all the gradual transitions to the common form of *occidentalis* are observable."[3] Even among the individuals from the single nest observed at Barro Colorado there are many gradations, including, at the one extreme, forms more highly maculated than White described under *scutellaris* and, at the other, almost wholly black individuals (seven in all) devoid of maculations on the scutellum but with a brief stripe on the mandibles and a faint band apically on the petiolate first segment of the abdomen. These melanistic specimens seem to come close to what de Saussure interpreted as *parvula* Fabricius or what du Buysson described as *Polybia occidentalis* var. *diguetana*.[4]

The methods employed in building by the colony at Barro Colorado may now be described. There is, I believe, a division of labor or what approximates a division of labor. Certainly again and again, after keeping close watch of a returning forager as she crawled about the nest distributing her load of pulp among the artisans there assembled, I have seen her finally deliver the last particle, make her toilet, refresh herself, and set forth, probably in search of more material. The laden

[1]Von Ihering, R., 1904, Revista do Museu Paulista, VI, p. 257, and Ducke, A., 1910, Ann. Histor.-Natur. Musei Nation. Hungarici, VIII, p. 497.

[2]Bertoni, A. de W., 1912, Anales del Museo Nac. de Hist. Natur. de Buenos Aires, (3) XV, pp. 97–146.

[3]Ducke, A., 1910, Ann. Histor.-Natur. Musei Nation. Hungarici, VIII, pp. 449–544; also 1907, Boletim do Museu Paraense, V, p. 178.

[4]Buysson, R. du, 1905, Bulletin de la Société entomol. de France, 1905, p. 9.

wasp arrived at the nest with her burden held not merely by her mandibles but enfolded like a bundle by her front pair of legs. Without releasing this hold, she walked about the nest on her middle and hind legs, seeking a worker with whom to share the pulp. Sometimes the entire load was handed over to an accommodating individual, and the foraging wasp was then free to set forth at once. More often, however, the receiving wasp took over only half the burden, holding it in like manner with mandibles and forelegs, and thereupon both wasps moved about over the nest, dividing their respective loads with other wasps, which in turn sought out additional members of the colony with whom to share, until finally the material was fractioned so finely that it could be used for building purposes.[1] These distributions were made most frequently on the top of the nest and in plain view. Sometimes the wasps there assembled were few in numbers, and under such circumstances it now and then happened that two laden individuals rushed up to each other, impelled by the same impulse, only to find that neither was in a position to accept the offering of the other.

While building material was being distributed by some of the returning foragers, others came back from their field trips with stores of liquid, almost certainly water,[2] which was likewise shared with the artisans, especially those on the roof of the nest. A glistening drop of fluid would suddenly appear between the opened mandibles of a returning wasp and would be imbibed by one of the nest occupants. A second drop would well up from the internal reservoir and would pass to the mouth of another waiting wasp. In some instances, just before a forager that had been distributing pulp set forth again on one of her flights, she would stop to take the offered sip of moisture. It may be that these distributions of liquid were made not primarily for purposes of refreshment—although the burning heat on sunny days might have seemed to justify such a conclusion—but rather for the lubrication of the building material, insuring its pliability. The newly applied building material was always of darker hue than the old, dried material and gave evidences of being saturated with moisture. I suspect that this saturation was at least in part accomplished by regurgitation of liquid during the process of subdivision.

[1]Janet (p. 63) observed no distribution of building material in the colonies of *Vespa crabro* although food often underwent division among the workers of the nest (Janet, Charles, 1895, Mémoires de la Société zoologique de France, VIII, pp. 1–140 with 41 figs.). Similarly Reaumur (p. 177) had previously recorded that foraging individuals of *Vespa crabro* themselves apply to the paper edifice the pulp that they have succeeded in gathering (Reaumur, M. de, 1742, Mémoires pour servir à l'Histoire des Insectes, VI, pp. 155–214).

[2]On one occasion (between 8:30 A.M. and 8:45 A.M., Nov. 22) I noted a worker visiting a leaf near the nest and lapping up a drop of water that had gathered on it. Thereupon the wasp flew back to the nest and shared the liquid with the wasps there assembled.

As in the case of the wasps providing building material so in the case of the water-carriers, I was able to observe repeatedly that after making their distributions they would fly forth from the nest presumably again to forage. It seemed possible that there was something approaching a division of labor not only between foragers and artisans but even between hod-carriers and water-carriers, for I doubt whether the hod-carriers would have partaken of a drop of liquid, as they now and then did, before setting forth on their flights if the object had been merely to bring this liquid back again to the nest. On Dec. 2 I noted that three of the foragers lapped water from a moist leaf before setting forth on what I assumed were further foraging expeditions. Nevertheless, it must not be concluded that the division of labor above mentioned was absolute. The members of the colony had sufficient versatility to assume on occasions other rôles. In one instance a wasp arrived bearing liquid but failed to find at once a recipient. At this point a second wasp arrived with building material, and the wasp that had the drop of moisture took over a part of the other's load.[1]

Nov. 12 was a day of considerable building activity and the record of laden wasps returning to the nest between 12:50 P.M. and 1:50 P.M. of that day is as follows:

	Wasps carrying building material to nest	Wasps bringing liquid to nest
12:50 P.M.—1:05 P.M.	9	7
1:05 P.M.—1:20 P.M.	10	6
1:20 P.M.—1:35 P.M.	10	9
1:35 P.M.—1:50 P.M.	7	8

A fuller record is available for the following day, Nov. 13, likewise a period of marked building activity:

	Wasps carrying building material to nest	Wasps bringing liquid to nest
7:45 A.M.— 8:00 A.M.	13	2
8:00 A.M.— 8:15 A.M.	13	3
8:15 A.M.— 8:30 A.M.	12	2
8:30 A.M.— 8:45 A.M.	14	0
8:45 A.M.— 9:00 A.M.	10	5
9:00 A.M.— 9:15 A.M.	12	3
9:15 A.M.— 9:30 A.M.	11	7

[1]Janet (pp. 114–116) expressed the belief that a division of labor exists in colonies of *Vespa crabro*, the recently emerged workers more frequently constructing the cells, while those of somewhat more advanced age usually tend to confine their activities to the envelope if they engage in building at all. He states that: "Even if individuals do not divide the work with precision among themselves, they appear, nevertheless, sometimes to specialize momentarily. Thus, I have noted several times that the same individual is frequently occupied during a day in doing the same tasks." (Janet, Charles, 1895, Mémoires de la Société zoologique de France, VIII, pp. 1–140, with 41 figs.).

