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ON THE

INSTINCTS AND HABITS

OF THE

SOLITARY WASPS

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AND

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MILWAUKEE

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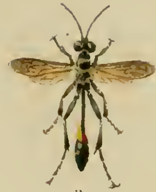

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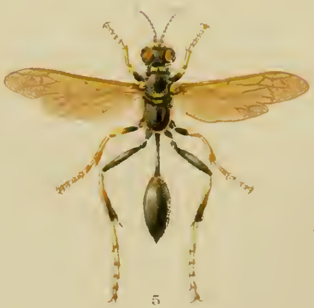

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PREFACE.

The work that has served as a basis for this volume has extended over several years, and has been done in Wisconsin, at the residence of Dr. Charles A. Leuthstrom, to whose forbearance in allowing us to use his gardens as a hunting-ground, we are greatly indebted. The field is a most favorable one since an island in the lake close by, acres of woodland all about, and a farm with two vegetable gardens, one on the top of a hill and one on lower ground, offer a rich variety of nesting places. It is in the lower garden, which is bounded by woods, that the wasps are found in greatest abundance.

The study of the solitary wasps was suggested to us by those most interesting and delightful of all entomological papers, the "Souvenirs Entomologiques" of J. H. Fabre, and however widely our conclusions may differ, we have for M. Fabre and for his work, the deepest respect and admiration.

We wish to express our indebtedness to Mr. W. H. Ashmead of Washington, for his cordial interest in the work and for his kindness in identifying for us the various species.

Milwaukee, October 30, 1897.

INSTINCTS AND HABITS OF THE SOLITARY WASPS.

INTRODUCTION.

For the purposes of this work wasps may be divided into two classes, the social and the solitary. Of these, those of the latter class are much the more numerous, there being over one thousand species in the United States alone, while there are only about fifty species of the social genera. That the social kinds are better known is due to the fact that the great size to which their communities often attain makes it comparatively easy to study them.

The social wasps most commonly met with in Wisconsin are the hornets and yellow-jackets of the genus *Vespa,* and a species of *Polistes* that builds open combs. For the sake of comparison let us sum up briefly the cycle of their lives. In the autumn the queens, having mated with the drones, creep away into crevices and sheltered corners where they pass the winter. In the spring they may be seen seeking for suitable nesting places, and forming, from the fibres of weather- beaten wood, which are scraped off and chewed up, the first layer of cells. So much being accomplished the queen deposits her eggs, one in each cell, and when these develop into grubs she feeds them until at the end of a week or ten days they spin their cocoons and become pupæ. In from eight to ten days the perfect wasp is formed and emerges from its cell ready to assume its share of responsibility in the work of the nest. These first wasps are always neuters, and hereafter all the duties which the queen has been obliged to perform, with the single exception of egg-laying, fall upon them. Before long many hundreds of neuters are busy at work, no drones appearing until the summer is somewhat advanced. While the warm weather lasts the nest continues to increase in size and numbers, but in the first cool days of fall the neuters and queens desert it, leaving the helpless drones and undeveloped grubs to starve. The neuters, after leading a wandering life for two or three weeks, perish with the first frosts, the queens alone being left, and doubtless many of these also die in the severe cold winter.

The solitary wasps differ from the social, in having only two sexes. Each female makes a separate nest and provisions it by her own labor; and in many cases a new nest is made for each egg. There is no coöperation among them, although in certain genera, as *Pelopaeus* and *Bembex*, a number of individuals build close together, forming a colony. The nests may be made of mud and attached, for shelter, under leaves, rocks, or eaves of buildings, or may be burrows hollowed out in the ground, in trees or in the stems of plants. The adult wasp lives upon fruit or nectar but the young grub or larva must have animal food, and here the parent wasp shows a rigid conservatism, each species providing the sort of food that has been approved by its family for generations, one taking flies, another bugs, and another beetles, caterpillars, grasshoppers, crickets, locusts, spiders, cockroaches, aphides or other creatures, as the case may be.

The solitary wasps mate shortly after leaving the nest, in the spring or summer. The males are irresponsible creatures, aiding little, if at all, in the care of the family. When the egg-laying time arrives the female secures her prey, which she either kills or paralyzes, places it in the nest, lays the egg upon it, and then, in most cases, closes the hole and takes no further interest in it, going on to make new nests from day to day. In some genera the female maintains a longer connection with her offspring, not bringing all the provision at once but returning to feed the larva as it grows, and only leaving the nest permanently when the grub has spun its cocoon and become a pupa.

The egg develops in from one to three days into a footless, maggot-like creature which feeds upon the store provided for it, increasing rapidly in size, and entering the pupal stage in from three days to two weeks. In the cocoon it passes through its final metamorphosis, emerging as a perfect insect, perhaps in two or three weeks, or, in many cases, after the winter months have passed and summer has come again. Probably no solitary wasp lives through the winter, those that come out in the spring or summer perishing in the autumn.

The social hymenoptera are born into a community, and their mental processes may be modified and assisted by education and imitation, but the solitary wasp (with rare exceptions) comes into the world absolutely alone. It has no knowledge of its progenitors, which have perished long before, and no relations with others of its kind. It must then depend entirely upon its inherited instincts to determine the form of its activities, and although these instincts are much more flexible than has been generally supposed, and are often modified by individual judgment and experience, they are still so complex and remarkable as to offer a wide field for study and speculation.

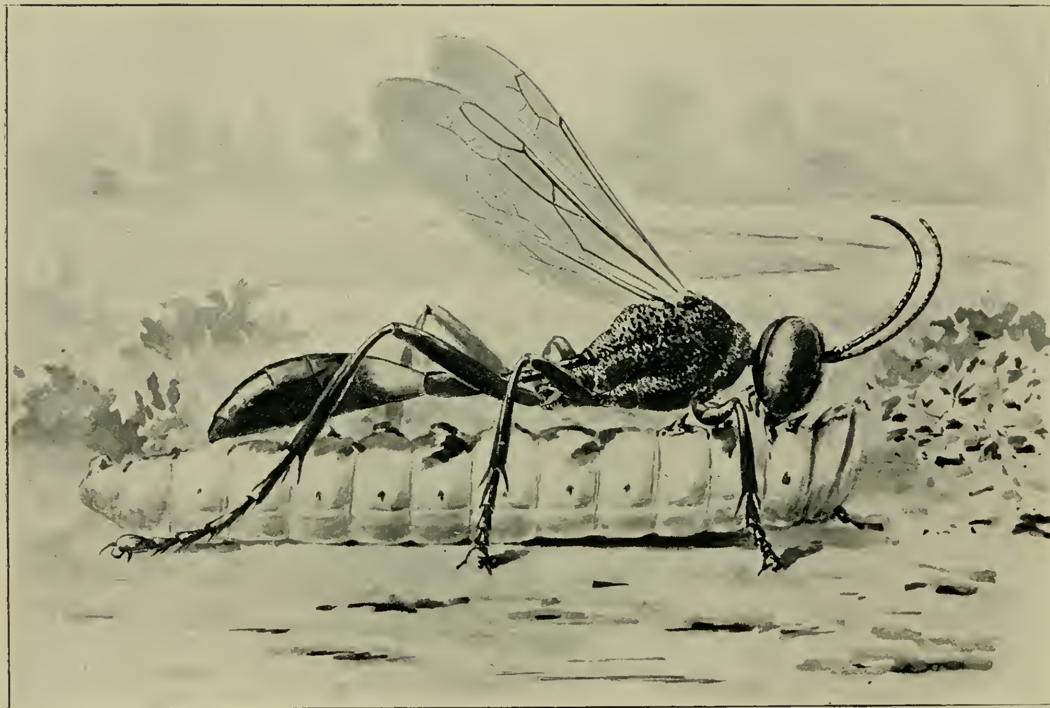
CHAPTER I.

AMMOPHILA AND HER CATERPILLARS.

Plates II., fig. 2; III.; IV.; V.; VIII., figs. 1–4.

Most graceful and attractive of all the wasps—"*taille effilée tournure svelte*," as Fabre describes them, the Ammophiles, of all the inhabitants of the garden, hold the first place in our affections. Not so beautiful as the blue *Pelopaeus* nor so industrious as the little red-girdled *Trypoxylon*, their intelligence, their distinct individuality, and their obliging tolerance of our society make them an unfailing source of interest. They are, moreover, the most remarkable of all genera in their stinging habits, and few things have given us deeper pleasure than our success in following the activities and penetrating the secrets of their lives. In our neighborhood we have but two species of *Ammophila*, *urnaria* Cresson (Pl. II., fig. 2), and *gracilis* Cresson, both of them being very slender bodied wasps of about an inch in length, *gracilis* all black, and *urnaria* with a red band around the front end of the abdomen. With two exceptions our observations relate to *urnaria*.

During the earlier part of the summer we had often seen these wasps feeding upon the nectar of flowers, especially upon that of the sorrel of which they are particularly fond, but at that time we gave them but passing notice. One bright morning in the middle of July, however, we came upon one that was so evidently hunting, and hunting in earnest, that we gave up everything else to follow her. The ground was covered, more or less thickly, with patches of purslane, and it was under these weeds that our *Ammophila* was eagerly searching for her prey. After thoroughly investigating one plant she would pass to another, running three or four steps and then bounding as



J. H. Emerton, del.

AMMOPHILA URNARIA CARRYING CATERPILLAR TO NEST.

though she were made of thistledown and were too light to remain upon the ground. We followed her easily, and as she was in full view nearly all of the time we had every hope of witnessing the capture, but in this we were destined to disappointment. We had been in attendance on her for about a quarter of an hour when, after disappearing for a few moments under the thick purslane leaves, she came out with a green caterpillar. We had missed the wonderful sight of the paralyzer at work, but we had no time to bemoan our loss for she was making off at so rapid a pace that we were well occupied in keeping up with her. She hurried along with the same motion as before, unembarrassed by the weight of her victim. (Plate III.) Twice she dropped it and circled over it a moment before taking it again. For sixty feet she kept to open ground, passing between two rows of bushes, but at the end of this division of the garden, she plunged, very much to our dismay, into a field of standing corn. Here we had great difficulty in following her, since far from keeping to her former orderly course, she zigzagged among the plants in the most bewildering fashion, although keeping a general direction of northeast. It seemed quite impossible that she could know where she was going. The corn rose to a height of six feet all around us; the ground was uniform in appearance, and, to our eyes, each group of corn stalks was just like every other group, and yet, without pause or hesitation, the little creature passed quickly along, as we might through the familiar streets of our native town.

At last she paused and laid her burden down. Ah! the power that has led her is not a blind, mechanically perfect instinct, for she has traveled a little too far. She must go back one row into the open space that she has already crossed, although not just at this point. Nothing like a nest is visible to us. The surface of the ground looks all alike, and it is with exclamations of wonder that we see our little guide lift two pellets of earth which have served as a covering to a small opening running down into the ground.

The way being thus prepared she hurries back with her wings quivering and her whole manner betokening joyful triumph at the completion of her task. We, in the meantime, have become as much excited over the matter as she is herself. She picks up the caterpillar, brings it to the mouth of the burrow and lays it down. Then, backing in herself, she catches it in her mandibles and drags it out of sight, leaving us full of admiration and delight.

How clear and accurate must be the observing powers of these wonderful little creatures! Every patch of ground must, for them, have its own character; a pebble here, a larger stone there, a trifling tuft of grass—these must be their landmarks. And the wonder of it is that their interest in each nest is so temporary. A burrow is dug, provisioned and closed up, all in two or three days, and then another is made in a new place with everything to learn over again.

From this time (July thirteenth) on to the first of September our garden was full of these wasps, and they never lost their fascination for us, although owing to a decided difference between their taste and ours as to what constituted pleasant weather all our knowledge of them was gained by the sweat of our brows. When we wished to utilize the cool hours of the morning or of the late afternoon in studying them, or thought to take advantage of a cloud which cast a grateful shade over the sun at noonday, where were our Ammophiles? Out of sight entirely, or at best only to be seen idling about on the flowers of the onion or sorrel. At such a time they seemed to have no mission in life and no idea of duty. But when the air was clear and bright and the mercury rose higher and higher, all was changed. Their favorite working hours were from eleven in the morning to three in the afternoon, and when they did work they threw their whole souls into it. It was well that it was so, for they certainly needed all the enthusiasm and perseverance that they could muster for such wearisome and disappointing labor. Hour after hour was passed in search, and often there was nothing to show at the end of it, for, since the caterpillars that they wanted were nocturnal species, most of them were under ground in the day-time. The species observed by Fabre knew, by some subtle instinct, where to find the worm, and unearthed it from its burrow. *Urnaria*, on the contrary, never dug for her prey, but hunted on bare ground, on the purslane, and most of all on the bean-plants. These were examined carefully, the wasp going up and down the stems and looking under every leaf, but the search was so frequently unsuccessful that in estimating their work we are inclined to think that they can scarcely average one caterpillar a day. When they were hunting over bare ground they often paused and seemed to listen, and in the beginning we expected to see them burrow down and drag a victim from under the soil, but this never happened.

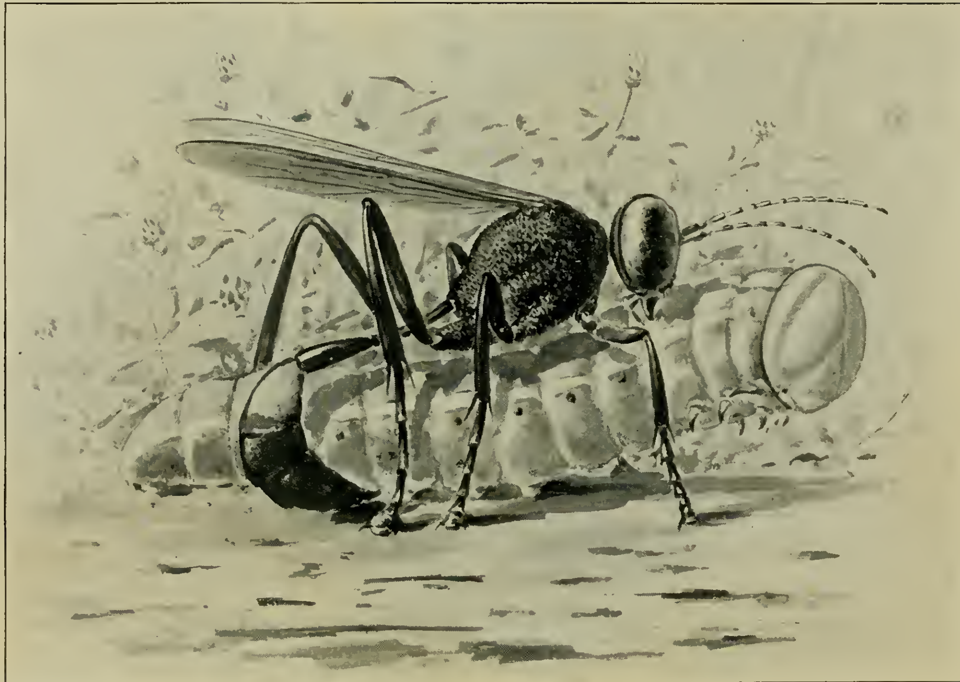
In this species, as in every one that we have studied, we have found a most interesting variation among the different individuals, not only in methods but in character and intellect. While one was beguiled from her hunting by every sorrel blossom she passed, another stuck to her work with indefatigable perseverance. While one stung her caterpillar so carelessly and made her nest in so shiftless a way that her young could only survive through some lucky chance, another devoted herself to these duties not only with conscientious thoroughness but with an apparent craving after artistic perfection that was touching to see.

The method employed by the *Ammophilae* in stinging their prey is more complex than that of any other predatory wasp. The larvæ with which they provision their nests are made up of thirteen segments and each of these has its own nervous center or ganglion. Hence if the caterpillar is to be reduced to a state of immobility, or to a state so nearly approaching immobility that the egg may be safely laid upon it, a single sting, such as is given by some of the *Pompilidae* to their captured spiders, will be scarcely sufficient. All this we knew from Fabre's "Souvenirs," and yet we were not at all prepared to believe that any plain American wasp could supply us with such a thrilling performance as that of the Gallic *hirsuta*, which he so dramatically describes. We were, however, most anxious to be present at the all-important moment that we might see for ourselves just how and where *Ammophila urnaria* stings her victim.

For a whole week of scorching summer weather we lived in the bean patch, scorning fatigue. We quoted to each other the example of Fabre's daughter Claire, whose determination to solve the problem of *Odynerus* led to a sun-stroke. We followed scores of wasps as they hunted; we ran, we threw ourselves upon the ground, we scrambled along on our hands and knees in our desperate endeavors to keep them in view, and yet they escaped us. After we had kept one in sight for an hour or more some sudden flight would carry her far away and all our labor was lost.