	Wasps carrying building material to nest	Wasps bringing liquid to nest
9:30 A.M.— 9:45 A.M.	10	4
9:45 A.M.—10:00 A.M.	10	6
10:00 A.M.—10:15 A.M.	11	5
10:15 A.M.—10:30 A.M.	12	5
10:30 A.M.—10:45 A.M.	7	13
10:45 A.M.—11:00 A.M.	7	9
11:00 A.M.—11:15 A.M.	9	6
11:15 A.M.—11:30 A.M.	7	9
11:30 A.M.—11:45 A.M.	10	9
11:45 A.M.—12:00 P.M.	6	9
12:00 P.M.—12:35 P.M. (observations omitted)		
12:35 P.M.—12:45 P.M.	4	3
12:45 P.M.— 1:00 P.M.	6	4
1:00 P.M.— 1:15 P.M.	3	4
1:15 P.M.— 1:30 P.M.	2	2
1:30 P.M.— 1:45 P.M.	1	2
1:45 P.M.— 2:00 P.M.	1	1
2:00 P.M.— 2:15 P.M.	1	2

The record is of interest in that it demonstrates an accelerated slackening of building activity as the day advanced until by early afternoon labor was virtually suspended and only occasionally and sporadically would a wasp give any attention to the nest structure. The record is furthermore of interest in that it shows the progressively greater proportion that the cargoes of liquid bore to those of solid materials as the hours advanced. This might seem to cast serious doubt on the interpretation suggested above that the liquid is distributed primarily to make the building material soft and pliable instead of solely as refreshment for the workers. But it must be remembered that in the rainy season, when these observations were made, the dew is very heavy and that during the early morning hours before the sun has had a chance to absorb the moisture everything is damp or dripping. Under such circumstances the building material is doubtless initially much more moist than is the case later in the day and a smaller admixture of liquid might, therefore, suffice to make manipulation of it easy.

The building activities of Nov. 13 as above indicated may be contrasted with the slackened efforts some ten days later, when only the occasional strengthening of the supports of the nest engaged the attention of the wasps. Thus the record for Nov. 22 reads:

	Wasps carrying building material to nest	Wasps bearing liquid to nest
8:15 A.M.— 8:30 A.M.	1	0
8:30 A.M.— 8:45 A.M.	1	1
8:45 A.M.— 9:00 A.M.	2	0
9:00 A.M.— 9:15 A.M.	0	0
9:15 A.M.— 9:30 A.M.	2	0
9:30 A.M.— 9:45 A.M.	1	0
9:45 A.M.—10:00 A.M.	2	0
10:00 A.M.—10:15 A.M.	0	1
10:15 A.M.—10:30 A.M.	0	0
10:30 A.M.—10:45 A.M.	0	0
10:45 A.M.—11:00 A.M.	0	0
11:00 A.M.—11:15 A.M.	0	0

We have reviewed the partitioning of the building material after it is brought to the nest, but what is the actual technique of building? When the original lump of material has been fractioned among a number of individuals, each has her bit adhering to the under part of her head immediately in back of the mandibles. It is, as a rule, so tiny that the assistance of the front legs is no longer needed to hold it in place. Let us observe a wasp applying her bit to a ridgelike surface,—for instance one of the stalactites. She places herself astride of the ridge with three legs on the one side and the opposing three legs on the other. Thereupon, moving backward, she trails the little lump along the edge of the ridge, spreading it over the surface. Simultaneously by incessant play of her mandibles she pinches and pats the newly laid-down material, thinning and firming it as she backs along. Not content with this, when the layer of building material has been applied, she again goes to the starting point and, once more moving backward, perfects her task by giving the ridge another series of pinches with her mandibles, thus insuring the more complete cohesion of the new material with the material previously laid down and compressing it to the requisite thinness. In one or two cases I thought I detected a slight assistance on the part of the front legs in this squeezing act but the main task of shaping the material nevertheless certainly devolves upon the mandibles.[1]

When it is a flat surface as distinguished from a ridge to which the new material is to be added, the technique differs. If, for instance, the roof of the nest is to be strengthened by an added coating of material or if the attachment of the envelope to one of the leaves is to be rein-

[1]Reaumur in his account of *Vespa crabro* indicates (pp. 177–178) that this wasp also lays a new layer of building material by walking backward and flattening the material with her mandibles. He states that in doing so she holds the pulp between her front legs. Like the subject of the present paper, she makes a point, after a layer has been laid, of going back over her task in order to improve her workmanship (Reaumur, M. de, 1742, Mémoires pour servir à l'Histoire des Insectes, VI, pp. 155–214).

forced, the wasps seem more or less to push or hammer the new materials into place. At such times there is a slight, quivering, up and down movement especially of the head and the fore part of the body as the wasps press the substance down, their drooping antennæ in contact with the surface.

Allusion has been made to the distribution among the nest occupants of what was almost certainly water, especially while building operations were in progress. An even more interesting phenomenon was the ejection of liquid by the wasps. I first witnessed this on the afternoon of Nov. 14, the day when to all practical purposes the nest structure had been completed. Between 4 P.M. and 5 P.M. of that day I noticed wasps on four occasions lean far out of the nest-hole, their front pair of legs swinging in air. Presently a drop of liquid, like a soap-bubble blown, would appear between their opened mandibles. If this did not fall readily of its own weight, it was given a push by the free front legs, being literally flung away.

Again on the morning of Nov. 15 I noticed wasps stretching out of the nest-hole, head downward, to let fall the shining globule of liquid that quivered between their widely opened mandibles. Although most of the ejections took place from the nest-hole, one individual on the roof also felt moved to rid herself of her store of liquid. Apparently careful not to moisten the nest, she walked, with what in a human being might have been described as punctilio, up to the edge of the roof. Then, leaning well over it, she disgorged her droplet into space.

These phenomena were observed repeatedly on succeeding days and it became a source of wonder whence all this liquid was derived and why it should be ejected. The very fact that it was ejected confirmed me in the belief that the distributions of liquid made during building operations were not primarily for refreshment.

These ejections of liquid from the nest-hole were usually particularly numerous in the morning hours. Between 8:05 A.M. and 9:30 A.M. of Nov. 16 no less than 76 drops were ejected by wasps that leaned out of the nest-hole for the purpose. During this period wasps on the roof of the nest dropped liquid thrice. In each such case they were careful to approach the edge of the roof before disgorging and the liquid fell free of the structure.

To indicate how much more frequent was the ejection of liquid in the morning hours of Nov. 16, for instance, than in the afternoon, I tabulate below the record kept over five minute intervals:

8:05 A.M.—8:10 A.M.	7 ejections
8:10 A.M.—8:15 A.M.	7 "
8:15 A.M.—8:20 A.M.	7 "
8:20 A.M.—8:25 A.M.	10 "
8:25 A.M.—8:30 A.M.	5 "
8:30 A.M.—8:35 A.M.	8 "
8:35 A.M.—8:40 A.M.	4 "
8:40 A.M.—8:45 A.M.	3 "
8:45 A.M.—8:50 A.M.	5 "
8:50 A.M.—8:55 A.M.	2 "
8:55 A.M.—9:00 A.M.	3 "
9:00 A.M.—9:05 A.M.	6 "
9:05 A.M.—9:10 A.M.	5 "
9:10 A.M.—9:15 A.M.	1 "
9:15 A.M.—9:20 A.M.	5 "
9:20 A.M.—9:25 A.M.	0 "
9:25 A.M.—9:30 A.M.	1 "
1 hour 25 minutes	79 "
average per 5 minutes	$4\frac{11}{17}$ "

1:20 P.M.—1:25 P.M.	5 ejections
1:25 P.M.—1:30 P.M.	1 "
1:30 P.M.—1:35 P.M.	3 "
1:35 P.M.—1:40 P.M.	2 "
1:40 P.M.—1:45 P.M.	1 "
1:45 P.M.—1:50 P.M.	2 "
1:50 P.M.—1:55 P.M.	2 "
1:55 P.M.—2:00 P.M.	5 "
40 minutes	21 "
average per five minutes	$2\frac{5}{8}$ "

3:00 P.M.—3:05 P.M.	0 ejections
3:05 P.M.—3:10 P.M.	2 "
3:10 P.M.—3:15 P.M.	1 "
3:15 P.M.—3:20 P.M.	1 "
3:20 P.M.—3:25 P.M.	0 "
25 minutes	4 "
average per five minutes	$\frac{4}{5}$ "

However, the number of ejections varied not only for different hours of the same day but for corresponding periods of succeeding days. In contrast to the 79 drops ejected between 8:05 A.M.—9:30 A.M. on Nov. 16, the corresponding period of Nov. 18 witnessed ejections of only 18, less than a quarter of the previous total. The rain gauge of the Barro

Colorado Laboratory indicated that there had been no rain on the night of Nov. 17–18, whereas $\frac{7}{100}$ inches fell between 8 P.M. Nov. 15 and 8 A.M. Nov. 16. Were these ejections an act of bailing and could this slight rain have penetrated the nest sufficiently to account for the difference in the number of the ejections? It seemed doubtful. The nest was well protected by the surrounding shrubbery, and even after a fairly heavy rain-fall that occurred around 1:15 P.M. on Nov. 16 the nest-envelope had the appearance of being dry.

Moreover, the wasps, with what had the semblance of intelligent foresight, seemed capable of taking measures against the threatened moistening of their roof. About 3:25 P.M. on Nov. 17 a very heavy, if brief, tropical storm burst. The storm was over at 3:40 P.M., and I hurried to the nest in time to witness a very interesting happening. The nest seemed to be dry; nevertheless the wasps were taking no chances. One of the leaves to which the nest was attached had a steep slant and shed water readily out into space without permitting it to wet the nest. The slope and position of two other leaves, however, were such that rain drops might readily trickle from them on to the nest. The thing that startled me was that on these two leaves, which were dripping wet from the penetrating rain, seven wasps were stemming the threatened inundation. Deliberately they sucked up the water, and then going down the leaves and across the roof to the edge of the nest they ejected the liquid clear of the structure. Again and again they went to and fro, performing this service.

Impressed by this experience, I resolved to create an artificial storm. On Nov. 18 there had been but a single ejection of liquid from the nest-hole between 12 P.M. and 12:30 P.M. This seemed, therefore, a favorable opportunity for observing whether water descending on the roof of the nest from the leaves would succeed in penetrating the nest in sufficient quantity to prompt bailing. Accordingly I poured several teaspoonfuls of water over the leaves supporting the nest, creating thin rivulets that flowed down on the roof. The wasps in numbers rushed out on the roof, where several large drops of water had gathered. Several of the wasps at once engaged in lapping up these drops as well as those that still lingered on the leaves. As before, they would swallow their sip, walk to the edge of the roof, regurgitate a drop and let it fall of its own weight or push it from their mouth with a stroke of one or both of their front legs. They cleared the nest of moisture above but left hanging below the envelope a large drop that remained there long after all lapping and ejecting activities had ceased.

I think the storm I created resulted in a much severer wetting than the sheltered nest would ordinarily have received from a natural fall of rain. Yet, thanks to the response made by the wasps in the emergency, I do not believe water penetrated the envelope. Certainly the number of ejections from the nest-interior as distinguished from the liquid dropped over the sides of the roof was not impressive. I have said that one drop was ejected from the nest-interior in the half hour preceding the experiment. In the half-hour period following the artificial shower there were three ejections, but two of these took place toward the end of this half hour when the wasps that had been lapping fluid on the roof had crawled back into the nest. In other words, the liquid ejected from the interior of the nest may have represented largely the residue of the water imbibed on the outside.

In the last-mentioned experiment the roof had been moistened only indirectly by dripping from the leaves. I wanted to test its resistance to moisture even more thoroughly. Accordingly, the next "cloud-burst" was made to descend directly on the roof itself. I filled a medicine dropper with water and squirted the contents over the entire roof. This time the wasps swarmed forth in even greater numbers, a few removing the water that had coursed to the lower part of the envelope while the majority were similarly engaged on the roof. So many wasps were assembled on the exterior, lapping up the water, that I let a few minutes go by until a fair part of the colony was again within the nest. Observations were then concentrated on the nest-hole. In the succeeding twenty minutes there were nine ejections of liquid from the nest-hole. In the next ten minutes there was one ejection, so that for the full half hour the number of ejections was ten. Two more ejections occurred during the succeeding ten minutes. The increased number of ejections after the inundation as compared with those before it occurred may have been due to moisture in the nest, the result of seepage through the envelope, but more probably it represented, as previously suggested, a final disgorging of the residues of liquid lapped up on the outside of the nest. In any event, the relatively restricted number of ejections tends to indicate that penetration of the nest by rain is not a satisfactory explanation of the origin of the liquid that I had seen ejected from the nest on numerous occasions.