At last, however, our day came. We were doing a little hunting on our own account, hoping to find some larvæ which we could drop in view of the wasps and thus lead them to display their powers, when we saw an *urnaria* fly up from the ground to the underside of a bean leaf and knock down a small green caterpillar. Breathless with an excitement which will be understood by those who have tasted the joy of such a moment, we hung over the actors in our little drama. The ground was bare, we were close by and could see every motion distinctly. Nothing more perfect could have been desired.

The wasp attacked at once but was rudely repulsed, the caterpillar rolling and unrolling itself rapidly and with the most violent contortions of the whole body. Again and again its adversary descended but failed to gain a hold. The caterpillar in its struggles, flung itself here and there over the ground, and had there been any grass or other covering near by it might have reached a place of partial safety, but there was no shelter within reach, and at the fifth attack the wasp succeeded in alighting over it, near the anterior end, and in grasping its body firmly in her mandibles. Standing high on her long legs and disregarding the continued struggles of her victim she lifted it from the ground, curved the end of her abdomen under its body, and darted her sting between the third and fourth segments.



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AMMOPHILA URNARIA STINGING CATERPILLAR.

From this instant there was a complete cessation of movement on the part of the unfortunate caterpillar. Limp and helpless, it could offer no further opposition to the will of its conqueror. For some moments the wasp remained motionless, and then, withdrawing her sting, she plunged it successively between the third and the second, and between the second and the first segments. (Plate IV.)

The caterpillar was now left lying on the ground. For a moment the wasp circled above it and then, descending, seized it again, further back this time, and with great deliberation and nicety of action gave it four more stings, beginning between the ninth and tenth segments and progressing backward.

Urnaria, probably feeling—as we certainly did—a reaction from the strain of the last few minutes, and a relief at the completion of her task, now rested from her labors. Standing on the ground close by she proceeded to smooth her body with her long hind legs, standing in the meantime, almost on her head, with her abdomen directed upward. She then gave her face a thorough washing and rubbing with her first legs, and not until she had made a complete and satisfactory toilet did she return to the caterpillar.

We saw *Ammophila* capture her prey only three times during the whole summer, but from these observations and from the condition of her caterpillars taken at various times from nests, her method seems to be wonderfully close to that of *hirsuta*, with just about the same amount of variation in different individuals.

Thus in our second example, she stung the first three segments in the regular order, the third, the second, and lastly (and most persistently) the first. She then went on, without a pause, to sting the fourth, fifth, sixth, and seventh, stopping at this point and leaving the posterior segments untouched. In our first example, it will be remembered, the middle segments were spared. The stinging being completed, she proceeded to the process known as *malaxation*, which consists in repeatedly squeezing the neck of the caterpillar, or other victim, between the mandibles, the subject of the treatment being turned around and around so that all sides may be equally affected.

In our third case a caterpillar which we had caught was placed in front of a wasp just after she had carried the second larva into her nest. She seemed rather indifferent to it, passing it once or twice as she ran about, but finally picked it up and gave it one prolonged sting between the third and fourth segments. She then spent a long time in squeezing the neck, pinching it again and again. It was then left on the ground, and as she showed no further interest in it we carried it home for further study.

In the three captures, then, that came under our observation, all the caterpillars being of the same species and almost exactly of the same size, three different methods were employed. In the first, seven stings were given at the extremities, the middle segments being left untouched, and no malaxation was practiced. In the second, seven stings again but given in the anterior and middle segments, followed by slight malaxation. In the third, only one sting was given but the malaxation was prolonged and severe.

Let us now compare these variations with those of Fabre. In his first case the sting entered at twelve different points, beginning between the first and second segments and progressing regularly backward. There was no malaxation. In his second example the third, second and first segments were stung in the order given, and thereafter each succeeding segment up to the ninth, nine stings being given in all, with careful malaxation following. In his later experiments, which seem to have been numerous, he found that as a usual thing all the segments were stung, although the posterior three or four were occasionally spared, but that the order in which they were operated upon, as well as the amount of malaxation, was very variable.*

*M. Fabre was most fortunate in making *hirsuta* sting under artificial conditions. Our experience with *urnaria*, on the contrary, recalls his failures with *sabulosa*. No matter how carefully we arranged for an experiment, placing the glass over the wasp out of doors, with the

Our conclusions, then, as to *Ammophila's* methods of stinging agree fairly well with those of Fabre. There is, however, one important exception. In his cases the middle segments, upon one of which the egg is laid in our species as well as in his, were invariably stung, and this he considers a point of extreme importance. In one of our cases the middle segments were not touched.

The point in which our observations differ most widely from those of Fabre is in the condition of the caterpillars after the stinging. He seems to have found that they always lived a long time but in a motionless or nearly motionless state, and he dwells at length upon the necessity of both of these conditions since he believes that while the wasp larva must have perfectly fresh food, any violent motion would imperil its safety. As a matter of fact we found a wide variation in the thoroughness with which the wasps performed their task. We had, in all, fifteen caterpillars upon which *urnaria* had worked her will, and while a few of them fulfilled to a nicety the conditions which Fabre believes to be imperative, most of them were far from doing so. Some of them lived only three days, others a little longer, while still others showed signs of life at the end of two weeks. *Urnaria* stores two caterpillars and in more than one instance the second one died and became discolored before the first one was entirely eaten. The wasp larva did not, as might have been expected, find fault with this arrangement, but proceeded to attack number two with good appetite, ate it all up, and then spun its cocoon as though nothing unpleasant had occurred.

The second condition was also violated. In one case the bite of the newly hatched larva caused the caterpillar to rear upon end in so violent a manner that it looked as though the little creature would surely be dislodged. Another caterpillar kept up a continuous wriggling without any external stimulation and

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sun at its hottest, while she was in the full fervor of hunting, and offering her the caterpillars that she preferred above all others, the fact of imprisonment was the only one present to her consciousness, and she never ceased in her restless endeavors to escape.

when it was touched it rolled about almost as these larvæ do in a healthy state, and yet the egg was not shaken off. The caterpillar which received but a single sting, although not motionless, would have been a safer repository for the egg than either of these. Others fulfilled Fabre's condition perfectly, lying immovable except when stimulated and then responding only by a slight quivering of the legs or skin.

To show more exactly the amount of variation we quote from our notes on the subject. These notes were made from day to day.

No. 15. July 13. Took two caterpillars from nest just after the second one had been put in. Both move posterior end of body without stimulation.

July 14, A. M. Caterpillars both alive. The egg has hatched and the one to which the larva is attached wriggles violently and constantly rears up at anterior end. P. M. Wasp larva eating. Caterpillar moves but little. The second caterpillar is still lively, moving at posterior end.

July 15. Wasp larva has grown large and green. The caterpillar does not move and the posterior half has turned yellow. The second caterpillar moves only when stimulated and then only at the posterior end.

July 17, 7:20 P. M. The second caterpillar is alive and moves when stimulated.

July 18, 9 A. M. The second caterpillar is dead. The anterior two-thirds of the venter are green but the rest of the body has turned brown. It lived four days and a half after being stung. The wasp larva is still at work on the first caterpillar.—6:30 P. M. The wasp larva has just begun to eat the second caterpillar.

July 19, 10 A. M. The wasp larva has eaten nearly all of the second caterpillar since last night. Have placed earth in bottom of tube to see whether it will spin its cocoon.

July 21, 9 A. M. Larva has just spun cocoon. It ate half of the inside of the second caterpillar, evidently without regard to the vital organs, taking everything as it came. The length of the cocoon is 14 mm., and the greatest width 6 mm. Color, light yellow.

No. 22. July 23, 9 A. M. Took from the nest the caterpillar which we saw stung yesterday.* It was much quieter than those in the nest

*This caterpillar had been stung in seven places, at the anterior and posterior ends. Owing to some disturbing element the egg, instead of being laid upon it, was dropped on the ground.

of No. 15. It does not move spontaneously but when it is touched the legs, particularly the anterior ones, quiver like those of a spider that has been stung.

July 24. When touched, moves at anterior end.

July 25, 9 A. M. The caterpillar is dead and some of the segments have turned yellow.

No. 25. July 25, P. M. Took three caterpillars. Two of these were from a nest. Of these the first had the egg (6 mm. long) attached on the right side of the sixth segment. The second one, we saw stung this morning. Seven stings were given in the first seven segments, with some malaxation. The third caterpillar is one which we offered to the wasp and which received one sting, in the third segment, followed by severe malaxation. All three are quiet but move when stimulated.

July 26, 9 A. M. Egg not yet hatched. The third caterpillar is alive. The posterior end, beyond fifth segment, moves without stimulation, stretching out and upward. The posterior legs cling to the finger tightly enough to support the weight of its body when it is lifted. The paralysis is general but is much lighter toward the posterior end.

July 27, 7:30 A. M. The third caterpillar is still lively but is not so plump. The posterior legs cling to the finger and support the body, the anterior end hanging down. These legs also make efforts to walk. So far as the egg is concerned this caterpillar would serve as well as those found in the nest. It has passed fæces twice.

July 27, 8 A. M. The egg has hatched and chlorophyll is visible in the larva.

July 28, 8 A. M. Larva growing fast. It is all green in color except the mouth, resembling the caterpillar that it is eating. This caterpillar is dead as is also the second one, which has begun to turn yellow at the anal segments. The third caterpillar is much shrunken but is still alive, at least in the posterior half.

July 30, 8 A. M. The larva has begun to eat the second caterpillar. The third caterpillar is dead.

August 1, 9:30 A. M. The larva has spun its cocoon which is 15 mm. long, and light yellow in color.

No. 56. August 17. We saw an *Ammophila* taking a caterpillar into her nest at eleven in the morning. At five in the afternoon we took it out. The egg was placed on one side of the sixth segment, near the dorsum. The caterpillar is very imperfectly paralyzed, all its posterior segments and the posterior feet wriggling violently when it is touched. This is the most active caterpillar that we have seen so far, and the egg must be tightly fastened on or it would be lost. The wasp appears to have stung only as far back as the fifth or sixth segment, the second part of the process being omitted. Touching it in front causes the posterior legs to open and close, while the posterior half of the body is thrown violently to one side.

August 18, 9 A. M. The caterpillar jerks up its posterior half without being touched. When stimulated it is so violent that we are concerned lest the egg be dislodged.

August 18, 10 A. M. We have just secured the caterpillar which should have completed the provisioning of this nest, the wasp having deserted it on finding that her burrow had been disturbed. This one has been stung in all the segments since it cannot move the posterior half about, nor wriggle as the first one does. Its neck, however, has not been malaxed, as the mouth parts open and shut when touched, and hold anything that is placed in them. The first caterpillar stung by the wasp had been so malaxed that the mouth parts were paralyzed.

August 19. The first caterpillar is still lively, while the second shows but little movement. We put both, with the egg, into alcohol.

No. 79. August 31. At eleven o'clock this morning we saw an *urnaria* storing a short, fat, brown caterpillar. At five in the afternoon we opened the nest and found not only the one that we had seen taken in but also a longer, thinner, green one. Upon this one was a wasp larva about one day old, which shows that, in all probability, three days must have elapsed between the storing of the first and second caterpillars. Besides the wasp larva, which has been attacked by something and looks sickly, there are, upon the unfortunate green caterpillar, three small parasitic larvæ which all look plump and healthy. In spite of being obliged to furnish food to all these creatures the caterpillar is still alive although a good deal shrunken and the worse for wear. The one put into the nest today is alive but only moves when stimulated.

September 1. Both caterpillars are alive. The wasp larva is dead, but the parasites are still feeding on the green one and are doing well.

September 2. Both caterpillars are alive. The green one is turning yellow at the eighth segment. It is on this segment that the three parasites are fixed, on the venter between the fourth and fifth pairs of feet. They are growing fast. The brown caterpillar has also a larva of some kind, which hatched today. It is placed on the right side between the fourth and fifth rings, just behind the third pair of feet.

September 3, 9 A. M. The green caterpillar is dead and has turned black. Only one parasite is to be seen and that one is boring into the body of its host. The brown caterpillar is still alive. Its parasite is large and is eating fast.

September 4. The parasite inside the green caterpillar is still eating. That on the brown one is crawling about on the outside. This brown caterpillar is barely alive.

September 5. The larva in the green caterpillar is eating as before. The brown caterpillar is dead and the parasite has gone inside of its body.

September 6. The first larva has burrowed into the earth, having eaten all the inside out of its prey. The other one is eating as before.

September 7. The brown caterpillar's parasite has also burrowed into the ground.

No. 80. September 1. Just after noon yesterday we saw an uncommonly large *urnaria* carry an uncommonly large green caterpillar into her nest. At eleven o'clock this morning we took it out. The egg is on the left side of the seventh segment.

September 3, 11 A. M. The egg has just hatched. It is nearly three days since it was laid. The weather is cool and it may be for that reason that a longer time than usual has elapsed.

September 4. The larva is growing slowly.

September 5. The larva grows very slowly. The caterpillar is alive and green.

September 6. The caterpillar is alive and looks fresh. The larva eats and grows very slowly.

September 8. The caterpillar is still alive and green. The larva has increased a very little in size.

September 10, 5 P. M The larva has grown very fast since yesterday morning. The caterpillar is dead. The last four segments have turned brown, but the rest is of the original green color.

September 15. The larva is still eating the dark colored remains of the caterpillar. It is now very large and fat and has taken on the green color of the caterpillar which it has devoured.

September 16. The larva is spinning its cocoon.

No. 81. August 31. This afternoon we saw an *A. gracilis* carry a green caterpillar, larger than the one ordinarily taken by *urnaria*, but not so large as that of No. 80, a long distance (261 ft.) over all sorts of ground. It received very rough usage and when, the wasp having deserted it, we took it into our possession, it was so contorted that the head and the first four segments were not in a plane with the rest of the body. The third segment, which had been grasped by the mandibles of the wasp, was badly bruised and discolored.

September 1. The caterpillar, as we look at it through the glass slide which covers the box in which it lies, continually moves the mouth parts and the anterior segments of its body. Now and then it slowly lifts the posterior half of its body and then lets it go back.

2

This is without the slightest stimulation as we do not even touch the box nor the shelf upon which it stands. The movement is not at all violent as in other caterpillars (see Nos. 15 and 56). The muscles have relaxed a little so as to let down the anterior segments, but the body is still in a curled up position.

September 5. The caterpillar is alive and is still tightly curled up.

September 6. It now lies flat. The body is shrunken and the color has faded to a livid blue.

September 15. The caterpillar looks as if it were dead but still responds to careful stimulation.

September 23. The caterpillar is now of a sickly yellowish hue and is shrunken to a quarter of its original size. We get a scarcely perceptible response to stimulation.

September 25. The caterpillar is unquestionably dead.

Among the fifteen caterpillars that we have taken from the nests of *urnaria* three kinds are represented, twelve of them belonging to one species, two to the second, and one to the third.

The egg, which is laid upon the side of the sixth or seventh segment* (Pl. VIII., fig. 5), hatches in from two to three days; the larva spends from six days to two weeks in eating, and then spins its pale yellowish cocoon.

The nesting habits of *urnaria* closely resemble those of the other members of the genus, as reported by various observers. The spot chosen is in firm soil, sometimes in open ground but much more freqeuntly under the leaves of some plant. The plan is a very simple one. A tunnel of about an inch in length leads to the pocket in which the caterpillars are stored. There is no hardening of the walls in any part. We took pains to draw every nest that we opened, and, as will be seen from the illustrations of some of them, there was a very considerable variation in the minor details, such as the obliquity of the entrance tunnel, the shape of the pocket, and the angle at which the tunnel and pocket were joined. (Pl. VIII., figs. 1–4.)

The work is done with the mandibles and the first legs. When it has proceeded so far that the wasp is partly hidden, she

*In the drawing the egg is, by mistake, shown upon the eighth segment.

begins to carry the earth to a little distance from the nest. In doing this she backs up to the edge of the opening and flying a little way, gives a sort of flirt which throws the pellet that she carries in her mandibles to a distance. She then alights where she is and pauses a moment before she runs back to the hole, or, in some cases, darts back on the wing. We watched the process of nest-making five times during the summer. In the first instance *Ammophila*, having made her excavation, ran off to a distance and after some search returned with a good sized lump of earth. This she laid over the opening which was now entirely hidden. She then flew to the bean patch close by, but after ten minutes she came back and looked at her nest. It was so neatly covered as to be almost indistinguishable, but to this fastidious little creature something seemed lacking. She pulled away the cover, carried out three or four more loads, and then began to search for another piece for closing. After a time she came hurrying back with a lump of earth, but when close to the nest she concluded that it would not do, dropped it, and ran off in another direction. Presently she found one which fitted into the hole exactly, and after placing it she brought a much smaller piece which she put above and to one side. She then stood back and surveyed the whole and it seemed to us that we could read pride and satisfaction in her mien. She then flew away and we supposed that that stage of the work was certainly completed. Upon coming back two hours later, however, we found that she had been trying some more improvements, as a number of little pellets had been piled up over the nest. This wasp, by the way, never succeeded in finding a caterpillar, since when we opened the nest a few days later it was still empty. Perhaps she came to some untimely end.