But if rain does not enter the nest, is it possible that the heavy dews account for the presence of the water? The nest-hole is relatively small and it would seem unlikely that this insignificant portal could give admission to enough dew to necessitate bailing. Moreover, on the

morning when the nest was opened, there was no trace of moisture within. The wasps, furthermore, do not permit the accumulation of moisture in the interior of their nest any more than they permit liquid to remain on the roof or the approaches to the nest. After making the above experiments on the exterior of the nest, I squirted a stream from the medicine dropper right into the nest itself. The reaction was, as I suspected it would be, one of feverish activity on the part of the wasps, which began as quickly as possible to clear the nest of this unexpected inundation. Indeed, with such rapidity did they eject drops out of the nest-hole that, if I had not had the kind aid of Mr. E. I. Huntington, I should, between observation of the nest and of my watch, certainly have lost track of the count. The record for the first eight minutes after the water had been injected into the nest reads:

1st	minute	51	ejections
2nd	"	30	"
3rd	"	22	"
4th	"	24	"
5th	"	18	"
6th	"	22	"
7th	"	9	"
8th	"	2	"
	Total	178	"

Thus in eight minutes the wasps bailed out more than twice the amount of liquid that they ejected during an hour and twenty-five minutes on the morning of Nov. 16, when 79 drops were regurgitated!

The experiments above recorded were made in the daytime. I wondered whether, if they were repeated at night, the colony would rouse itself in defense of the nest. Accordingly at 7 P.M. of Nov. 23, when it had been dark for some time and the stars were out, water was again squirted on the roof. One wasp came out of the nest and crawled on the roof but shortly reëntered the nest. Thereupon, after an interval of a few minutes, I squirted a light stream into the nest-hole itself. Instantly the wasps began ejecting the water but not quite so energetically as during the daytime experiment, or it may be that fewer devoted themselves to the task. Even so, more than 70 drops were ejected in about seventeen minutes. During the first part of this time the wasps made their ejections only from the nest-hole, but by and by four of them crawled out on the roof and cleared the water also from the external parts of the nest. They were still at work when I left about 7:30 P.M.

These evidences that both by day and by night the wasps stand ready instantly to bail out their nest make it seem unlikely that the early morning ejections of liquid represent accumulations in the nest of rain or dew. More likely these ejections represent a disgorging of water distributed or lapped up on the previous day. Yet I confess that this offered explanation, the only one available, does not wholly satisfy me. The ejections of liquid at times occurred in such number that it was hard to believe that enough liquid could have been imbibed on the previous day to account for them. Thus my record for Dec. 2, for instance, reads:

6:15 A.M.— 6:30 A.M.	18 ejections
6:30 A.M.— 6:45 A.M.	19 "
6:45 A.M.— 7:00 A.M.	(observations omitted)
7:05 A.M.— 7:15 A.M.	24 ejections (or at the rate of 36 ejections for the full fifteen minutes)
7:15 A.M.— 7:30 A.M.	18 "
7:30 A.M.— 7:45 A,M.	29 "
7:45 A.M.— 8:00 A.M.	20 "
8:00 A.M.— 8:15 A.M.	26 "
8:15 A.M.— 8:30 A.M.	18 "
8:30 A.M.— 8:45 A.M.	23 "
8:45 A.M.— 9:00 A.M.	19 "
9:00 A.M.— 9:15 A.M.	15 "
9:15 A.M.— 9:30 A.M.	10 "
9:30 A.M.— 9:45 A.M.	3 "
9:45 A.M.—10:00 A.M.	4 "
10:00 A.M.—10:15 A.M.	2 "
10:15 A.M.—10:30 A.M.	1 "

While these ejections were going on, building material was being brought in, and I also noticed the occasional arrival of wasps with water for distribution. Such distribution was made for the most part on the roof of the nest while the ejections took place largely from the nest-hole. In other words, the wasps that were ridding themselves of liquid were distinct from those that were receiving it in the course of the building operations. After 9 o'clock building activity, which had been in full swing till then, slackened perceptibly. After 10:30 it ceased, a time when ejections of liquid were likewise virtually suspended. But though building activity was not resumed and no building material was brought in during the afternoon, the lull in the ejection of liquid was only temporary Between 11:10 A.M. and 11:55 A.M. the record of ejections was as follows:

11:10 A.M.—11:25 A.M.	8 ejections
11:25 A.M.—11:40 A.M.	12 "
11:40 A.M.—11:55 A.M.	12 "

At 11:55 it began raining but soon stopped.
At 12:40 observations were resumed as indicated in the following record:

12:40 P.M.—12:55 P.M. (sky slightly overcast)	20 ejections
12:55 P.M.— 1:10 P.M. " " "	13 "
1:10 P.M.— 1:20 P.M. (sky overcast and rain)	5 "
1:20 P.M.— 1:30 P.M. (heavy pelting rain)	(observations suspended)
1:30 P.M.— 1:45 P.M. (rain)	31 ejections (including many drops ejected from roof)
1:45 P.M.— 2:00 P.M. (mostly overcast)	21 ejections
2:00 P.M.— 2:15 P.M. (overcast)	18 "
2:15 P.M.— 2:30 P.M. "	13 "
2:30 P.M.— 2:45 P.M. "	(observations suspended)
2:45 P.M.— 3:00 P.M. "	(observations suspended)
3:00 P.M.— 3:15 P.M. "	13 ejections
3:15 P.M.— 3:30 P.M. "	21 "
3:30 P.M.— 3:45 P.M. (overcast and a few drops of rain)	23 "
3:45 P.M.— 4:00 P.M. (overcast)	21 "
4:00 P.M.— 4:15 P.M. "	19 "

My observations were not continuous but, even granting that there may have been some slackening or even suspension in the ejections during these gaps, the fact remains that for nearly ten hours there were ejections that rarely fell below the rate of one per minute and frequently exceeded that rate. It is hard to account for the source of all this liquid. Several times I noticed incoming wasps distribute water and probably there were other instances of this kind that escaped by attention, but these replenishments were trivial compared with the liquid disgorged.

Brief notation was made of the weather conditions in the record of Dec. 2. in the possibility that cloudiness may induce the wasps to regurgitate. Further observation on this point is desirable. It may well be that the negligible number of ejections on the afternoon of Dec. 3d, which are tabulated below, simply indicate that the reservoirs were empty after so plenteous a discharge on the previous day, but it is barely possible, too, that liquid was retained on Dec. 3 because of the sunny weather or the lower relative humidity or both.