Of the other wasps that we saw making a temporary closure of their nests, one wedged a good sized stone deep down into the neck of the burrow and then filled the space above, solidly, with smaller stones and earth. Another placed two lumps of earth just below the surface of the ground, filled the opening with pellets loosely thrown in, and then kicked some light dust over the whole. The others used only two or three lumps of earth which they fitted neatly into the opening just below the surface. Although it is usual for *urnaria* to leave her nest closed while she is off searching for her prey, there is no invariable rule in the matter even for single individuals. Once having seen a wasp dig her nest and close it up, we drew some radiating lines from the spot, in the light dust that covered the place, that we might find it again. When we returned, two hours later, the same wasp had made a nest four or five inches distant from the first one, and had left it wide open, while she had gone off to search for her caterpillar. She had probably been alarmed by the marks that we had made and had felt it necessary to dig a new nest, but being in a hurry to lay her egg had omitted the usual process of closing it. We witnessed the storing of the caterpillar and the final closing.

From Fabre we learn that *A. argentata* and *A. sabulosa*, like our own *urnaria*, close the nest as soon as it has been made, at least when the provisioning is to be postponed until the next day, while *A. holosericea* leaves it open until it is completely stored. He suggests an explanation for this variation by dwelling upon the inconvenience that would result if it were opened every time that the wasp brought in a caterpillar, since *holosericea* stores up five or six small larvæ instead of one or two large ones. But what, then, shall be said of *A. yarrowi*, which, according to Dr. Williston, while it also stores a number of small caterpillars, takes the greatest pains to close and conceal the entrance every time that it comes out? We see the same habit in other genera where the mother continually passes in and out, as in *Bembex* and *Oxybelus*.

Fabre thinks that *A. hirsuta* has the habit, unusual for *Ammophila*, of catching her prey first and then digging the hole in which she bestows it. As she takes only one large caterpillar she is thus relieved of the necessity of closing the nest more than once.

As has been said, *urnaria* usually hunts a long time before she finds her caterpillar, and one or two days may pass before anything is put into the nest. During this prolonged search she often revisits the spot and thus keeps fresh the memory of its locality. As soon as the first caterpillar is stored she lays an egg on it and then closes the nest as before. The second one may be brought in within a few hours, but in one instance that came under our notice (No. 79), we feel sure that the interval was as much as three days. We saw the interment of the second caterpillar, and upon excavating, found upon the first one a larva at least a day old; and we suppose that at least two days had elapsed between the laying and the hatching of the egg.

When the provisioning is completed the time arrives for the final closing of the nest, and in this, as in all the processes of *Ammophila*, the character of the work differs with the individual. For example, of two wasps that we saw close their nests on the same day, one wedged two or three pellets into the top of the hole, kicked in a little dust and then smoothed the surface over, finishing it all within five minutes. This one seemed possessed by a spirit of hurry and bustle, and did not believe in spending time on non-essentials. The other, on the contrary, was an artist, an idealist. She worked for an hour, first filling the neck of the burrow with fine earth which was jammed down with much energy, this part of the work being accompanied by a loud and cheerful humming, and next arranging the surface of the ground with scrupulous care, and sweeping every particle of dust to a distance. Even then she was not satisfied but went scampering around hunting for some fitting object to crown the whole. First she tried to drag a withered leaf to the spot but the long stem stuck in the ground and embarrassed her. Relinquishing this she ran along a branch of the plant under which she was working and, leaning over, picked up from the ground below a good sized stone, but the effort was too much for her and she turned a somersault on to the ground. She then started to bring a large lump of earth but this evidently did not come up to her ideal for she dropped it after a moment, and seizing another dry leaf carried it successfully to the spot and placed it directly over the nest. A third instance of the final closing of the nest was intermediate between these two, the work occupying twenty minutes. The wasp first put a plug well down, then dropped in several large pellets and brushed in a quantity of fine earth, and finally smoothed the surface over.

We had another much less worthy example, one, indeed, that went to the extreme of carelessness. We first saw her in the morning carrying her caterpillar across the field. She frequently dropped it and ran or flew to a little distance, and when she took it again the venter was sometimes up and sometimes down, just as it happened. Her nest was a very poor affair just beneath the surface, and after the caterpillar was carried in, it was visible from above. She filled the hole with loose particles of earth and then scratched the surface of the ground a little in a perfunctory sort of way, as different as possible from the painstaking labor that we had been accustomed to in her sisters. That afternoon we opened the nest and removed its contents. The next morning we saw this wasp bringing home her second caterpillar. She was much puzzled and disturbed at the destruction of her nest, and hunted for it for an hour and a half, leaving the caterpillar on the ground near by. We could not help feeling sorry that we had interrupted the contented routine of her life. She finally gave up in despair and we took possession of the deserted caterpillar.

Just here must be told the story of one little wasp whose individuality stands out in our minds more distinctly than that of any of the others. We remember her as the most fastidious and perfect little worker of the whole season, so nice was she in her adaptation of means to ends, so busy and contented in her labor of love, and so pretty in her pride over her completed work. In filling up her nest she put her head down into it and bit away the loose earth from the sides, letting it fall to the bottom of the burrow, and then, after a quantity had accumulated, jammed it down with her head. Earth was then brought from the outside and pressed in, and then more was bitten from the sides. When, at last, the filling was level with the ground, she

J. H. Emerton, del.

AMMOPHILA URNARIA USING STONE TO POUND DOWN EARTH OVER NEST.

brought a quantity of fine grains of dirt to the spot and picking up a small pebble in her mandibles, used it as a hammer in pounding them down with rapid strokes, thus making this spot as hard and firm as the surrounding surface. (Plate V.) Before we could recover from our astonishment at this performance she had dropped her stone and was bringing more earth. We then threw ourselves down on the ground that not a motion might be lost, and in a moment we saw her pick up the pebble and again pound the earth into place with it, hammering now here and now there until all was level. Once more the whole process was repeated, and then the little creature, all unconscious of the commotion that she had aroused in our minds, unconscious, indeed, of our very existence and intent only on doing her work and doing it well, gave one final, comprehensive glance around and flew away.

We are claiming a great deal for *Ammophila* when we say that she improvised a tool and made intelligent use of it, for such actions are rare even among the higher mammals, but fortunately our observation does not stand alone, although we supposed this to be the case at the time that it was made. Some weeks later, seeing a note of a similar occurrence by Dr. S. W. Williston, of Kansas University, we wrote to him on the subject. In his reply he said that he had waited for a year before venturing to publish his observation, fearing that so remarkable a statement would not be credited. His account* is so interesting that we quote it at length.

NOTE ON THE HABITS OF AMMOPHILA.

By S. W. Williston, Lawrence, Kan.

Even the casual observer, to whom all insects are bugs, cannot help but be struck by the great diversity and number of the fossorial Hymenoptera of the plains. Water is often inaccessible, trees there are few or none, and only in places is the vegetation at all abundant. A much larger proportion of insects, hence, find it necessary to live or breed in holes in the ground, than is the case in more favored localities. Especially is this the case with the Hymenoptera, great numbers and

*Entomological News, Vol. III., 1892, p. 85.

many species of which thus breed in excavations made by themselves.

While packing specimens on an open space, uncovered by buffalo grass, in the extreme western part of Kansas, the early part of last July, the attention of a friend and myself was attracted by the numerous wasps that were constantly alighting upon the ground. The hard, smooth, baked surface showed no indications of disturbance, and it was not till we had attentively watched the insects that we learned what they were doing. The wasp is a very slender one, more than an inch in length, with a slender, pedicellate abdomen; it is known to entomologists as *Ammophila Yarrowi* Cres. They were so numerous that one was distracted by their very multiplicity, but, by singling out different individuals, we were enabled to verify each detail of their operations. An insect, alighting, ran about on the smooth, hard surface till it had found a suitable spot to begin its excavation, which was made about a quarter of an inch in diameter, nearly vertical, and carried to a depth of about four inches, as was shown by opening a number of them. The earth, as removed, was formed into a rounded pellet and carefully carried to the neighboring grass and dropped. For the first half of an inch or so the hole was made of a slightly greater diameter. When the excavation had been carried to the required depth, the wasp, after a survey of the premises, flying away, soon returned with a large pebble in its mandibles, which it carefully deposited within the opening; then, standing over the entrauce upon her four posterior feet, she (I say she, for it was evident that they were all females) rapidly and most amusingly scraped the dust with her two front feet, "hand over hand," back beneath her, till she had filled the hole above the stone to the top. The operation so far was remarkable enough, but the next procedure was more so. When she had heaped up the dirt to her satisfaction, she again flew away and immediately returned with a smaller pebble, perhaps an eighth of an inch in diameter, and then standing more nearly erect, with the front feet folded beneath her, she pressed down the dust all over and about the opening, smoothing off the surface, and accompanying the action with a peculiar rasping sound. After all this was done, and she spent several minutes each time in thus stamping the earth so that only a keen eye could detect any abrasion of the surface, she laid aside the little pebble and flew away to be gone some minutes. Soon, however, she comes back with a heavy flight, scarcely able to sustain the soft green larva, as long as herself, that she brings. The larva is laid upon the ground, a little to one side, when, going to the spot where she had industriously labored, by a few, rapid strokes she throws out the dust and withdraws the stone cover, layiug it aside. Next, the larva is dragged down the hole, where the wasp remains for a few minutes, afterwards returning and closing up the entrance precisely as before. This, we thought, was the end, and supposed that the wasp would now be off about her other affairs, but not so; soon she returns with another larva, precisely like the first, and the whole operation is again repeated. And not only the second time, but again and again, till four or five of the larvæ have been stored up for the sustainment of her future offspring. Once, while a wasp had gone down the hole with a larva, my friend quietly removed the door stone that she had placed by the entrance. Returning, she looked about for her door, but not finding it, apparently mistrusted the honesty of a neighbor, which had just descended, leaving her own door temptingly near. She purloined this pebble and was making off with it, when the rightful owner appeared and gave chase, compelling her to relinquish it.

The things that struck us as most remarkable were the unerring judgment in the selection of a pebble of precisely the right size to fit the entrance, and the use of the small pebble in smoothing down and packing the soil over the opening, together with the instinct that taught them to remove every evidence that the earth had been disturbed.

Since the wasps of our two species of *Ammophila* make their nests first and then do their hunting it follows that they must sometimes carry their prey for a considerable distance. The most ambitious attempt of this kind that we ever witnessed is the subject of one of our observations on the habits of *A. gracilis*.

The wasp was first seen carrying a large green caterpillar, which projected at both ends beyond her own body, across the potato field at the lower end of the garden. We could not tell how far she had already brought it, but judging by the direction from which she was coming, and by the fact that we had never seen that species of caterpillar in the garden, she had probably come through the fence from the woods beyond. She moved along briskly over the remaining part of the potato field, and then through an adjoining bean patch into the corn field. This had been a place of much anxiety to us earlier in the summer but now the corn had been stacked and we could follow her without difficulty. So far she had been going due south, but now she made a turn and plunged into the long, tangled grass which grew around and among some large, overgrown raspberry bushes. To keep track of her here seemed a hopeless task, but we resolved to do our best and followed anxiously after. The wasp worked her way along about two inches above the ground and very much below the top of the grass, clinging to the blades with her feet and making surprisingly good progress. When half way through the raspberry bushes she carried the caterpillar up on to a branch, deposited it there, and after circling about to take her bearings, flew away, doubtless to visit her nest and to make sure that she was going in the right direction.

We, ourselves, were very glad of the chance to rest our tired eyes and nerves from the strain of following her. The journey, so far, had occupied nearly an hour, at almost every instant of which it had been exceedingly difficult to keep her in view. But for our united efforts we should certainly have failed.

While standing guard over the caterpillar we noticed that it moved its head from side to side, showing that the first segment could not have been severely stung as is usually the case in the work of *urnaria.*

In five minutes the wasp returned and, with the air of feeling that everything was right, picked up her burden and carried it laboriously through the remaining bushes and then through the grassy space that edged the garden, as far as the rail fence which separated this part of the grounds from the woods. Without a pause she climbed on to this fence to the height of the second rail, passed through, and flew down on the further side. Here she paused a moment, perhaps to take breath, and we looked at each other in some dismay. Whither was she leading us? We had now been following her for over an hour and she looked equal to as much again as she started off once more, rapidly this time, for the grass was short here and the traveling was easy. Soon, however, it became evident that things were going wrong, although we could not determine what was the matter. The caterpillar was laid down while the wasp absented herself for six minutes. She returned and carried it for fifteen minutes and then left it for half an hour. Once more she came back, and carried it for ten minutes, and then she flew away. It was now four o'clock, and we had been following her since two. We watched over the caterpillar for an hour longer, but saw no more of the wasp.

Did she become discouraged at the magnitude of her task? It would have been a thousand times easier for her to have dug her nest close by the place of capture, but perhaps she had one larva already stored with her egg upon it. The caterpillar was carried two hundred and sixty-one feet while we watched her, with an unknown distance at each end to complete the line between the place of capture and the nest. She could scarcely have lost her way since at every return she proceeded on her journey in one general direction without any hesitation. It seems probable then, that she had hunted too far afield and did not realize, when she started with her booty, what an undertaking it would be to carry it to her nest.

The affairs of *Ammophila* must frequently go wrong, since in still another of our few examples we saw much trouble and labor wasted. The wasp, in this case an *urnaria*, captured her caterpillar successfully and proceeded to carry it off. She was far from being in a hurry, going along for a foot or so and then making a long pause, during which she would lay it down and either circle above it, perhaps to take bearings, or spend the time in cleaning herself off, stroking and smoothing every part of her body with the utmost care and deliberation. Her stops were so frequent and so lengthy that nearly an hour was occupied in going about twenty-five feet. When, at last, the nest was reached, the plug was removed from the entrance and the caterpillar dragged in, but almost immediately the wasp came out backwards with the point of an egg projecting from the extremity of her abdomen. She ran around and around the nest in a distracted way four or five times and then went back, dragged the caterpillar out, and carried it away. The egg came out further and further, and finally dropped on the ground and was lost. The wasp, carrying the caterpillar, led us a long dance, in a great semicircle over the field, coming back to the nest at last. Instead of going in, however, she was about to start off on another tour when we took her prey from her and placed it in the nest. The wasp remained in the neighborhood for over an hour, but finally disappeared. The nest was not closed, and when we dug it up on the following day it contained only the caterpillar that we had put in.

Our second example of *gracilis* promised well in the beginning but turned out badly. She was a big, powerful creature and, when we saw her first, was carrying large pellets of earth, in her mandibles, out of her tunnel and flinging them away. This was at two o'clock in the afternoon and within half an hour she had finished the nest and had filled in the upper part of it, but in a very untidy fashion, throwing in some bits of cornstalk and pellets of earth and then scratching in a little dust.

On the next day, September fourth, the wasp came back at about ten o'clock and spent a few minutes in enlarging the nest, after which she again closed it up. During the remainder of that day we saw her frequently in the neighborhood but on the fifth, sixth, seventh, and eighth she visited the nest only once each morning and then disappeared. After the eighth we saw her no more and the nest had not been reopened when we left our country home on September tenth.

We could usually enter into the feelings of the *Ammophilae* and understand the meaning of their actions, but we were puzzled once, when we saw an *urnaria* that had stored her second caterpillar and closed her nest permanently, spend the rest of her morning in hunting. Why in hunting? She had not dug a nest, she could not lay another egg at once, she did not want a caterpillar, for when we offered her one she stung it and then left it lying on the ground. The sun was bright, the sorrel-blossoms invited her. Surely it would have been the part of a rational wasp to have passed the rest of the day in feasting and fun.

We have said that *urnaria* stores two caterpillars but this rule is not without its exception. It was on the last day of the summer, that on a visit to our dear and fruitful potato field, we came upon the Grandmother of all the Ammophiles, for so we named her on account of her immense size. Twice as large as an ordinary *urnaria*, she made, when flying, a loud hum that at once attracted attention. She was just completing and closing her nest and we determined to watch and see what kind of a victim she would bring in, as it seemed improbable that this great creature would content herself with the ordinary fare of the species. The opening to the nest measured half an inch in diameter.

It was eleven o'clock when she flew away. At half past twelve she reappeared, coming from the direction of the woods, opened her nest and took out a few more pellets. Then she flew to a bush which grew against the fence, three feet away, and following her quickly we saw an immense green caterpillar placed high up on a branch. It must have taken both strength and perseverance to drag this heavy weight so far from the ground. She seized it at once and carried it down, not flying, as these wasps sometimes do when they are descending with a burden, and then dragged it into her nest, where it fitted rather tightly. This nest was so shallow and so obliquely directed that the caterpillar was plainly visible after it had been taken in.

After she had laid her egg she crawled out, getting past the caterpillar with some difficulty, and closed the nest. There was certainly no room for any further store of provisions and from the size of the caterpillar we judged that it would furnish sufficient nourishment even for the offspring cf this wasp. We were, therefore, not surprised, upon opening the nest two days later, to find that nothing more had been brought. We have said that the wasp larvæ spend from six days to two weeks in eating. To be more exact, all that we watched, with the exception of the one which developed from the egg of this big wasp, ate from six to eight days and then spun their cocoons, but this one seemed determined to reach the size of its mother and ate continuously for fourteen days. Of course long before this time had expired the remnant of the caterpillar had become a dry, dark-colored mass which looked little likely to tempt the appetite, but the great larva ate away with unabated relish, gradually acquiring the color and almost the thickness of the caterpillar it had destroyed.

Westwood states that *Ammophila*, when she has captured her prey, walks backward, dragging it after her,* but in all the cases that came under our notice she walked forward, the caterpillar being grasped near the anterior end, in her mandibles, and either lifted above the ground or allowed to drag a little if long and heavy. It is usually held venter up, but in one case, in which the wasp, while carrying it to her nest, frequently laid it down and picked it up again, it was held with the venter down or up indifferently.

The all-important lesson that Fabre draws from his study of the Ammophiles, is that they are inspired by automatically perfect instincts which can never have varied to any appreciable extent from the beginning of time. He argues that deviation from the regular rule would mean extinction. For example, if the wasp should sting ever so little to one side of the median line the prey would be imperfectly paralyzed and the egg would consequently be destroyed; or a sting in the wrong place might cause the death of the caterpillar and thus the death of the wasp larva, which, he thinks, can only be nourished by perfectly fresh food.

The conclusions that we draw from the study of this genus differ in the most striking manner from those of Fabre. The one preëminent, unmistakable and ever present fact is variability. Variability in every particular,—in the shape of the nest and the manner of digging it, in the condition of the nest (whether closed or open) when left temporarily, in the method of stinging the prey, in the degree of malaxation, in the manner of carrying the victim, in the way of closing the nest, and last, and most important of all, in the condition produced in the victims of the stinging, some of them dying and becoming "veritable cadavers," to use an expressive term of Fabre's, long before the larva is ready to begin on them, while others live long past the time at which they would have been attacked and destroyed if we had not interfered with the natural course of

*Introduction to Modern Classification of Insects, vol. II., p. 189.

events. And all this variability we get from a study of nine wasps and fifteen caterpillars!

In his chapter on "Méthode des Ammophiles" Fabre says that each species has its own tactics, allowing no novitiate. "Not one could have left descendants if it were not the handy workman of today. Any little slip is impracticable when the future of the race depends upon it." And yet we find that the prey may be stung so slightly that it can rear and wriggle violently or so severely that it dies almost at once, and in neither case is a break made in the generations of the Ammophiles, since in the former, the egg or larva is so firmly fastened as to keep its hold, while in the latter the dead and decomposing caterpillar is eaten without dissatisfaction or injury.

Nor do we, in gathering evidence for the evolution of the instincts of these wasps, need to rely entirely upon our own observations. Fabre himself gives many facts which point in the same direction, but he draws a line between those actions which are the result of mechanical and unvarying instinct and those which come within the sphere of reason, and in relation to which the insect must consider, compare, and judge. Yet this line, even in the light of his own work, is so extremely variable, needing readjustment with every new species and often among the individuals of the same species, that it loses for others the meaning which it has for its author. He himself speaks of certain individuals of the genus *Sphex* which refuse to be duped when he withdraws their prey to a distance. These, he says, are the élite, the strong-headed ones, which are able to recognize the malice of the action and govern themselves accordingly, but these revolutionists, apt at progress, he goes on to say, are few in numbers. The others, the conservators of old usages and customs are the majority, the crowd. Yes, but is it not always the strong-minded few that direct the destiny of a race?

Darwin's suggestion in relation to the stinging instincts of the solitary wasps is that they originally killed their prey by stinging them in many places on the lower and softer side of the body (this habit of killing outright is still seen in *Bembex* and many other genera), and that to sting a certain segment being found the most successful method, this habit was inherited like the tendency of a bull dog to pin the nose of a bull, or of a ferret to bite the cerebellum; and that the next step in advance was to prick the ganglion only slightly, thus giving the larvæ fresh instead of dried meat.* It seems to us more probable that we have in these instincts examples of the action of natural selection, the primary advantage of the use of the sting being to reduce the prey to helplessness. Our *Ammophila*, with their many-ganglioned caterpillars, have been carried some steps further, and if, as may be possible, those larvæ which have provided for them caterpillars that cannot move and that yet are alive and fresh, derive any advantage from these conditions, the present variable state of things may merge into one in which the instinct will be better adjusted, approaching and perhaps finally reaching that which Fabre finds in the species which he has observed; but at present, speaking for *A. urnaria*, we may say that this instinct, wonderful, complex and difficult to explain as it unquestionably is, is still far from being exact, either in its methods or in the results obtained.

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*Life and Letters, Vol. II., p. 420.

CHAPTER II.

THE GREAT GOLDEN DIGGER.

Sphex ichneumonea Linn.

Pl. II., fig. 4; XI., fig. 1, XII., figs. 1, 2.

This wasp is one of our most beautiful species, its great size and its brilliant color, as it flies among the flowers, serving to make it well known to all observers of nature. During the later part of July, all through August, and even in the early days of September it is commonly found at work making or storing its burrow. It is rare in our garden, however, and we thought ourselves fortunate in being able to keep track of one individual from the making to the closing of the nest. Although large and powerful it is gracefully formed. In color it is brown, with two pairs of yellow spots on the abdomen. (Pl. II., fig. 4.)

On the morning of the third of August, at a little after ten o'clock, we saw one of these hunters start to dig a nest on the side of a stony hill. After making some progress in the work she flew off and selected a second place where she dug so persistently that we felt confident that this was to be her final resting-place, but when the hole was two and one-half inches deep it, too, was deserted. Again our wasp chose a spot and began to burrow. She worked very rapidly and at twenty minutes before twelve the hole was three inches deep. At high noon she flew away and was gone forty minutes. The day was excessively hot, about 98° Fahr., and we ourselves were only deterred from taking a noonday rest by our fixed determination not to leave the place until we had seen all that there was to be seen in the manœuvres of *ichneumonea.* On returning she appeared very much excited, fairly quivering with vitality as she resumed her work. She came up backward carrying the earth with her mouth and anterior legs, and went back from the opening some little distance, when it was dropped and she at once went in again. While in the burrow we could hear her humming, just as the *Pelopaei* do when, head downward in the wet mud, they gather their load for nest-building. In five or six trips a little mass of earth would accumulate, and then she would lie quite flat on the heap and kick the particles away in all directions. As the work progressed the earth was carried further and further away before it was placed on the ground, and as she backed in different directions the material brought out was well spread about from the down-hill side of the nest. Sometimes she would spend several moments in smoothing the débris all around so that the opening presented much the appearance of an immense ant-hill, only the particles were much larger. During the first hour that we watched her she frequently turned directly toward us, and, sometimes remaining on the ground and sometimes rising on her wings to a level with our faces, appeared to be eyeing us intently for four or five seconds. Her attitude was comical and she seemed to be saying, "Well, what are you hanging around here for?"

As the afternoon wore on she worked more calmly and her fidgety and excited manner disappeared, the excavation progressing steadily until half-past three. At that time she came out and walked slowly about in front of her nest and all around it. Then she rose and circled just above it, gradually widening her circle, now going further afield and now flying in and out among the plants and bushes in the immediate vicinity. The detailed survey of every little object near her nest was remarkable and not until her tour of observation had carried her five times entirely around the spot did she appear satisfied and fly away. All her actions showed that she was studying the locality and getting her bearings before taking her departure. (Pl. XII., fig. 1–2.) A fact that impressed us very much was that with the two nests that she had begun and then deserted she had taken no such precaution, but simply came up and flew off. Had she made up her mind, if we may be allowed to use the term, that the localities were in some way unsuitable and that hence she had no occasion to return to them? Had she decided, in the last instance, that she would return and so must get her bearings? We wondered how far the different acts were instinctive, or were, as Huber has it, an evidence of a "little dose of judgment." Bates, in speaking of *Monedula signata*, says that he often noticed in taking a few turns about the locality of its nest and that he was convinced that it was doing so for the purpose of getting its bearings. Belt, having described how he fed a specimen of *Polistes carnifex* with a caterpillar, which the wasp cut into two parts, goes on to say: "Being at the time amidst a thick mass of fine-leaved climbing plant, it proceeded, before flying away, to take note of the place where it was leaving the other half. To do this, it hovered in front of it for a few seconds, then took small circles in front of it, then larger ones around the whole plant. I thought it had gone, but it returned again, and had another look at the opening in the dense foliage down which the other half of the caterpillar la."* He then remarks that when the wasp came back for the remaining half it flew straight to its nest without taking any further note of the locality. Both of these writers believe that many of the actions of insects that are ascribed to instinct are really evidence of the possession of a certain amount of reasoning power.

To return to our *Sphex*. When she flew away we naturally supposed that she had gone in search of her prey, and we were on the *qui vive* to observe every step in her actions when she came home. Alas! when she came back half an hour later, she was empty handed. She dug for four minutes, then flew off and was gone two minutes, then returned and worked for thirty-five minutes. Another two minutes' excursion, and then she settled down to work in good earnest and brought up load after load of earth until the shadows grew long. We noticed that on these later trips she flew directly away, depending upon her first careful study of the suroundings to find her way back. At

*Naturalist in Nicaragua, p. 136.

fifteen minutes after five the patient worker came to the surface and for the second time made a detailed study of the environment. She flew this way and that, in and out among the plants, high and low, far and near, and at last, satisfied, rose in circles, higher and higher and disappeared from view. We waited for her return with all the patience at our command, from fifteen minutes after five until fifteen minutes before seven. We felt sure that when she came back she would bring her victim with her and when we saw her approaching we threw ourselves prone on the ground, eagerly expecting to see the end of the drama, but her search had been unsuccessful,—she carried nothing. In the realms of wasp-life disappointments are not uncommon, and this time she had us to share her chagrin, for we felt as tired and discouraged as she perhaps did herself. When we saw her entering without any provision for her future offspring we were at a loss what to do next and it may be that this state of mind was shared by her also, for she at once began to fill in the entrance to her nest. We now thought it time to act, and decided to capture her, to keep her over night in one of our wasp-cages, and to try to induce her to return to her duty on the following day. We therefore secured her in a large bottle, carried her to the cottage, and having made every possible arrangement for her comfort, left her for the night.

On the next morning, at half after eight o'clock, we took Lady Sphex down to her home and placed the mouth of the bottle so that when she came out she had to enter the nest. This she did, remaining below, however, only a moment. When she came up to the surface she stood still and looked about for a few seconds, and then flew away. It surprised us that having been absent from the place for so many hours, she made no study of the locality as she had done before. We thought it a very unpromising sign, and had great fears that she was deserting the place and that we should see her no more. One would need to watch a wasp through the long hours of a broiling hot day to appreciate the joy that we felt when at nine o'clock, we saw her coming back. She had no difficulty in finding her nest nor did she feel any hesitation as to what ought to be done next, but fell to work at once at carrying out more dirt. The weather, although still hot, had become cloudy and so threatening that we expected a down-pour of rain every moment, but this seemed to make no difference to her. Load after load was brought up, until, at the end of an hour, everything seemed completed to her satisfaction. She came to the entrance and flew about, now this way, and now that, repeating the locality study in the most thorough manner, and then went away. At the expiration of an hour we saw her approaching with a large, light green meadow-grasshopper, which was held in the mouth and supported by the fore legs, which were folded under. On arriving the prey was placed, head first, near the entrance, while the depredater went in, probably to reassure herself that all was right. Soon she appeared at the door of the nest and remained motionless for some moments, gazing intently at her treasure. Then seizing it (we thought by an antenna) she dragged it head first into the tunnel.

The laying of the egg did not detain her long. She was up in a moment and began at once to throw earth into the nest. After a little she went in herself and we could plainly hear her humming as she pushed the loose material down with her head. When she resumed the work outside we interrupted her to catch a little fly that we had already driven off several times just as it was about to enter the nest. The *Sphex* was disturbed and flew away, and this gave us an oportunity to open the burrow. The grasshopper was placed on its back, with its head next to the blind end of the pocket and the legs protuding up into the tunnel. In digging out these nests we have found that by pushing the slender stem of a plant into the hole before the wasp fills it up we are greatly aided in following the direction of the tunnel and in finding the prey at the bottom. Before using this simple device we often went astray and lost the nest.

We found that the egg of the wasp, which was seven millimeters long, and rather slender, was placed on the under face of the thorax at a right angle to its length, and parallel with the femur of the second leg. This leg had apparently been stung so that it had swollen and folded over the free end of the egg, which was thus firmly held in place at both extremities.* Upon examination we found that the abdomen of the grasshopper was beating regularly and automatically but the closest observation failed to discover any other movements nor would any part respond when stimulated. At three o'clock in the afternoon we found the abdomen still pulsating, and, in addition, that both antennæ moved several times when we lifted off the cover of the jar that contained the insect. On the next morning the grasshopper was very lively, the antennæ and labial palpi moving without stimulation. It had passed fæces, and was able to lift its abdomen, which was curved over toward the head, as it lay on its back, frequently and with considerable violence. On the next afternoon (August sixth) there was no change in the movements but the egg was dead. On the seventh the grasshopper responded to stimulation by a slight movement of the palpi and the end of the abdomen. The pulsation of the abdomen continued until the afternoon of the eighth when it ceased, no effort of ours succeeding in starting it again. The movements of the antennæ and palpi grew weaker and weaker on the ninth, and on the morning of the tenth the insect was dead, a period of five and a half days having elapsed since it was brought into the nest. We caused a wasp of the genus *Polistes* to sting a grasshopper of the same species on the under surface of the thorax. The insect was paralyzed and died on the third day. In the wasps studied by Fabre the egg hatched in from three to four days, and the grub ate from ten to twelve days before spinning its cocoon. Probably *ichneumonea* does not differ greatly from the other species in these particulars.

We had not supposed that the digging up of her nest would much disturb our *Sphex* since her connection with it was so

*Fabre says that all of the three species of *Sphex* that he has studied lay the egg on this identical place. He lays immense importance on this point which seems to us rather fanciful. He also noticed the pulsation of the abdomen and the movements of the other parts.

nearly at an end, but in this we were mistaken. When we returned to the garden about half an hour after we had done the deed, we heard her loud and anxious humming from a distance. She was searching far and near for her treasure house, returning every few minutes to the right spot, although the upturned earth had entirely changed its appearance. She seemed unable to believe her eyes, and her persistent refusal to accept the fact that her nest had been destroyed was pathetic. She staid about the garden all through the day, and made so many visits to us, getting under our umbrellas and thrusting her tremendous personality into our very faces, that we wondered if she were trying to question us as to the whereabouts of her property.

Dr. Packard describes *Sphex ichneumonea* as nesting in gravelly walks, where it digs to a depth of from four to six inches, using its jaws and fore legs to do the excavating. While the wasps that he observed completed the hole in half an hour, ours was actually at work a little over four hours. Her nest, as is shown in the drawing (Pl. XI., fig. 1), measured seven and one-half inches to the beginning of the pocket, which was three-quarters of an inch wide by one and one-half inches long. The yellow-winged *Sphex*, a native of France, was found, by Fabre to take several hours to make her nest, working in hard ground, while another species, also studied by this distinguished observer, dug in soft earth, either in the ground or in the accumulations on the roofs of buildings, and completed her work in fifteen minutes at the most. These variations in the habits of closely related species should be carefully studied in any attempt toward an explanation of their instincts.

Fabre's account of the genus *Sphex*, as it appears in France, is most interesting. He says that the yellow-winged species, living in colonies, first digs her nest and then secures her cricket, which is brought, on the wing, to the neighborhood of the burrow, the last part of the journey being accomplished on foot. The cricket is dragged by one of the antennæ and is not left until the nest is reached. It is then placed so that the antennæ reach precisely to the opening, and there it is left while the wasp descends hurriedly into the depths of the burrow. In a few seconds she reappears, showing her head outside, seizes the antennæ of the cricket and drags it below. These manœuvres are repeated with a striking degree of invariability. One experiment of M. Fabre was as follows: As the *Sphex* descended into the nest he took the cricket from the entrance and moved it a few inches away. The wasp coming up, looked about with astonishment, and seeing its victim too far away, came out, seized it, and placed it again in the desired position. This done it again descended, but alone. The same manœuvre was repeated by M. Fabre, the same disappointment was exhibited by the wasp on her return. The prey was again brought to the entrance of the burrow but she again went down without it. The experiment was repeated again and again until the patience of the observer was exhausted. He made the test about forty times on the same individual but the tactics of the wasp never varied.