The nest got the morning sun, not the afternoon, and the references to sunlight in the following table apply, therefore, to the general landscape; the nest, due to its sheltered position, was never sun-illumined in the afternoon.

Dec. 3, 1930

12:45 P.M.— 1:00 P.M.	(sunny and slight shower)	0 ejections
1:00 P.M.— 1:15 P.M.	(slightly overcast to sunny)	0 "
1:15 P.M.— 1:30 P.M.	(bright sunlight)	0 "
1:30 P.M.— 1:45 P.M.	" "	0 "
1:45 P.M.— 2:00 P.M.	(bright sunlight, then fairly heavy rain)	0 "
2:00 P.M.— 2:15 P.M.	(dull to bright sunlight)	0 "
2:15 P.M.— 2:30 P.M.	(mostly bright sunlight)	1 "
2:30 P.M.— 2:45 P.M.	(sunlight)	0 "
2:45 P.M.— 3:00 P.M.	(bright sunlight)	2 "
3:00 P.M.— 3:15 P.M.	(subdued sunlight)	0 "
3:15 P.M.— 3:30 P.M.	" "	0 "
3:30 P.M.— 3:45 P.M.	" "	0 "
3:45 P.M.— 4:00 P.M.	" "	0 "
4:00 P.M.— 4:15 P.M.	(late afternoon light)	0 "

The relative humidity record for the days and hours covered in the above tabulations was as follows:

Dec. 2, 1930		
	6 A.M.	95
	8 A.M.	96
	10 A.M.	96
	noon	78
	2 P.M.	92
	4 P.M.	94
Dec. 3, 1930		
	noon	75
	2 P.M.	70
	4 P.M.	75

On an earlier page, allusion was made to the action of the wasps in removing raindrops from a leaf that sloped down upon the nest, thereby eliminating a danger before it had a chance to threaten. In the end, however, the wasps solved this difficulty in a still more adroit and summary manner, namely, by removing the leaf itself. One lone individual or another had, even during the earlier history of the nest, made now and then a sporadic effort to get rid of some of the vegetation. Thus, what I like to describe as the roof-tree—the little twig to which the nest was attached and solely attached in its incipient stage—had originally terminated in an end leaf flanked by two other leaves. These leaves I

had snipped off in order the better to see the nest, but the stems were still in place and indeed frequently served as a kind of perch from which foraging wasps took flight. During the morning of Nov. 15 two of these stems (those representing the flanking leaves) were neatly bitten off at the base by one of the wasps. In the course of the morning of Nov. 26 I noticed a wasp bearing a fragment of a leaf as she moved across the roof of the nest. Presently she transmitted this fragment to another wasp, which thereupon walked to the edge of the roof and dropped the fragment over the side.

On Nov. 30 the major operation of this character, requiring the united effort of several wasps, took place. Nov. 28–29 had been a period of especially heavy rain, with comparatively little fair weather. For the twenty-four hours from 4 P.M., Nov. 28, to 4 P.M., Nov. 29, the rain gauge recorded 3½ inches. On the morning of Nov. 30 about 9 o'clock I went to take a glance at the nest and to my surprise found the wasps engaged in removing one of the leaves that was in contact with the nest. The leaf in question was only partly attached to the roof (the portion that had been built into the roof measured only about 11 mm. by 6 mm.) and much of its undulating surface stood free of the nest. Had its tip extended beyond the nest it might have served as a watershed; instead it acted as a conduit, discharging the growing rain drops on the roof. When my observations were begun, the work of demolition had already progressed considerably. The leaf—or rather what was left of it—had a soft, moisture-soaked, flimsy appearance, which may have been caused by the rain but more likely was due to squeezing by the mandibles of the wasps. The texture of the leaf was in contrast to that of the shiny, smooth surface of the healthy leaves of the shrub. Several wasps were engaged in removing the leaf. They worked not only on its edges, astride after the manner of leaf-cutting bees (*Megachile*), but above and even below the leaf, and little rents that were visible here and there on the surface of the leaf seemed due almost certainly to the nibbling and ripping action of this wrecking crew. The work was hard for the wasps. They seemed not so much to cut as gradually to tear the leaf to pieces. Sometimes a substantial leaf particle would be loosened through the joint action of several wasps, and its further fragmentation would then take on the aspect of a tug of war.

When a single wasp, however, remained in possession or ultimately achieved ownership of a detached fragment, the method of disposal was usually the same. The wasp would carry the leaf particle beneath her body, holding it with her mandibles and usually supporting it in addition

with the front pair of legs. Instead of dropping the leaf particle over the side of the nest, however, as had been done in the case of the water drops, she took to her wing with the green burden, wheeled in air till she faced the nest at the distance of a foot or more, and then darted off into space. This was the almost invariable procedure. Only one wasp was observed to walk to the edge of the nest and drop her burden over the side without going through the formality of flight. Occasionally particles were not retained by the wasps or got away from their control in the course of their struggles, slipping of their own accord down the sides of the nest and so to the ground. No attempt was made to recover such particles.

The leaf was in process of destruction when I witnessed the incident around 9 A.M. Its free parts had been completely removed shortly after 10 A.M. That portion of the leaf which was attached to the nest and which constituted indeed an essential part of the architecture of the nest was not tampered with.

The distribution of water among the individuals on the roof of the nest was a relatively calm and unemotional procedure with brief contact of the mouth-parts as the droplet was transferred from distributor to receiver. In contrast to this was the vivid agitation that was observed every now and then when a returning wasp would arrive at the nest bearing something that was evidently eagerly desired by the nest occupants. These would hurry toward her expectantly or thrust their heads out of the nest-hole in anticipation. The arriving wasp and the recipient would take a position more or less at right angles to each other. One of them would lean to one side and tilt her head until it was almost vertical or at least oblique to the horizontally held head of the other. In this position their mouth-parts were brought into prolonged and intimate contact, while their antennæ were in lively agitation. At times the individual holding her head sideways would lose her balance and fall partly on her side, but even under such circumstances the two wasps would still cling in close embrace with their mouth-parts joined.