The other Sphex (called by Fabre *Sphex languedocien*,) first secures her prey, which is too large and heavy to be carried far, and then digs her nest in the neighborhood of the capture. This being done she returns to her victim and straddling it, drage it by one or both of the antennæ. Sometimes the whole journey is accomplished at once, but oftener the wasp suddenly drops her burden and runs rapidly to her nest. Perhaps it seems to her that the entrance is not large enough to accommodate a creature of such size; perhaps she imagines some imperfections of detail which would impede the process of storing it up. The work is retouched, the doorway enlarged, the threshold smoothed. Then she returns to her booty and again starts with it. After a few steps the *Sphex* seems to be seized with another idea. She has visited the doorway but has not seen the interior. Who knows whether all is well within? She drops her prey and again runs off. The visit to the interior is made, more touches given, and once more she returns. Will the journey be accomplished this time? Impossible to say. Some wasps, more suspicious than others perhaps, or more forgetful of the small details of architecture, to repair their neglect or to clear up their suspicions, abandon their booty five or six times in succession to retouch the nest or simply to visit the interior. The prey, once brought to the nest, is carried in without the preliminaries that are common to the other species.

CHAPTER III.

THE INHABITANTS OF AN OLD STUMP.

Rhopalum pedicellatum Pack., and *Stigmus Americanus* Pack.

In a search for the nests of one of our garden wasps we found, in the woods to the north of the fence, and not far distant from it, an old, weather-beaten stump which was riddled with holes both large and small. The large ones were evidently the passage ways of ants and were in constant use. The small ones seemed to be uninhabited but thinking that possibly they might contain the nests we were in search of, and hoping that if we watched long enough we might see our wasps flitting in and out, we settled ourselves close by. We were resolved to stay as long as was necessary and we blessed the fate that made it our duty to sit on the grass under the shade of a wide-spreading oak rather than in the distressing glare and heat of the garden, for this was on the tenth of July, and the weather was what the farmers call "seasonable."

Twenty, thirty, forty minutes passed. Our eyes ached with persistent gazing and we had nearly made up our minds that the likely looking little holes were untenanted, when lo! a tiny wasp, carrying something which we could not see distinctly, darted into one of them. It was gone so quickly that we could not be sure that it was the species we were looking for, and when it reappeared, after two or three minutes, we saw that it was not. This point being determined we watched the hole with redoubled interest.

It was wearisome work, for the wasp stayed away a long time and we dared not let our gaze wander lest she should slip in without our knowledge. At the end of thirty-five minutes she returned, but again we failed to see what she carried. She flew with great rapidity and we scarcely caught sight of her before she vanished into her nest. We could not but wonder at the ease and certainty with which she recognized her own doorway among the hundreds of holes on the side of the stump. This power of localization, while it is one of the most common among wasps, is surely also one of the most remarkable.

Our little *Rhopalum pedicellatum*, for that proved to be her name, made six more journeys within the next two hours. At the end of this time we opened the tunnel, and, after a great deal of sawing and cutting, succeeded in finding the nest five inches from the surface. It was nothing but a slight enlargement of the gallery, in the soft decaying wood. In it we found thirty-three gray gnats of the genus *Chironomus*, all of them being dead excepting two. On one of the dead ones was the egg, which had probably been laid within a few hours.

The egg hatched two days later, on July twelfth, but on the fifteenth the larva died. By this time many of the gnats looked very dry, although we had tried to arrange for both moisture and ventilation by packing the bottom of the tube with pith and covering the top with muslin.

Further watching gave us one more wasp of this species, in the same stump. This time the nest was only two inches from the surface. It contained four dead gnats and two live ones, but no egg, showing that the egg is not always laid on the first ones stored.

Much later in the season, toward the end of August, we found another species of *Rhopalum* which proved to be new, and for which Mr. Ashmead has proposed the name *rubrocinctum* since it wears a red girdle around the front end of the abdomen, being otherwise dressed in black like *pedicillatum*. It makes its home in the stalks of raspberry bushes. We opened a stem which contained thirteen compartments, separated by partitions of pith. These were filled with black, gray, and green gnats, which were packed in so closely that they were doubled over and pressed all out of shape. Each cell contained from twenty-five to thirty gnats. In some of them were cocoons, in others, larvæ, and in one, an egg. The gnats were very carefully examined, and all of them, from the cells that had been filled last as well as from those provisioned earlier, were dead.

Other species of *Rhopalum* are said to prey upon spiders and aphides.

Stigmus americanus Packard.

Rhopalum was not the only wasp that had found a home in the old stump. By dint of patient watching we discovered yet other tiny black creatures going in and out of one of the little holes. These wasps, which were scarcely more than one-eighth of an inch in length, proved to belong to the species *Stigmus americanus*, and we soon found that they were busily collecting aphides which they probably took from the choke-cherry bushes on the other side of the fence, since their journeys only occupied three or four minutes. We could see that three wasps were using the same gallery, all working together in peace and harmony. The hole appeared to be an old one, but whenever they came out they carried grains of pith, thus enlarging it to suit their necessities.

After having watched their goings and comings for several hours we determined to open the nest. Following the tunnel with some difficulty for four inches we found a depression. In this was a curious looking mass which proved, upon close examination, to be made up of grains of pith mixed with aphides. To the ventral surface of one of these an egg was attached. Half an inch further on was another depression holding a similar mass, the egg, in this case, having been placed upon the dorsal surface. There were, in all, forty-five aphides, about equally divided between the two nests. We tested them very carefully and found that they were all dead. The gallery then, must have been a general hall or passage-way used by several individuals. We had seen three wasps and we found only two nests, but probably we missed the third one amid the difficulties of sawing and cutting.

Hoping to rear the larvæ we preserved the contents of both nests, but we were successful with only one of them. We had taken the eggs on July eleventh, and on the following day one of them hatched. By this time many of the aphides had dried up and were turning yellowish. On July fifteenth there were only two or three green ones left, all the rest being brown or black, but the larva continued to eat contentedly. On the twenty-first the aphides were all dry and the larva now ate only the inside, leaving the shell. On the twenty-sixth it spun a light yellow cocoon within which it remained until September second. On that day there came forth not a wasp at all, but a brilliant green Chrysis fly (*Omalus corruscans*) which we had often seen in close attendance upon *Diodontus americanus.* The egg of the wasp would probably have been laid after the nest was fully provisioned, but since the fly had the start the wasp larva would have had small chance of finding a sufficient food supply.

The only notes that we find concerning this genus are one in Mr. Ashmead's paper which says that *Stigmus argentifrons* provisions its nest with aphides, and one in Westwood stating that Mr. Kennedy discovered the cells of *Stigmus troglodytes* in hollow straws of a thatch, the cells being filled with minute insects, which appeared to be the larvæ of a Thrips, as many as fifty being found in one cell.*

*Modern Classification of Insects, Vol II., p. 195.

CHAPTER IV.

THE TOILERS OF THE NIGHT.

Crabro stirpicola Packard.

Pl. II., fig. 5; XI., figs. 6, 7.

We have, in this locality, a number of species of the genus *Crabro*, several of which are quite common. All, so far as we have observed them, make their nests in the stems of plants, being especially common in the stalks of the raspberry and the blackberry. Our *Crabro stirpicola* is about one-quarter of an inch long, and is black with yellow legs, yellow bars on the thorax and interrupted yellow bands on the abdomen. (Pl. II., fig. 5.) It is seen in numbers, through the middle of July, flying about in a leisurely way, but it is only toward the end of the month, or in the early days of August that they settle down to the work of making their homes. On the afternoon of July twenty-seventh, after some very lively work in the heat of the day, we walked down to the berry garden at half past five o'clock, rather to rest ourselves than with the thought of undertaking anything new; but a wasp-hunter cannot afford to choose his own hours and we thankfully accepted the sending of fortune when we came upon a *Crabro* busy at work in digging out her nest. She had only begun to excavate and had reached a length just equal to that of her own body. Her manners were an agreeable contrast to those of the wasps that we had been watching through the day. The feverish excitement of their ways seemed quite in keeping with the burning heat of noon, while *Crabro's* slow and gentle movements harmonized perfectly with the long shadows of evening. To fully appreciate the difference between *Pompilus* or *Ammophila* and *Crabro* it is necessary to see them at work. The one is the embodiment of all that is restless, vying with the humming-birds in swiftness and energy, while the other is calm, quiet, and stately in all that she does.

Some ten feet away was a second *stirpicola* at work, and this one, to judge from the depth to which she had penetrated, must have been at work for about two hours. We watched them both and saw them bring up load after load of pith. They bit out the pellets with their mandibles and passed them back between the legs and under the body until a quantity had accumulated above the tip of the abdomen. They then walked backward up the stem and thus pushed out the mass as they came to the top. Often they used the hind legs to assist in getting it out of the way, sometimes kicking it to a little distance. Once in every two or three trips they would come out far enough to expose part of the thorax. They appeared and disappeared with the regularity of a machine, never stoping to rest.

We remained with them until seven o'clock when we placed a long large bottle over each stem (Pl. XI., fig. 7), in such a way that while it did not interfere with the work of the wasp it caught the chips of pith as they fell out. At the end of an hour we noted the amount of accumulation in the tube and thus had a measure of their rate of work. The drawing gives an idea of the arrangement of the tube on the stem. When we left them they were still digging and delving.

At half past nine we took a lantern and went down to visit our charges. We expected to find them at rest and asleep but on the contrary they were working as busily as ever, and upon examining the measuring glasses we found that they had not paused since we left them. We measured the depth of the débris in the bottles and then emptied them for the night. At four o'clock on the next morning we went to the garden and were much surprised to find that the two wasps had worked without intermission throughout the night. Indeed they seemed to have shortened a little the time that it took to make a round trip down the gallery and up to the opening again, since there was more pith in the bottles than we could have expected if they had worked only at their former rate. Neither the coolness of the air nor the darkness of the night had made the slightest difference to them. After watching them a few minutes and marvelling at their powers of endurance, we cleared out the tubes and returned to bed. At half past eight we found them still at work. Unlike us, they had taken no morning nap, but had gone on with their tunneling in their usual steady way.

From this time their ways diverged and they must be described separately. At nine o'clock the one that we had first seen came up to the opening walking head first, and flew off, remaining away seven minutes. When she returned she at once resumed her work and kept at it without a pause until two in the afternoon. At this hour she went away and we never saw her again. We suppose that she was killed, for it seems improbable that so faithful a creature could have deserted her half-finished home. *Pompilus quinquenotatus* often deserted a partly finished nest for some more enticing spot, and *Sphex* started several excavations before making a final choice, but we cannot believe that there was anything fickle about *Crabro.*

The second wasp came up head first to the entrance of her hole at two minutes after nine, as though she had been influenced, in some subtle way, by her neighbor's example, but after looking about for a moment she went back. She repeated this observation several times and finally, at twenty-five minutes after nine, came out and flew to a leaf near by. Then she circled around, alighting a number of times, and, at last, departed. Her stay was brief for at just thirty-five minutes after nine she returned and at once settled down to her work.

We now began to make notes as to the length of time that it took her to go down and bring back her load. We timed her again and again and found that she was remarkably regular, each of her trips occupying from forty-five to fifty seconds.

All that day we kept her under strict surveillance and never once did she suspend her operations either for rest or refreshment. Late in the afternoon while we sat watching her as she appeared and disappeared with almost the regularity of clock work, we found it difficult to realize that the patient little creature had been at work for more than twenty-four hours, with only one brief intermission. Without hurry or flurry she kept at her task, reminding us, in her business-like ways of the social wasps of the genus *Vespa*. When we left her, at dusk, we attached the recording tube to the stem, and at ten o'clock in the evening we found that she had not stopped working. We emptied the glass and left her.

At seven o'clock in the morning of July twenty-ninth we paid her a visit, and could scarcely believe the testimony of our senses when we saw that the record was one of unceasing toil through the long hours of the second night. We began to wonder if she would ever finish her task. Wonderful though she was we had grown a little weary of our long session of watching. We had been glad that she worked through the first night; it was creditable to her and interesting to us, and we admired her even more for sticking to it through the second, but when it looked as though we might have to remain by her side through another long day, watching an endless series of loads as they were carried out, we confess that we thought she was rather overdoing it. Gradually, however, she slowed up her work, taking two or three minutes to make a journey down and up. At last, at just nine o'clock, her head appeared at the top of the stalk, and after a slight hesitation she flew away. The nest was completed.

We have studied hymenoptera for a number of years and we feel that we are on terms of more or less intimacy with many of the species, but never before have we known one to work after day was done. We have often gone out with a lantern at bedtime for a tour of inspection among our nests and have always found the inhabitants quiet and presumably asleep. The social wasps are very industrious but during the hot nights of July they are to be seen clustered together on the outside of their paper nests in deep repose, and although the *Vespa* wasps that nest in the ground sometimes come home late in the twilight we have never seen them work after it was really dark. *Polistes fusca* may be said to share our cottage, so thickly does she hang her combs under the shelter of our porches, and from observations taken at all hours we know that she is quiet through the night. Sir John Lubbock in "Ants, Bees, and Wasps," speaks of the great industry of wasps. He has known them to work from early morning until dusk without any interval for rest or refreshment; but here was our little *Crabro* toiling from three in the afternoon of July twenty-seventh, through that night and the day and night following until nine o'clock on the morning of the twenty-ninth,—a period of forty-two consecutive hours with one intermission of ten minutes on the morning of the twenty-eighth. Surely she takes the palm for industry, not only from other wasps but from the ant and the bee as well.

The nest was completed but the work of storing it remained to be done. The wasp flew away at nine o'clock, and ten minutes later came back with something, we knew not what, for she dropped into her hole so quickly that she was out of sight almost before we knew she was there. Two minutes later she came up and was off again. This time she was gone twelve minutes and when she came back we were again baffled in our effort to see what she was carrying. When she came out she alighted upon a leaf and attended to her toilet, cleaning both body and wings by rubbing them off with her hind legs, and from this time on she never started on a hunting expedition without paying this attention to her personal appearance. On her third trip she was gone twenty minutes. We tried to delay her entrance, when she returned, in order to see what she was bringing in, but did not succeed. In another twenty minutes she came home again and this time we saw that she was carrying a small fly. Her record for the rest of the morning is as follows:

Returned.	Left.
10.28	10.30
10.42	10.44
11.1	11.3
11.6	11.7
11.23	11.26
11.34	11.35

Some of these last journeys were merely short flights around her domicile, and not for the purpose of seeking prey.

We now left her but came back at half past two in the afternoon. She was working, and she kept up her goings and comings until four o'clock when she suspended operations for the day. On the next morning we were called away and know nothing of what she did, but on the following day, July thirty-first, we resumed our observations. She worked hard all the morning, but in the afternoon her trips were few and were made at long intervals. On the morning of August first she worked from eight to nine, when she departed and never returned. We watched for her, at intervals, all through that day and the next, when we were forced to conclude that our faithful little worker had fallen a victim to some bird or beast. We did not disturb the nest until the fifth, when we cut the stalk and examined it.

We found that the tunnel was thirty-nine centimeters in length. This was a long distance for her to excavate, and, all things considered, her progress had been rapid. We have opened a number of stems that had been stored by this species and all the excavations were from thirty to forty centimeters in length, the width of the gallery being about three and one-half millimeters, while on each side there was from one to one and one-half millimeters of pith that had not been cut away. Of course these points varied with the diameter of the stem and also with the size of the worker.

We found that our little *stirpicola* had stored one cell, had laid an egg, and had built a partition of pith across the stem as a floor to the second cell, before her untimely taking off. Had she lived, ten or twelve cells would have been stored, one above the other. The completed cell contained a larva and parts of eighteen flies of different sizes, four species being represented, *Opthirsia punctipennis* Wlk., *Anthomyia* sp., *Calliphora vomitaria*, and another that we could not identify. The flies had all been attacked by the larva, the abdomens of some and the thoraces of others having been eaten. The larva continued to eat until the seventh and then spun its cocoon. (Pl. XI., fig. 6.) If we suppose that two days passed before the hatching of the egg the larval life lasted for six or seven days.

As the flies in the nest were all partially destroyed we know nothing of their condition when they were brought in, but during the summer we took many stalks which had been filled by *stirpicola* and made notes on the state of the contents. A description of one of these will serve as an example of all the rest.

On August ninth we opened a stalk which had been partly filled. The upper cell had just been stored, no pith partition having been made above it, and no egg yet laid. It contained twenty-three flies of the species *Opthirsia punctipennis*, all of them dead, though plump and fresh. We examined them carefully but they had been killed, not paralyzed. They had been packed in very closely. The cell just below contained twenty-two flies of the same species, the larva having just begun to eat. All of the flies were dead. We took them as well as those of the first lot and examined them, one by one under a two-thirds objective, lest there should be some mistake as to their condition. The third cell contained twenty-two flies which were dead, as was also the larva, which had eaten only five abdomens. In the fourth and last cell were twenty flies, all dead. The larva had eaten parts of ten of them and was still at work.

In almost every instance the flies were all dead although once in a long time we found one which gave a slight response to stimulation. In many cases we found the larva eating them after they were dry: thus the evidence of *stirpicola* still further confirms us in our belief that the health of the growing larva does not at all depend upon its being furnished with fresh food.

All the pupæ that we have kept have wintered in the cocoon and have come out in the spring.

CHAPTER V.