For a long time these actions mystified me. The mouth-parts were so closely interlocked that I usually failed to detect the transfer of any substance. Once, however, I was able to note a tiny drop of liquid (probably nectar), and on another occasion I was under the impression

that something pastelike was transferred.[1] Almost invariably the first recipient would at the termination of the contact crawl into the nest, and this circumstance and the fact that I had noted the transfer of the tiny drop led me to conclude that the incoming wasps were bringing food, which, paralleling the procedure in the case of the building material, was handed over by the forager to a waiting nurse before being fed by her to the brood. If this was the case, however, it was the first recipient that usually obtained, I think, the lion's share and the one on whom apparently devolved the duty of feeding the young. The wasps next in line had usually briefer contacts with the forager and, unlike the first recipient, did not on separation head for the interior of the nest. Possibly they shared only the dregs or their efforts may even have gone unrequited. Not infrequently even wasps on the nest itself would approach one another and engage in this interlocking of mouth-parts, possibly merely in futile gesture.

The number of these contacts as recorded on Nov. 22 was as follows:

8:15 A.M.— 8:30 A.M.	1
8:30 A.M.— 8:45 A.M.	7
8:45 A.M.— 9:00 A.M.	6
9:00 A.M.— 9:15 A.M.	1
9:15 A.M.— 9:30 A.M.	5
9:30 A.M.— 9:45 A.M.	6
9:45 A.M.—10:00 A.M.	2
10:00 A.M.—10:15 A.M.	5
10:15 A.M.—10:30 A.M.	2
10:30 A.M.—10:45 A.M.	4
10:45 A.M.—11:00 A.M.	2
11:00 A.M.—11:15 A.M.	4

Because of the frequency with which these contacts occurred and on the theory that they represented transfers of nutriment, I was almost tempted to conclude that regurgitated food might be the only kind fed to the larvæ. But at 11:30 A.M. on Nov. 22 I noted a wasp bearing in

[1]Janet, in discussing (p. 105) the transfer of liquid nutriment among the adults of *Vespa crabro*, says: "The queens, when the day comes that they no longer leave the nest, and likewise the newly emerged workers are nourished principally by liquid which, upon their solicitation, their companions disgorge before their mouth.

"I have seen a queen, in order to eat, force herself between two workers engaged in sipping the liquid which one of their companions disgorged for them, so that food was being dispensed to three hornets at one time.

"When a worker disgorges liquid nutriment for one of her companions, it is rather easy to distinguish the one that gives from the one that receives. The one that gives has the mandibles and also the antennæ widely spread apart. The one that receives has the mandibles close together and the antennæ are most frequently brought into contact with the mandibles of her companion in order to palpate them." (Janet, Charles, 1895, Mémoires de la Société zoologique de France, VIII, pp. 1–140, with 41 figs.)

what seemed to be a small greenish-white larva[1] and almost immediately thereafter another wasp arrived similarly laden. Both of them flew directly into the nest-hole, where they were met by other wasps. Thereupon there occurred what seemed to be a partitioning of the material among the adult wasps within the nest. On Dec. 2 I had two opportunities to verify this observation. The wasps laden with food, instead of flying into the interior of the nest, alighted on the roof and there in full view the food was partitioned[2] much as building material had been subdivided on other occasions. The process of preparing the food was deliberate. The worker receiving a share would hold the tit-bit with her front legs while malaxating it. Finally she would enter the nest presumably to feed the larvæ within. Because in the early history of the nest no instances were observed of wasps arriving with prey, I came to wonder whether the younger larvæ were fed on regurgitated food only (possibly mostly nectar) while the malaxated caterpillars were reserved for those farther along in development.[3] Where many phenomena are

[1]In the case of the South American representatives of *scutellaris* mature forms rather than larvæ seem to constitute the prey. Von Ihering (p. 45) states that in Brazil *scutellaris* always brings in the prey unmalaxated, although more or less mutilated, with the wings of the victim invariably removed. He mentions houseflies and termites as the principal objects of the chase (Ihering, H. von, 1896, Zool. Anzeiger, XIX, pp. 449–453). Of a colony of *Polybia scutellaris* var. *paulista* von Ihering says: "The larvæ were provided with various insects, flies (*Musca domestica* L.) and winged ants (*Solenopsis geminata* F.), all deprived of their wings and in part of their extremities." (Ihering, H. von, 1896, Bull. Soc. zool. de France, XXI, pp. 159–162.)

Wasmann (p. 277) quotes P. A. Schupp (Natur und Offenbarung, 1896, pp. 143–151) to the effect that *scutellaris* removes not only the wings of flies but bites off also the legs and if, notwithstanding these mutilations, the prey is still too heavy, trims off likewise a part of the body. Termites were similarly reduced to a portable size. Wasmann adds that he had opportunity to examine prey secured from *scutellaris* nests collected in different localities and in different years. In all cases the termites were *Eutermes ater* although the closely related *Eutermes tenebrosus* is known to occur in the same region. The condition of these termites was as follows:

"From most of them the wings had been bitten off near the base, likewise the legs, at least most of the legs. In the case of three-fourths of the total number of specimens the heads were missing, those of the larger individuals invariably, those of the smaller more rarely. Even in the case of the latter, however, the antennæ were entirely or partly bitten off. Some specimens, on the other hand, still retain their wings, at least in part; others still have an uninjured antenna; such specimens are invariably small individuals. Most of the specimens are ♂ ♂, but I was able to recognize with certainty in spite of desiccation also several ♀ ♀ by the rounded hind margin of the larger sixth ventral segment. Many of the specimens that still retained their heads had received a bite in these parts from the mandibles of the wasps." Wasmann found also among the prey various ants: males of *Dorymyrmex pyramicus*, some wholly or nearly unmutilated, others with head or antennæ or legs removed or wings reduced to stumps; 2 ♂ ♂ of a species related to *Wasmannia auropunctata;* finally a ♂ of *Ponera punctatissima* var. *trigona.*" (Wasmann, E., 1897, Zool. Anzeiger, XX, pp. 276–278.)

More than once in the course of my observations of the Barro Colorado nest a small ant by chance or design crawled on to the roof of the nest. She was always menaced immediately by one of the workers and forced to a hasty retreat, but never was an attempt made to seize her as food.

Simulid flies have also been reported to be the prey of *scutellaris*, the wasps actually seizing the flies from the cattle that they were victimizing (Bertoni, A. de W., 1912, Anales del Museo Nac. de Hist. Natur. de Buenos Aires, (3) XV, pp. 119–120).