TWO SPIDER HUNTERS.

Stinging Habits of *Salius conicus* Say.

At noon on the third day of August we saw this little black wasp hunting for prey. (Pl. XIII., fig. 2.) She was on the ground, running around and around the base of a weed, the place seeming to interest her greatly. Before long she discovered a tiny male *Lycosid* and dashed at it, but the spider escaped. Apparently accustomed to such mishaps she began to move very rapidly in a circle around the place where she had lost her prey. She was greatly excited and moved with marvellous celerity, but never once used her wings. We have one wasp (*Pompilus quinquenotatus*) whose movements suggest a tornado, but this new depredator had the ways of a whirlwind. As the circles narrowed she again caught sight of her victim and made another dash but met the same fate as before. The *Lycosid* was, in his way, quite as much of a runner and jumper as his enemy and the contestants were well matched. Four times in succession the wasp attacked but failed to grasp her victim, but at last she succeeded and the two rolled over and over in deadly embrace. Lest they should escape we placed our collecting bottle over them and at this they separated, but as soon as the glass, with them in it, was lifted up, the wasp threw herself upon the unfortunate spider, seized him by the head, and bending her long slender body around and underneath thrust her sting into the middle of the underside of the cephalothorax. Almost instantly the spider collapsed. As we turned the glass they fell apart, and again she dashed at her victim and with as much ardor as before gave a second thrust after the manner of the first. She then seized a leg and, moving backward like *Pompilus*, began to drag her booty about.

Full of excitement we hurried about and caught another spider, a female of the same genus but of a different species. Would she take it? Not at all. She had her preferences and was too good a systematist, as Fabre would say, to be confounded by such a procedure. Again we rushed off and hunted over the field until we caught sight of a male of the species that she had just taken. These little spiders run like lightning and are very difficult to catch, but after a long chase he was captured and we were ready for our second experiment. Thirty minutes had passed since we left the wasp and we feared that her zeal for game might have abated but as we put the spider in at one end of the glass she recognized it from the other, pounced upon it, and laying hold as she had before, delivered her sting to one side of the middle of the ventral face of the thorax. We were holding the glass so that the combatants were in full view and the whole affair was watched from step to step. This was the third time that we had seen the sting given but we wanted further evidence. We shook the two apart, and for the fourth time saw this enemy of the arachnids do her deadly work.

Thus we learned the method of *Salius* in capturing her prey, but we were still in doubt as to the effect of the operation just performed under our eyes. Was it a dead body that she was dragging about the glass or had her cunning reduced the poor little spider to an inert mass of living matter, paralyzed, not killed? Both of the limp *Lycosids* were submitted to a careful examination. We tested their legs and stimulated their falces but there were no responsive twitchings and after patient study we concluded that both were dead. At evening we examined them again with the same result. On the next day and the day following we looked for signs of life but failed to find them. The thrust of the wasp was fatal—it is not a mere hurt that she inflicts but a death-blow. What shall we say of her? that she is a mere butcher, and not the skilled operator that we expected her to be? For our part we make no accusations nor do we propose to intrude our notions into her affairs. Her ways are doubtless the fittest for her purpose and to call the killer brutal, or the paralyzer cruel is to do a wrong to the whole race of wasps. It may be that other species of *Salius* deal differently with their victims, just as the French *Pelopaei* always kill their spiders while ours often only paralyze, but *S. conicus* gives a fatal thrust.

At another time we saw one of these little wasps running backward with a small *Lycosid* in her mandibles. She dropped it repeatedly to rush about as though looking for something. Soon she came to a small fresh looking hole which ran down obliquely and into this she backed with the spider. Half an hour later she came out and we then attempted to open the nest, but the tunnel ran into a large cavity that had been filled by a piece of decaying wood and we could not trace it.

Aporus fasciatus Smith.

This is a dark gray species and is less than half an inch in length. (Pl. XIII., fig. 5.) We were working one day in the melon field when we saw one of these little wasps going backward and dragging a female of *Maevia vittata* which was much larger than she was herself. She twice left it on the ground while she circled about for a moment, but soon carried it up onto one of the large melon leaves and left it there while she made a long and careful study of the locality, skimming close to the ground in and out among the vines; at length she went under a leaf that lay close to the ground and began to dig. After her head was well down in the ground we broke off the leaf that we might see her method of work. She went on for ten minutes without noticing the change and then, without any circling, flew off to visit her spider. When she tried to return to her hole it was evident that some landmark was missing. Again and again she zig-zagged from the spider to the nesting-place, going by a sort of a path among the vines from leaf to leaf and from blossom to blossom, but when she reached the spot she did not recognize it. At last we laid the leaf back in its place over the opening, when she at once went in and resumed her work, keeping at it steadily for ten minutes longer. At this point she suddenly reversed her operations and began to fill the hole that she had made, kicking in the earth until the entrance was hidden. She then glanced at the spider, selected a new place and began to dig again. Surprisingly large pellets of earth were carried out, backward, and loose dirt was kicked under the body by the first legs. At the end of two or three minutes she paused and remained perfectly still for a time. She was considering the situation. Her conclusion was adverse to the locality for she soon filled in the hole, looked once more at the spider and started a third nest in a new place. This in turn was soon abandoned as was also a fourth. The fifth beginning was made under a leaf that lay close to the ground, so that we could not see her at all. We had now watched her for an hour in the intense heat of noonday and most devoutly did we hope that she was suited at last, but no—after twenty minutes' work this place also was abandoned and a sixth nest started. This, however, was the final choice and after forty-five minutes spent in digging it was completed. As the spider was brought toward the nest it was left again and again while the nervous little wasp flew to the hole, went in, examined and came out again. At last she backed in, caught the spider by the abdomen and dragged it down. It was too big—the head stuck in the hole; but she pulled from below while we pushed gently from above and it slowly disappeared. When she came out we opened the nest and took the spider. The egg was fastened to the middle of the left side of the abdomen. This one, as was also the case with a second and third afterward taken from *fasciatus*, was much less affected by the poison than is usual among the victims of solitary wasps, moving from the time it was taken, without any stimulation, and improving rapidly from day to day. Our second spider appeared to be blind, and died upon the sixteenth day, while the third had entirely recovered by the seventeenth day after it was stung, and was released. *Fasciatus*, then, probably depends upon packing her victim in tightly to keep it quiet.

It was three days and a half before the egg that we had taken hatched. The larva developed rapidly retaining its hold at the spot to which the mother had attached it. The spider remained alive for six days, and the larva continued to grow for two days longer when it died also, being at the time about two-thirds grown. We had great trouble in protecting our growing larvæ from the inroads of fungi and this was one of the many that perished from that cause.

The next example of *fasciatus* that came under our notice was a remarkable contrast to the one that we have just described, being as slow and dignified as the other was nervous and hurried. She chose a place and kept to it, her steady labor being only interrupted by occasional visits to the spider, but it took her fifty minutes to complete the nest. When finished it was a small gallery running down obliquely for an inch and a half into the ground.

The three spiders taken from *fasciatus* were all *Attidae* but represented three different genera, *Phidippus*, *Attus*, and *Maevia*.

The one habit that this species can claim as peculiar to itself is that of filling up the partly made nests that it is about to abandon. We have never seen the sense of order carried to so high a point in any other wasp.

Our observations on *fasciatus* were made between July thirtieth and August twenty-fifth.

CHAPTER VI.

AN ISLAND SETTLEMENT.

Bembex spinolae St. Fargeau.

Plates II., fig. 6; VI.; XI., 4.

When we found that our field of work was so rich in material that we could not possibly do it justice we brought the children of the family on to the ground as assistants, and it is to our boy George that we owe the discovery of the *Bembex* colony. On returning from an expedition to an island in the lake close by, he reported that he had found a lot of bees or wasps, he did not know which, and upon going to investigate the matter we found a bare space of soft, rich earth, about eight feet wide by ten feet long, fairly riddled with the holes of *Bembex spinolae.*

These wasps are about three-quarters of an inch long and are broad, heavy and somewhat clumsy, being shaped much like bees. In color they are black, banded with bluish white. (Pl. II., fig. 6.) On this, our first visit, the weather was hot and sunny and the ground as well as the air above it was alive with the large, showy wasps. Our arrival on the scene was the signal for a general hubbub. Evidently we were not *personae gratae* to their majesties, for with a most intolerable buzzing they darted at us on all sides at once, chasing us for some distance as we retreated, and when they turned back and left us in peace we were surprised to find that no wounds had been inflicted. The battle had been all sound and fury signifying nothing. With renewed courage we again approached them, more cautiously this time, and soon learned that if we preserved an extremely composed and dignified demeanor our presence on the field would be tolerated.

Bembex, like *Philanthus* and some species of *Sphex,* lives in a sort of semi-social state, a number of individuals occupying the same space of ground, although each one has its separate nest. *Bembex*, however, differs from these genera and from almost all of the solitary wasps in her habit of feeding her young from day to day, or rather from hour to hour, as long as it remains in the larval state. This difference in her maternal cares as compared with those of other species results in a less numerous progeny. The larva, for a period of two weeks, demands constant attention from the mother, so that a second egg cannot be laid until the first-born has gone into its cocoon, unless, indeed, she feeds two larvæ at once, which does not seem probable. The season of work is ten or twelve weeks so that Wesenberg is probably correct in allowing only five or six young ones to each mother for the summer.*

In watching our wasps we found that the new nests were usually made in the out-skirts of the colony which was thus continually extending its limits. Like many other species *Bembex* has great difficulty in deciding just where to dig. Our *Sphex* made three beginnings before finally settling down. The only *Ammophila* that we watched from the beginning changed her place after working for ten minutes. *P. quinquenotatus* often tried half a dozen places before she was satisfied, and *spinolae* is quite as difficult to please.

When, at last, the right place is found, the labor of excavation is carried on vigorously. The mandibles are used for loosening the earth and for lifting, but the greater part of the work is done with the first pair of legs, the tarsi of which are doubled up while the dirt is swept out with the brush of stiff spiny hairs on the second joint. This attitude gives them a very comical aspect, making them look as if they were sweeping with their elbows. They sometimes lie far over to one side while loosening the earth with their mandibles. While digging, the body is held high by the straightening of the third pair of legs and the dirt comes out behind in a rapid stream, flying to a distance of three or four inches. Before long the wasp is lost to sight but every few moments she comes backing out, pushing behind her the dirt that she has displaced below. In about fifteen

*Copenhagen Entomologiske Meddelelser, vol. iii., 1891.

minutes the nest is ready and the wasp turns her attention to scattering all the dirt that has been thrown out, sweeping the ground clean so that no sign of her work remains. We have often speculated as to the meaning of the careful and conscientious performance on this part of her task. With those wasps that nest by themselves it is not easy to see what enemy they are providing against in hiding the entrance to the nest, but the precaution seems still more unnecessary and even absurd in the *Bembex* field, where there is no possibility of concealing the colony, and where the nests are only an inch or two apart so that an enemy might burrow anywhere with the certainty of finding one. Moreover, the only enemy that we could discover was the parasitic fly which never attempts to enter when the hole is closed. However, unmoved by our opinion on the subject, *spinolae* spends five or six minutes of her precious time in making the neighborhood of her home quite tidy, and then she fills in the mouth of the nest with a little loose earth before going away to catch her fly.

Oxybelus, though she is limited in choice by her small size, can catch a fly in three or four minutes. *Bembex* is strong enough to take anything that she sees, and she has no preference for one species above another, yet she seldom finds one under twenty or twenty-five minutes. When she comes back nothing of the fly is visible unless it is unusually large, so closely is it held under her body by the second pair of legs. She alights and scratches away the loose earth at the entrance of the nest with her first legs, and then, as she creeps within, she passes the fly along from the second to the third pair, so that the end of its body, projecting beyond the abdomen of the wasp, is visible for an instant before it is carried inside. Sometimes she drops the fly behind her and then, turning around, pulls it in with her mandibles. In other cases, where a longer portion of the tunnel has been filled with earth, the fly is left lying on the ground while the wasp clears the way. This offers a favorable opportunity to parasites, especially as the fly is not placed with any regard to its safety but is dropped anywhere. The dirt that is kicked out sometimes covers it over so that when the way is clear the careless proprietor must search it out and clean it off before she can store it away. In one instance, in which we had been opening a nest close by, the tunnel was entirely blocked by the loose earth which we had disturbed, and the wasp worked for ten minutes before she opened a way to her nest. During part of this time she held the fly, but when she realized that it was going to be a long piece of work she laid it down near by. As the wasp enters she sometimes leaves the hole open behind her, but oftener fills it by pushing up earth from below. When she comes out again she throws in a little dirt and then begins to circle about the place. She seems not quite easy about the nest, however, returning three or four times to scratch earth over the entrance, before finally taking her departure.

We opened a good many nests in the course of the summer and found them all very much alike, much more so than is the case with other species. The entrance tunnel runs in obliquely for from three to five inches below the surface of the ground, as is seen in the drawing. (Pl. XI., fig. 4.)

We grow accustomed to marvels and from our familiarity with other wasps we take as a matter of course the unerring accuracy with which *Bembex* swoops down upon the exact spot at which the entrance to her nest is hidden. And yet how strange a power it is! There is not the least sign to help her—not a stone, not a blade of grass is to be seen on the field. Our method of marking a nest which we wished to find again was to place tiny pebbles at exactly equal distances from it, one on either side, so that the middle point of the straight line between them gave us the desired spot. By what mysterious insight does the mother wasp, returning with food for her young, recognize that undifferentiated spot of ground as the portal of her home?

We once smoothed over the entrance to a nest, after seeing the wasp go out, pressing down the earth to make the surface smooth and compact. When the owner came back she seemed greatly puzzled, circling about and alighting several times. At last she made up her mind as to the spot where the entrance had been and began to loosen the earth with her mandibles. It required a good deal of digging and sweeping to open up the gallery but she finally succeeded.

A curious thing about these wasps, and one which shows how much common feeling they have, is that they work in waves, all starting off on their hunting expeditions within a few minutes of each other, and returning together after the chase. At one time all the residents seem to be present, digging their nests, carrying in their booty, dashing at each other and chasing the parasites with a tremendous amount of humming and swooping about. Then suddenly they are all gone. Nothing remains but multitudes of flies which keep up a giddy dance over the field, and for ten or fifteen minutes the place seems deserted. Then the wasps begin to return, several coming at a time, and as if by magic the whole scene awakens to life. More than half of the wasps bring nothing home with them, and these fall to robbing their more fortunate companions. Those that are carrying flies must pause a moment, burdened as they are, to scratch away the earth at the entrance to the nest. When unmolested they go in very quickly, but it is just at this point that the marauders fall upon them, displaying an amount of persistence and energy in their attacks that, were it properly directed, might easily enable them to secure flies for themselves.

We once saw a wasp that had been fortunate enough, or perhaps unfortunate enough, to catch an immense fly, the wings of which stood out on both sides very conspicuously. This made her an especial mark for her unprincipled relatives. Half a dozen of them chased her about like chickens pursuing one of their number that has found a worm. She circled and settled and circled and swooped around for five or six minutes, continually pursued and attacked by the robbers, and quite unable to get into her nest. At last, curious to see what she was carrying, we made her drop the fly and secured it for ourselves. We found it to be *Tabanus atratus*. It was quite dead but

J. H. Emerton, del.

BEMBEX SPINOLAE LOOKING OUT OF NEST.

showed no marks of violence. It was not wasted for we afterward fed it to one of our wasp nurslings at home.

At another time we saw one wasp attack another that was bringing in a fly. In the struggle that ensued the owner lost her booty, as the two rolled over and over on the ground. As they parted it was seized by the thief. They clinched again and rolled on the ground as before, and this time the fly was recovered by the rightful owner. At this point, thinking that perhaps one of the wasps was a male, and that this might be their style of courtship, we seized both of them, whereupon the fly was dropped and the two wasps turned their attention to attacking us. Both proved to be females. Not only do the *Bembecids* fight in this way for the possession of their prey, they even quarrel without any apparent cause. We have seen two females digging their nests at a little distance apart, one of which was repeatedly attacked by the other although she did nothing to provoke the aggressor. They are certainly very unneighborly and have no idea of living in harmony. When flying in a threatening manner, either at us or at each other, they have a way of wagging their abdomens violently from side to side in a way well calculated to inspire terror.

In warm sunny weather *spinolae* works industriously through the middle of the day and seems determined to provide abundantly not only for her own offspring but for any unbidden guests that it may be her fate to care for. She never works more than four or five hours a day, however, and in unfavorable weather she does not work at all. On going over to the island one cloudy morning to spend some hours in watching the *Bembex* activities, we found the spot quiet and lifeless. No one seeing it for the first time would have dreamed of the multitudes of living creatures beneath his feet. The nests seemed to be all closed, but on peering curiously about we found one on sloping ground, in the suburbs of the colony, of which the door was open. Just within was the proprietor gazing out on the landscape, as she is shown in the illustration. (Plate VI.) She seemed to leaning on her elbows, and her face, enlivened by two great goggle eyes, had an irresistibly comical aspect. With the exception of the omnipresent flies, this wasp was the only sign of life about the place. Even in good weather and in working hours, the wasps sometimes rest, for we have seen them go in empty handed, closing the door behind them, to remain for half an hour at a time.

There is one thought that must strike the most casual observer of a colony like this. Why do not these wasps, fly-catchers as they are by profession, kill the parasitic flies that infest their homes, thriving abundantly on the fruits of their labor, a continual menace to the life and safety of their offspring? To the uninitiated it would seem that these flies would serve as food for the wasp larvæ quite as well as any of the dozen species that they actually take, but even if the wasp-mother believes that they possess indigestible qualities, it would be much less trouble to kill them and throw them away than to be perpetually chasing them to a little distance only to see them return as soon as she gives her attention to anything else. Whatever the reason for it may be the relation between the wasps and the flies is certainly most curious and puzzling. Fabre's explanation is that since this miserable little fly has its own part to play in nature, *Bembex* must respect it, thus preserving harmony in the world of living things. The idea is perfectly in accord with his own theories, but we find ourselves quite unable to accept it.

There can be no doubt that the parasites are a grave danger to *Bembex*. She suffers from them far more than any other wasp that we are familiar with, her mode of feeding the young rendering her peculiarly susceptible to their attacks. Of the ten or twelve nests that we opened only one was free from them, the others containing from two to five lively maggots nearly as large as the wasp larvæ, which were sharing the food brought in by the mother. Fabre, who has studied the question thoroughly, has found as many as ten parasitic larvæ in one nest. He has also noticed that where the parasites are most numerous the wasp-larva is proportionately small and emaciated, reaching only one-half or one-third of its normal size. When it attempts to spin its cocoon it has not strength enough to do so and thus perishes miserably among the pupæ of the interlopers, which have the advantage of developing more rapidly. He has proved, by experiments upon nests transported to his study, that although the invaders preserve friendly relations with the rightful owner of the nest so long as food is abundant, they nevertheless, at the first suggestion of scarcity, fall upon the wasp larva and ruthlessly devour it. This "black action" he has seen with his own eyes. In view of this base ingratitude we are more than ever impressed with the troubles of the poor *Bembex* mother as she tries to feed a dozen mouths where she has bargained for only one.

We several times saw a fly follow a wasp into her nest, remaining within for half a minute, and it is probable that they go in to lay their eggs. According to Fabre, it is the habit of the flies that are parasitic upon the half-dozen species of *Bembex* that he has studied to seize the moment at which the fly projects from under the abdomen of the wasp as she enters the nest, and he has even known them to lay two or three eggs on one fly in the instant of time that its body was exposed.

When we first found the colony on August tenth, it was strong in numbers, and it continued to grow up to the first of September. On going over one day in the middle of August we found a good deal of work going on, but to our surprise the flies had disappeared. A careful search showed only two instead of the usual numbers. Their place was taken by dozens of little wasps, which proved to be *Pompilus biguttatus* Fabr. These wasps seemed to be merely loafing about amusing themselves, neither eating nor working. Whether their presence was in any way connected with the absence of the flies we are unable to say but it seems probable that they had congregated on the *Bembex* ground merely because it was an open spot, since on looking about we found them covering every open sunny space that the island afforded.

Fabre took a partly grown *Bembex* larva from the nest, where it was surrounded by the remains of twenty flies. He fed it generously and it ate sixty-two more, making a total of eighty-two in the eight days that passed before the spinning of the cocoon. Our experiments in this line gave similar results. We took charge of a partly grown larva on the afternoon of August tenth and between that date and August fifteenth, when it spun its cocoon, it ate forty-two house flies besides a big *Tabanus*.

Fabre thinks that under natural conditions the mother does not give the larva all it can eat at one time but provides it with what she considers a reasonable amount of food, and keeps anything that she catches beyond this out of its reach. He draws his conclusion from the fact that he has found several flies in the tunnel leading to the nest, while the larva had as many more close to it. It would certainly be convenient for *Bembex* to have a reserve of this kind in case of rainy weather, but the forethought required for such an action seems to require a higher degree of intelligence than can be claimed for her.

In one nest we found a single fly with a long cylindrical egg attached to the left side of the thorax just at the origin of the third leg. In another, which we had seen made and provisioned, we found, six days later, a larva which we judged to be four days old. Assuming that the egg was laid on the first day it must have taken it about two days to hatch. Other nests gave us larvæ in all stages of development, surrounded by the remains of diptera, among which *Syrphus*, *Tabanus*, and *Musca* were represented.

In regard to the condition of the flies captured by *Bembex* we have never seen the crushing of the thorax, which is noted by both Wesenberg and Fabre. Indeed the flies that we found were not always dead, since in two instances they responded readily to stimulation. Similar results have been obtained by Mr. S. W. Dunning of Hartford, Connecticut, whose note on the subject is as follows:

"One female observed around burrow. Burrow ran at an angle of 40° from surface, was 4-5 inches deep and contained one larva and a number of partially destroyed and some whole diptera. Those that were whole quivered the legs on provocation. Larva was 1-3 of an inch long. The flies consisted of one small *Asilid*, one *Syrphus*, and one Blue-bottle, with three or four other partially destroyed and smaller species."

Twice we have seen our *spinolae*, as she was bringing home her prey, alight near the nest and sting it as it was held with the second pair of legs. We could see the process distinctly since she is slow and clumsy, and, in one instance, had difficulty in reaching the fly, falling over to one side in an awkward manner. It is probable, then, that this is a habit with the wasp, but that the sting is usually given at the place of capture.

Fabre explains the habits of *Bembex* in regard to feeding her young by the nature of her prey. Diptera must be seized while in rapid motion—therefore they are likely to be crushed and killed as there is no time for nicety of handling. They contain, relatively, but a small amount of moisture—therefore they cannot resist desiccation and would become unfit for food if they were stored up in numbers to last through the period of larval life.

This seems reasonable, although we know that *Bembex* can, since she often does, catch her flies so delicately that not a hair is injured. As to the rapidity of desiccation, this would scarcely hold true, for the crickets used by *Lyroda* in feeding her young from day to day, and at any rate, some of the big, soft-bodied flies that are taken by *Bembex* are quite as juicy as the *Gasteracanthidae*, beloved of *Pelopaeus fistularis*,* or as some of the beetles taken by *Cerceris*. Be that as it may, we have another suggestion to offer.

May it not be that instead of having departed from the ordinary habits of the solitary wasps, *Bembex*, in its relations to the larva, represents the original or least modified form of all the wasps? In their semi-social habits the wasps of this genus seem to show a stage in the transition from the earlier state of the truly solitary species toward the more complex and higher relations existing among those that live in communities. The

*Bates, Naturalist on the Amazon, p. 186.

Bembecids cannot strictly be called solitary, and yet the extent of their coöperation seems to be limited to the act of driving intruders away from their nesting-grounds. Beyond this they have no common cares nor duties.

As to their relation to the larva, however, there seems to be nothing transitional. Compared with the solitary wasps they are at a great disadvantage, both as regards the burden of feeding the young and the consequent low rate of increase, and in their constant exposure to the attacks of parasites; and they are very evidently in a less developed stage than the social wasps, where all the workers join together in the labor of feeding the young.

It may be possible, then, that all wasps originally fed their larvæ from day to day as *Bembex* now does, and that while the instinct of paralyzing the prey and of storing the whole supply of food once for all was working itself out among the solitary wasps, the instincts connected with life in a true society, and of joining together in the work of feeding the larvæ, have, on the other hand, developed into those of our wasp communities.

If we look at the matter from this point of view we find among the *Ammophilae* an instance which looks like a connecting link between the habits of *Bembex* and those of the solitary species. *A. urnaria* stores one caterpillar, lays an egg on it, catches another and stores it as soon as she can and then closes the nest. As a usual thing, no doubt, the nest is finally closed before the egg is hatched, so that she never sees her larva. In one of our instances, however, the capture of the second caterpillar was so much delayed that when it was brought in the mother-wasp found a larva of a day old feasting on the one already provided.*

We opened a number of the nests of *spinolae* but only succeeded in raising one of the larvæ. Our notes on the subject are as follows:

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*Something like this was suggested by Prof. Duncan in 1872 (See Romanes', "Mental Evolution in Animals," p. 191).

No. 44. August 10, 3 P. M. Opened nest and found a half grown wasp larva and five larvæ of parasitic flies, all eating. The fly larvæ were very lively and were two-thirds as large as the other. They were surrounded by the remains of large numbers of flies. We gave the wasp larva seven house-flies.

August 11, 8 A. M. The larva has eaten all the flies put in yesterday. We now give it six house-flies and the large *Tabanus* taken at the colony.

August 12, 5 P. M. The flies are all eaten. The larva is very large. We now give it ten house-flies.

August 13, 9 A. M. The flies are not quite gone but we give it eight more.

August 14. The larva has eaten all the flies. We give it six more.

August 15, 8 A. M. We give the larva eight flies.—5 P. M. The larva has left three flies uneaten and has begun to spin its cocoon. In five days it has eaten forty-two flies besides the big *Tabanus*.

No. 46. August 10. We saw *spinolae* take a fly into the nest. After a short time we opened the nest and found the fly with an egg attached to the left side of the thorax just at the base of the third leg. It was long and cylindrical. The fly belonged to the genus *Syrphus*.

August 13. The egg is evidently dead.

No. 54. We opened a nest and found a larva two-thirds grown, three active maggots, and the remains of flies.

No. 55. On August 10, 3:45 P. M. We saw a nest made and a fly taken in. We opened it today, August 16. Assuming that the egg was laid on the first day, we judge that it hatched in two days, since the larva seemed to be about four days old. We found no maggot in this nest, and not many remains of flies.

Mr. Hudson gives an account of a common La Plata species of this family that has the same habits.* This wasp, *Monedula punctata*, digs her hole and lays therein a single egg. When the grub hatches the parent keeps it bountifully supplied with insects since it is sometimes surrounded by an accumulation of six or seven which are still untouched. The prey taken consists to some extent of fire-flies and other insects, but flies are always preferred. The nest is always closed by the wasp before she leaves it, to protect it, Mr. Hudson thinks, from hunting-spiders, ants, and tiger-beetles. No mention is made of

*Naturalist in La Plata, p. 162.

parasitic flies. Can it be that there is one spot in the world where the wasp is free from them?

Probably *Monedula*, like *Bembex*, lives in colonies, since it is said that as a usual thing many of their holes are found close together. It occasionally captures insects on the wing but more frequently pounces down on them when they are at rest.

This species, then, differs from *Bembex spinolae* in its capture of other insects, besides flies, and in its habits of laying the egg in the empty nest, no food being brought until the grub is hatched. In both respects the southern species seems to have made an advance upon the intelligence of our *Bembecidae*.

Another interesting variation is that of *Bembex ciliata* observed by Mr. Bates in Santarem.* This wasp excavates her gallery and then goes off to catch her fly, leaving the door open. This sometimes happens with *spinolae*, but never with the European species *rostrata*, and, as we have seen, *Monedula* also carefully closes the door before leaving it. *Ciliata*, to be sure, does all that is necessary, since after the fly has been taken in and the egg laid, the doorway is filled up. *Ciliata*, as well as *spinolae*, circles about and takes her bearings carefully before leaving the spot.

Mr. Bates has also some notes on *Monedula signata*, which differs to a remarkable degree from *punctata* since it not only taken nothing but flies, but even confines itself to a single species, although it must sometimes go half a mile away to find it. This reminds us of *Pompilus quinquenotatus* which never takes anything but *Epeira strix*.

A considerable contribution to our knowledge of the genus *Bembex* has been made in the paper by Wesenberg (written in Danish) which has already been referred to. This paper deals with *Bembex rostrata*. It was translated for Mr. Ashmead by Mr. Martin Linell.† The account is most interesting.

It seems that *rostrata* makes its nest in solid sand, covering

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*Naturalist on the Amazon, p. 181.

†Aculeate Hymenoptera, III., Psyche, vol. 7, no. 216, p. 62.

it up with loose sand and usually, also, with a little flat stone, to prevent parasites from entering. The cell measures one cubic inch, the entrance tunnel being one and one-half centimeters long, and arcuate. A cell contains four or five fresh flies (*Lucilia, Eristalis*, etc.), and torn off wings, sucked out thoraces, and in the middle of these, a big flat larva.

When the larva is hatched the mother brings more and more flies, the flies being larger and larger as it grows. This adjustment of the size of the fly to the growth of the larva has also been noted by Fabre.

Wesenberg says that fifty *Bembecids* will nest on a spot as big as a room during a period of three months. The time required for the development of the larva is two weeks, this giving five or six young ones for the season. He queries, "Does each female have more than one nest? and if so how can she remember them?" To determine this point we marked six wasps by touching them with differently colored paints, putting near their nests pebbles painted to correspond with the owners, and then watched them closely for three hours. During this time the red wasp returned regularly to the red nest, the blue to the blue, and so on. They were watched for an hour and a half on the following day with the same result. So that it seems quite certain that *spinolae* has only one nest at a time. To feed two larvæ at once, with interlopers thrown in, would be a heavier task than the most determined industry could accomplish.

Wesenberg states that all the digger-wasps with the exception of *Bembex* furnish the food for their young once for all, either first laying the egg and then putting in food, or first filling the cell with food and then laying the egg upon it, and covering the whole without again visiting the cell or seeing their larva. We know now that this too general a statement. At least one species of *Lyroda* (*subita*) brings food to its young from day to day. We have seen that *Monedula* does the same. In Westwood's "Classification" we find that the same habit has been claimed for *Mellinus* by Mr. Curtis (p. 175); for *Pelopaeus* by Bonnet (p. 206); and for *Sphex* by Mr. Bartram (p. 207). These statements, and also those pertaining to *Bembex*, were disbelieved by Westwood who thought that only social wasps revisited the nest after the egg had been laid. Certainly *Sphex* and *Pelopaeus* have entirely different habits. Of *Mellinus* we have no knowledge.

CHAPTER VII.

THE LITTLE FLYCATCHER.

Oxybelus quadrinotatus Say.

Plates VIII., fig. 7; XIII., fig. 3.

In studying the species that come in our way we are continually developing unaccountable likings for some kinds above others. The appearance of one of these favorites is always hailed with delight, and when the season's work is over we remember them with lively pleasure.

It is thus, dear little *Oxybelus,* that we dwell upon the thought of you and your pretty ways. No other wasp rose so early in the morning, no other was so quick and tidy about her work, so apt and business-like without any fuss or flurry. No other was more rapid and vigorous in pursuit of her prey, and we think with admiration and gratitude of the number of flies that you must have destroyed in the course of the summer.

O. quadrinotatus is only one-quarter of an inch long and is dark gray with four whitish spots on the abdomen. It was before nine o'clock in the morning that, while out on an early inspection tour in the garden, we saw our only example of this species descend upon a sandy spot and after a moment's rapid scratching with her first legs, enter the hole that she had opened.* Under her body she was carrying a fly which looked like the common domestic species. It was upside down, its head being tightly clasped with the third pair of legs, and all of its abdomen projected beyond the abdomen of the wasp. Ashmead quotes from Fabre the remarkable statement that *Oxybelus* carries her flies home impaled on her sting. This

*During the following summer this species became so common that we studied many examples.

idea probably arose from the fact that nearly the whole body of the fly is visible.

Our new found wasp stayed only a moment in her nest, although, as we afterward found, it was long enough for her to lay her egg on the fly. When she came out she quickly smoothed the sand over the spot with her head and legs so that there was nothing to mark the nest, and flew away. In three minutes she returned with another fly. She alighted two or three inches away and scratched for an instant, but quickly saw her mistake and found the right spot.

Again and again the pretty little worker went and came, while we sat watching close by, admiring her deft handiwork in opening and closing the nest and wondering at the ease with which she found it at each return. There was nothing tiresome or dilatory about this species. Within twenty minutes we had seen six flies stored up. The nest was closed and the place smoothed over every time before she went away, but when she entered she left the door open behind her. We once tried to make her drop the fly, but when disturbed she flew up and alighted on a plant near by, keeping her hold on it. The whole performance was brisk and business-like but without the feverish hurry of *Ammophila* and *Pompilus*.

After the sixth fly was taken in we were afraid to let her go again for fear that the nest was now completely provisioned, and that she would not return. She was such a charming little wasp, scarcely bigger than a fly herself, and yet so useful in her industry, that we hated to disturb her, but as we were obliged to have her for identification we first caught her and then opened the nest. (Pl. VIII., fig. 7.) It contained only the flies that we had seen taken in, the egg being attached to the one lowest down on the left side, between the head and the thorax. It was long and cylindrical. The flies were dead but showed no marks of violence.

She must have dug the nest before catching the first fly, as there was no delay when she brought it in; and if, as seems probable, the work was done that morning, the task must have been begun at a very early hour.