[2]Janet indicates (pp. 28, 63, 98) that in the case of *Vespa crabro* an unwieldy mass of food may be distributed among the workers by a returning forager and that even the queen may take over a share of the load; transfers *in toto* of the food sometimes take place (Janet, Charles, 1895, Mémoires de la Société zoologique, de France, VIII, pp. 1–140 with 41 figs.).

Williams observed (p. 163) a returning forager of *Stenogaster varipictus* engaged in dividing a load of food with one of the adult wasps of the nest (Williams, Francis X, 1928, Bull. Exp. Stat. Hawaiian Sugar Planters' Assoc., Entom. Series, No. 19, pp. 1–179 with text figs.).

[3]Since hazarding this interpretation I have come upon the interesting paper by Rau (Rau, Phil, 1928, Biol. Bull. Woods Hole, LIV, pp. 503–519 with 1 fig.) in which he presents evidence for believing that the young larvæ of *Polistes pallipes*, *P. annularis*, and *P. variatus* are fed on regurgitations of honey. Rau cites Sharp's Insects, part 2, p. 84, that "saccharine matter" is the first food given to some unspecified social wasp. Rudow, too, states (p. 81) that "often several females (of *Polistes*) participate in the first construction and feed the larvæ with the fragrant honey of umbelliferous plants," (Rudow, Dr., 1913, Ent. Rundschau, XXX, pp. 69–69, 74–76, 81–82, 88–90, 100–102, 112–114, 118–120, 125–126.)

offered for observation, it is necessary, however, to concentrate on one phase or another, and my preoccupation with other nest activities may have resulted in my overlooking food-gathering acts during the first two weeks.

The bringing in of the prey occurred very irregularly. Just as on Nov. 22 I noted the almost simultaneous arrival of two laden wasps, so on Dec. 3 several wasps bearing what seemed to be small larvæ arrived in rapid succession—1 P.M., 1:05 P.M., 1:06 P.M., 1:07 P.M.—after which there was a gap of nearly an hour (2:02 P.M.)—before another forager arrived. The latter was followed at 2:26 P.M. by another laden individual. No other instances of larva-bearing foragers were noted subsequently on that afternoon. The swift succession of arriving wasps followed by the long gap of inactivity suggests the possibility that a single source of supply was raided and perhaps exhausted.[1]

Just as the wasps got rid on occasions of undesired liquid, so likewise they would drop from the nest-hole solid particles that were not wanted. Once or twice after a distribution of building material I noticed that what seemed to be a residuum of such material was flung out. On several occasions in the course of the afternoon of December 3 wasps stretched out of the nest-hole to divest themselves of crumblike particles, possibly remnants of food, as no building material had been brought in during the afternoon. They seemed in these instances to be making their toilet. While the nest was in course of construction, I had several times noticed wasps performing a cleansing act. Sometimes they would make a tripod of the anal end of their abdomen and their hind legs while brushing themselves with their front and middle legs. On two occasions at least I noticed a wasp that was attached to a cell by its mandibles, hanging thus with only the additional support of its front legs while it scraped its pendant body with its middle and hind legs.

On several occasions one or another wasp on the nest engaged in more or less prolonged vibration of its wings.[2] Such cases were observed even while building operations were in progress and when the explanation could hardly have been that of ventilating the nest. It is barely possible that such fanning served the purpose of drying the building

[1] Wasmann (p. 277) quotes P. A. Schupp to the effect that hundreds of wasps of *scutellaris* arrived at the nest simultaneously, laden, one and all, with termites. (Wasmann, E., 1897, Zool. Anzeiger, XX, pp. 276–279.)

[2] Janet states (p. 111) of *Vespa crabro:* "It is not unusual to see one or two hornets stationed on the envelope of the nest or under the cell-containing combs, and violently beating their wings. This beating of the wings which produces a rather audible sound and an energetic ventilation appears to me to be often only a manifestation of anger, a menace and as a result a means of defense." (Janet, Charles, 1895, Mémoires de la Société zoologique de France, VIII, pp. 1–140, with 41 figs.)

Janet's interpretation would not, I think, apply to the behavior of *scutellaris*. The wasps engaged in vibrating their wings were lone individuals performing solo and gave no evidence of directing their "anger" against any offender.

material more rapidly, but, if so, I think this was merely incidental to what was probably a purposeless act. Similar acts after the completion of the nest may also have been purposeless, but sometimes the position taken by the wasp suggested an attempt on her part to ventilate the interior. Thus, on Nov. 14, I noticed a wasp standing above and just to the right of the nest-hole, with her front legs raised and her middle legs placed at the edge of the hole, while she was vibrating her wings vigorously and protractedly and almost inevitably cooling the interior.

The most prolonged vibrating of the wings that I observed on the part of any wasp came to my attention on Nov. 21. From 1:48 P.M., when I arrived at the nest, until 2:10 P.M., I noticed a wasp with her wings almost continuously aquiver. How long before 1:48 P.M. she began vibrating her wings I do not know. During this long demonstration of more than twenty minutes she took positions, for the most part, fairly close to the nest-hole, now on one side of it, now on the other, and below as well as above it, often with the feet of one side of her body holding to the edge of the hole. While she was vibrating her wings, she had the singular mannerism of rubbing her right antenna with her right leg, and it was because of this peculiarity of behavior that I felt justified in believing that a wasp which I observed subsequently that afternoon in the act of vibrating and which was characterized by a like idiosyncrasy was the same individual. This time I had opportunity to observe her in action from 3:35 P.M. to 4:25 P.M. How much before 3:35 P.M. she had begun vibrating her wings or how long after 4:25 P.M. she kept it up, I cannot say. Perhaps she had been thus engaged almost continuously from 1:48 P.M., when my first observation was made. Although in the course of this long period she moved about and occasionally wandered rather far from the nest-hole, for the most part she stood so close to it that I was under the impression she was engaged in ventilating the interior.

When the nest was collected, I proceeded to measure its external parts (the measurements are given in the earlier part of this paper) and then proceeded to open it from below, revealing the larger of the two combs. This consisted of approximately 280 cells, each measuring just under 3 mm. in diameter.[1] The larger larvæ occupied the cells near the center of the comb and there was a gradual tapering off in the size of the larvæ as the periphery of the comb was approached. The arrangement was, however, not absolute, for even in the cells near the center there were

[1]R. von Ihering records (p. 256) the diameter of the cell of the Brazilian representatives of *scutellaris* as 2.8 mm. (Ihering, Rudolf von, 1904, Revista do Museu Paulista, VI, pp. 95–309.)

larvæ of intermediate size interspersed with full-grown larvæ. Nevertheless, the general arrangement was such as to suggest that egg-laying had begun at the center and had spread thence out toward the circumference.[1] The two rows of cells constituting the periphery were devoid of contents, while in the row inward of these there was only an occasional occupant. There were 131 larvæ in the cells of this larger, lower comb and eight additional, full-grown larvæ that had wriggled out of their cells (presumably vacated ones near the center of the comb) were found on the floor of the envelope.[2] In addition to the larvæ there were in this larger comb six eggs. These were fastened by their smaller axis to the point of junction of the base of the cell with one of the sides and they thus hung downward at a slight angle.

The entrance to the smaller or upper comb (the original entrance to the nest before the second or lower comb was built) was larger than the outer entrance (the final nest-entrance). It measured 1¾ cm. by 9 mm. The approximately 109 cells of the upper comb were in places rather irregularly linear in arrangement, making an accurate count difficult. The irregularity was even more striking in the case of the depth of the cells. In contrast to the gradual, symmetrical convexity from circumference to center noted in the case of the lower comb, the cells of this upper comb showed a notable difference of level, some towering above others and presenting a jagged appearance. I think it possible that they were enlarged after the completion of the nest-envelope concealed activities within the nest. I do not recall such irregularities when the comb was in its initial stage and still exposed. After the completion of the external architecture of the nest on Nov. 13, building material was still from time to time taken into the nest and it may be that it was applied to the lengthening of these cells.

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[1]This more or less concentric arrangement of the different stages of the brood has been frequently observed in the case of the social Hymenoptera. Janet (Janet, Charles, 1895, Mémoires de la Société zoologique de France, VIII, pp. 1–140) has published a series of diagrams showing the increase in numbers of the brood and the development of the individual members day by day in a nest of *Vespa crabro*, and these diagrams clearly indicate that laying begins near the center of the comb and continues thence toward the peripheries. Ritchie (Ritchie, James, 1915, Scottish Naturalist, 1915, pp. 318–331) on p. 319 speaks of the immature forms of *Vespa vulgaris* as lying "in successive waves of life outwards from the center of the comb." Schmidt (Schmidt, Hugo, 1917, Zeitsch. wissensch. Insektenbiol., XIII, pp. 153–160) indicates (p. 155) that at the center of one of the combs of *Vespa germanica* were the capped cells, beyond these were cells containing larvæ while the cells near the circumference were empty. In nests of meliponid bees it is, according to von Ihering (Ihering, H. von, 1904, Zool. Jahrb. Syst. Geogr. u. Biol., XIX, pp. 179–287) the central part of the comb from which the imagos first emerge. Concentric arrangement of the brood occurs also in the honey bee, *Apis mellifica*.

[2]These larvæ were still alive. They squirmed about and though legless were capable of slight progress. Ritchie (p. 318), who injected at night a few drops of "aqueous solution of potassium cyanide" through the entrance of a nest of *Vespa vulgaris*, found that all the adult wasps with one moribund exception were dead next morning. Not so the larvæ, however, which "seemed to retain their usual activity." Ritchie concludes: "This resistance to the cyanide fumes seems to indicate a much lower rate of metabolism in the larvæ than in the adult wasps." (Ritchie, James, 1915, Scottish Naturalist, 1915, pp. 318–331.)

In this upper comb there were 20 capped cells, all located near the center of the comb, but with four uncapped cells scattered among them. One of these uncapped cells had a larva of fair size, the remaining three contained eggs. The silken caps of the closed cells were white, and rose in cylindrical shape about 4 mm. above the cell itself. When one or more of these capped cells were opened, they proved to have larvæ of a stage of development like that of the full-grown larvæ of the lower comb. I suspect that the capping of the cells had taken place only a little time before the nest was opened and that the full-grown larvæ of the lower comb would very shortly have presented the same condition.

The time from the laying of the egg to the capping of the cell could not, therefore, have occupied much more than three weeks and may have occupied less, all depending on when oviposition occurred. As to this, one can merely speculate. My impression is that oviposition probably began very shortly after the construction of each of the combs. This would make the time from the laying of the egg to the attainment of full size by the emerging larva approximate that recorded for *Vespa vulgaris*.[1] Janet[2] has shown in the case of *Vespa crabro* that the egg stage may last from four days to twenty-one days while that of the larva is completed in from eight days to nineteen days, depending on conditions of temperature and other factors. A minimum of thirteen days from the laying of the egg to completion of the larval stage would thus seem to be indicated for *Vespa crabro*, and this suggests the possibility that, in the case also of the Barro Colorado wasp, development may have been accelerated. In this connection it is interesting to compare observations made on *scutellaris* in Brazil. H. von Ihering states that in that country new nests of *scutellaris* having three or four combs reveal themselves when opened as still completely devoid of eggs. Once, however, von Ihering did find even in Brazil a nest of three combs in which brood was already present.[3]

That portion of the upper comb that contained the capped cells was brought to New York. About six weeks later (Jan. 24, 1931), as no wasps had emerged, these cells were opened. In all but two cases they contained wasps that after completing their development had died without piercing the silken barrier, which became their shroud. Is it possible that the aid of the free-moving adult wasps was needed to

[1] "In the common wasp [*Vespa vulgaris*] the larva is hatched 8 days after oviposition, it grows to its full size in 12 or 14 days, then spins its delicate hood, casts its integument . . . . and after a passive pupa state of 10 days emerges a perfect insect." (Owen's 'Invertebrate Animals,' cited by Ritchie, James, 1915, Scottish Naturalist, 1915, pp. 318–331.)

[2] Janet, Charles, 1895, Mémoires de la Société zoologique de France, VIII, pp. 1–140, with 41 figs.

[3] Ihering, H. von, 1896, Zool. Anzeiger, XIX, pp. 449–453.

liberate these prisoners?[1] In addition to the capped cells, the upper comb contained 16 larvæ and six eggs. The larvæ of this upper comb graded off in size toward the circumference just as did the larvæ in the lower comb.

Among the 130 adult wasps taken with the nest, which constituted the entire colony except for at most three or four that escaped, there was not a single male.

[1]Janet notes (p. 85) that in exceptional cases workers of *Vespa crabro* perforate the cap of the cell several days before the emergence of the adolescent wasps (Janet, Charles, 1895, Mémoires de la Société zoologique de France, VIII, pp. 1–140, with 41 figs.).