The egg, which was laid just before nine o'clock on the morning of August seventh, hatched at a little after nine on the morning of August eighth. The larva began to eat at once and devoured all the inside of the thorax and abdomen of the fly to which it was attached, in the first twenty-four hours. On August twelfth it had reached the sixth fly, and we supplied it with three more. On August fourteenth these were gone and we again replenished its larder, this time with two flies. The larva had partly eaten these when something went wrong. Its appetite failed, and on August sixteenth it died.

We find but meagre notes on the genus *Oxybelus*. Ashmead says that no observations have been made on the American species but that in Europe they are found to burrow in sand and to provision their nests with dipterous insects. He also says that according to Verhoeff the species in this genus do not paralyze their prey by stinging as they are unable to do so on account of the rigidity of the abdomen, but that instead, they crush the thorax with the mandibles just beneath the wings, the centre of the nervous ganglia. He found in one nest a dozen flies (*Hydrotaca*) and all had the thorax crushed and were dead. In the case of our wasp we do not know how the flies were killed but there was no crushing of the thorax. The larva devoured, in all, ten flies. At the time of its death it had probably finished the larval stage of its existence since nine days had elapsed since the hatching of the egg. It may be that this period just before pupation is a critical point in the life history of a wasp. We lost several of our nurslings at this time, and Fabre has noted that when, on account of the presence of parasites, the larva of *Bembex rostrata* had lacked something of its usual amount of nourishment, it perished miserably at the end of its larval stage, not having strength enough to spin its cocoon. No waspling in our charge ever died from lack of nourishment—on that score our consciences are clear; but it was sometimes difficult to make their conditions quite normal, and for this reason we may have been, indirectly, the cause of their death.

The way in which our *Oxybelus* carries its prey is peculiar to itself. *Bembex* and *Philanthus* also hold their prey under the body but use the second pair of legs, so that it does not project behind except at the moment of entrance into the nest. *Quadrinotatus*, as we could distinctly see, since she passed close to us several times in quick succesison, clasps the head of her victim in the third pair of legs, and flying thus, with its whole body sticking out behind her, she certainly presents a very remarkable appearance.

CHAPTER VIII.

THE WOOD-BORERS.

Trypoxylon albopilosum Fox and *Trypoxylon rubrocinctum* Packard.

Plate XIV., fig. 1.

In the autumn of 1895 we published some notes on these two species.* Since that time we have given a good deal of attention to these wasps and have gathered some new facts as to their habits, and we have therefore thought it best to rewrite their life history, including such portions of our former paper as would serve our purpose. They are both slender-waisted black wasps, *albopilosum* having bunches of snowy white hairs on the first legs, and measuring three-quarters of an inch in length, while *rubrocinctum* is a little smaller, and, as the name implies, wears a red girdle.

Although these wasps are called wood-borers they will use convenient cavities in any material. When we went out to our summer cottage, in the last days of June, 1895, we found many little wasps of the species *Trypoxylon rubrocinctum* busily working about a brick smoke-house on the place. Closer examination showed that in the mortar between the bricks were many little openings leading back for a considerable distance, which were occupied by the wasps. It would seem that these holes were excavated by some other agency than the wasps themselves as they were so much too deep for their purposes that before using them they built a mud partition across the opening about an inch from the outside of the wall. Later on we found nests of the same species in the posts which support an upper balcony

*Psyche, Nov., 1895, pp. 303–306.

of the cottage, and here, too, the wasps made use of holes which were already excavated.

In the following summer we found large numbers of these wasps at work in a straw-stack. The stack had been cut off perfectly smooth on one side so that many thousands of the cut ends of the straws were exposed to view, and these proved very attractive to *rubrocinctum*. This species is very cosmopolitan in its tastes, for we also found it utilizing the small holes in the sticks of a wood-pile. The straws made the daintiest nesting-places, however, and were well adapted to our purposes since they could be drawn out of the stack and split lengthwise so that the contents could be easily studied. The two halves could then be brought together again without injuring the inhabitants, and thus we often kept several sets under observation long enough to watch the changes from the egg to the pupa. We found *Trypoxylon albopilosum* nesting in holes made by beetles in posts and trees, but never in straws. A third species, *bidentatum*, was very common, nesting in the stems of plants. During the month of August we saw many individuals of this species hunting for spiders on the blackberry bushes, but at this time we were so much absorbed in *Crabro stirpicola* that we never followed them to their homes.

Rubrocinctum was more conveniently studied, and through July and August we watched the comings and goings of these little wasps. They were very good-tempered, never resenting our close proximity nor our interference with their house-keeping. By working hard they could prepare a nest, store it with spiders and seal it up all in the same day. This we have seen them do in several instances. In other cases the same operation takes three or four days. In the second summer that we worked with them we found one very energetic mother that stored four nests in one day. It had rained hard on the twenty-sixth of July and no wasp works in such weather. On the afternoon of the twenty-seventh we took a straw just as the little mother was bringing in a spider. We opened it and found that the innermost cell contained eight *Epeirids*, with an egg on the abdomen of the last one taken in; the second cell was provisioned with ten spiders with the egg on the seventh, so that three had been brought in after it was laid; the third cell had the egg on the last spider, as did also the fourth. All of these eggs hatched on the twenty-ninth, the two outer ones, that were laid last, between eight and nine o'clock in the morning and the two that were laid earlier between two and three in the afternoon. This was the biggest day's work that we have ever recorded for any of our hunting wasps.

With both species (*T. rubrocinctum* and *T. albopilosum*), when the preliminary work of clearing the nest and erecting the inner partition has been performed by the female, the male takes up his station inside the cell, facing outward, his little head just filling the opening. Here he stands on guard for the greater part of the time until the nest is provisioned and sealed up, occasionally varying the monotony of his task by a short flight. As a usual thing all the work is performed by the female, who applies herself to her duties with greater or with less industry according to her individual character; but the male doubtless discharges an important office in protecting the nest from parasites. We have frequently seen him drive away the brilliant green *Chrysis* fly which is always waiting about for a chance to enter an unguarded nest. On these occasions the defense is carried on with great vigor, the fly being pursued for some distance into the air. There are usually two or three unmated males flying about in the neighborhood of the nests, poking their heads into unused holes, and occasionally trying to enter one that is occupied, but never so far as we have seen, with any success, the male in charge being always quite ready and able to take care of his rights. The males, however, made no objection when strange females entered the nest as they sometimes did by mistake, nor did the females object to the entrance of a strange male when the one belonging to the nest happened to be away, but in such cases the rightful owner, on his return, quickly ejected the intruder. We often amused ourselves, while we were watching the nests, by approaching the little male, as he stood in his doorway, with a blade of grass. He always attacked it valiantly, and sometimes grasped it so tightly in his mandibles that he could be drawn out of the nest with it.

When the female returns to the nest with a spider the male flies out to make way for her, and then as she goes in he alights on her back and enters with her. When she comes out again she brings him with her, but he at once re-enters, and then, after a moment, comes out and backs in, so that he faces outward as before.

In one instance, with *rubrocinctum*, where the work of storing the nest had been delayed by rainy weather, we saw the male assisting by taking the spiders from the female as she brought them and packing them into the nest, leaving her free to hunt for more. This was an especially attentive little fellow, as he guarded the nest almost continuously for four days, the female sometimes being gone for hours at a time. On the last day he even revisited the nest three or four times after it had been sealed up.

It is upon the female that the heaviest part of the work devolves. As soon as she has put the nest in order she begins the arduous task of catching spiders wherewith to store it. It usually takes them from ten to twenty minutes to find a spider and bring it home, but they are sometimes absent for a much longer time. When the spider has been carried to the nest the process of packing it in begins. This occupies some time and, apparently, a good deal of strength, the female pushing it into place with her head with a total disregard of its comfort, all the spiders that are caught being pressed and jammed together into a compact mass. While she is busied in this way she makes a loud, cheerful humming noise. The number of spiders brought seems to depend upon their size, in which quality they vary greatly, the largest ones being six or eight times as large as the smallest. *Rubrocinctum* fills her nest with from seven to fourteen, while the larger *albopilosum* brings as many as twenty-five or thirty. Those that we examined represented many different genera, and even different families, although they were usually *Epeiridae*.

In a number of cases, during the first summer, after several spiders had been stored, we gently drew them out with a bent wire. In one nest in which there were five spiders, we found, two hours after they had been stored, that three were alive and two were dead. In another, which the wasp had just begun to seal up, were ten spiders. Three of these were injured in being drawn out. Of the remainder four were alive and three dead. On the anterior part of the dorsum of one of the living spiders was the egg. It had probably been fertilized as the female carried the male into the nest on her back.

When we discovered *rubrocinctum* in the straw-stack we made many observations as to the position of the egg and the number and condition of the spiders. We found that the egg was always placed either on the side or the back of the anterior part of the abdomen. The number of spiders stored was, as we have already stated, from seven to fourteen. A fact that interested us greatly was the remarkable accuracy shown by the wasp in never selecting too large a spider for the calibre of the straw. Oftentimes it was an extremely close fit, but it could always be squeezed down. When they nested in posts they used at times much larger prey. Unfortunately we never saw this species capture its prey, nor could we prevail upon it to sting in captivity, but the number of spiders that we found in straws was so large as to afford abundant evidence concerning the degree of surgical skill possessed by the wasps. Most of the spiders taken by *rubrocinctum* are inoffensive creatures and there is no need to be careful or adroit in dealing with them.

The concentration of the nervous system in the *Arachnida* would seem to conduce very strongly to uniform results from the stinging of the wasps. Unlike the larva used by *Ammophila*, with its chain of ganglia, in the *Araneidae* the whole central nervous system, including the brain and the ventral cord, forms a single mass, pierced by the œsophagus. The greater part of this mass, which lies behind the œsophagus, represents the fused ventral cord from which the nerves radiate. The drawing (Pl. VIII., fig. 8), gives a clear idea of this nervous aggregation, and shows how little difficulty would be encountered by the sting of the wasp in entering it. It is evident that a thrust given in almost any part of the ventral face of the cephalothorax, or even on either side of the anterior half of its edges, would reach the nervous center. With these facts before us let us turn to the notes made upon the condition of the spiders that had been stung and stored up in the nests of the straw-stack. By the "first cell" we mean the last one stored, which was naturally the first one opened.

July 11. Opened a nest of *rubrocinctum.* The first cell contained fourteen live spiders with a newly laid egg. Some of the spiders were very lively, moving spontaneously. Second cell, ten spiders, one dead, others alive, and an egg. Third cell, eight spiders, three dead and five alive, and the egg.

July 12. In each of the first and second cells one spider has died since yesterday, while in the third there is no change in their condition. The egg in the third cell hatched at nine in the morning, and the one in the second cell at three in the afternoon.

July 13. In the first cell all the spiders are dead but one, and in the second, all but four, while in the third none are alive.

July 15. All the spiders in the second cell are dead.

July 16. The one spider in the first cell has outlived all the others, but that, too, died today.

The record of another set of nests is as follows: On July eighth we took a straw with a wasp as she went in with her spider. The cell was not sealed up. It contained fourteen specimens of three species of *Epeirids*, and the egg was, apparently, just laid. The spiders were pushed in very tightly and the legs and abdomens were, in many cases, bent to one side. All were limp, but alive. By July tenth, four were dead; on July eleventh the egg hatched. By July thirteenth all of the spiders were dead.

It is unnecessary to give the history of other nests in detail, since these facts make it clear that there is a great variation in the degree of severity with which the spiders are stung, so that while with some the paralysis is complete, with others it is only partial. Some were killed outright, others lived two or three days, while still others survived for two weeks. Compared with the work of the *Pelopaei* it would seem that a smaller number of the spiders are killed at once, while a larger number die after the lapse of a few days. None of the victims of *Trypoxylon* live so long as the most perfectly paralyzed spiders of the mud-daubers. The two longest lived spiders of *Trypoxylon* lived ten and fifteen days respectively, while with *Pelopaeus* one survived until the thirty-eighth and one until the fortieth day.

The accompanying table shows the number of days that the *Trypoxylon* spiders lived after having been captured and operated upon. We wish to avoid any suggestion that would imply a lack of skill on the part of the wasps, from the fact that they killed rather than paralyzed their victims. Possibly the best criterion of their success is the rapidity with which the spiders are captured and stored, irrespective of their condition. Dead spiders seem to be quite as wholesome for their nurslings as living ones.

TABLE NO. I.—*Showing length of life of spiders found in nests of T. rubrocinctum.*

No. of nest.	*Condition of spider when found.*		*Number of days that the spider lived after the nest was opened.*								*Remarks.*
	Dead	Alive	1	2	3	4	5	6	10	15	
1	9	4	.....	.....	.....	.....	3	.....	1	.....	Larva two days old.
2	5	2	.....	.....	.....	.....	.....	2	.....	.....	Larva one day old.
3	......	12	.....	2	.....	5	5	.....	.....	.....	Egg just laid.
4	......	14	.....	1	12	.....	.....	1	.....	.....	Egg one day old.
5	1	9	1	.....	4	4	.....	.....	.....	.....	Egg one day old.
6	3	6	.....	.....	5	.....	.....	.....	.....	.....	Egg nearly two days old
7	......	10	.....	2	8	.....	.....	.....	.....	.....	Egg on abdomen of spider.
8	2	7	.....	.....	3	3	.....	.....	1	.....	Egg one day old.
9	4	5	.....	.....	1	.....	2	.....	1	1	Egg just laid.
Total	24	68	1	5	33	12	10	3	3	1	

The egg requires from forty to sixty hours for its development and the larva feeds for seven or eight days before spinning its cocoon. Those that we watched, usually first disposed of the abdomen and then of the cephalothorax; sometimes they would consume several abdomens before attacking the other parts. After the body was devoured the legs were picked up and eaten. When the supply of food was generous, portions of the spiders were sometimes left untouched. The cocoons resembled in general appearance and structure those of *Pelopaeus*.

When a female returns with her load she usually hunts about for a few moments before finding her nest, sometimes entering, first, two or three that are empty or are occupied by other wasps, but we do not wish to cast any reflection upon the sense of locality of a creature that is able to find one particular straw out of the many thousands in an expanse of stack twenty feet high by twelve wide. We ourselves can testify, from experience, to the extreme difficulty of the task.

After the storing process is completed the female seals up the nest with mud. In the case of one *rubrocinctum* that we were watching she began to close the opening at four in the afternoon and finished her work just thirty minutes later. In this time she made ten journeys for mud, bringing it in pellets in her mandibles. In another case, also a *rubrocinctum*, the female, after bringing so many spiders that the cell was full up to the very door (which we saw in no other case), went away without closing it and never returned. The male seemed uneasy at her conduct and several times flew away, staying an hour or two and then returning; but after a time he too deserted the nest. Whether some evil fate overtook the female or whether there was some failure of instinct on her part can only be conjectured, but the latter hypothesis is not untenable, since out of seventy-six nests that we had under observation seven were cleaned out and prepared and were then sealed up empty. We have often found similar cases among the nests of the blue mud-dauber wasps, where it is not a very uncommon thing for the absent-minded females to build their pretty little cylindrical nests with infinite care and patience and then to seal them up without putting anything inside.

Cocoons of *rubrocinctum* that were gathered in the month of August remained over the winter and hatched in May and June.

Almost as interesting as *rubrocinctum* is the slightly larger species, *T. albopilosum.* This wasp has a great liking for the posts that support the balcony of our cottage, a preference that is very convenient for us, as it enables us to sit in the shade and watch their doings at our ease.

One afternoon as we sat, literally, at our posts, a female of *albopilosum* came humming along, looking very important and energetic, as though she had planned beforehand exactly what to do. She entered an empty hole, head first, and at once began to gnaw at the wood, kicking it out backwards with considerable violence. After a few minutes she changed her method of work, and began to carry out loads of wood dust in her mandibles, dropping it in little showers just outside the nest, and then hastening back. In forty minutes she carried out, in this way, upwards of fifty loads. She then flew away, but returned in ten minutes with a male. She alighted, he took his place on her back and they went in together.

After a time they came out and both flew away, but the next morning they came back and the nest was stored.

In this species the male does not always come out of the nest when the female brings a spider. Perhaps the nest is enough larger than in *rubrocinctum* to accommodate them both comfortably. As a usual thing, however, he enters on the back of the female. The spiders brought by *albopilosum* are larger than those used by *rubrocinctum.* They sometimes bring such heavy specimens of *Epeira insularis* that they are carried with difficulty, the wasp alighting and dragging the spider into the hole instead of flying directly in as usual.

We watched a number of *albopilosum* nests during the second summer, finding them in several instances through the loud humming of the female while she was pushing the spiders into her hole. From our not very extensive study of the spiders taken by this species we are of the opinion that some are killed at the moment of capture, and that those that are only paralyzed die in the nest from day to day.

Mr. W. H. Ashmead has noted that *albopilosum* stores its nest with aphides, but in the cases that we observed they used only spiders. There can be no mistake on this point as we more than once took the spider from the wasp as she was entering the nest. In a recent letter Mr. Ashmead says that his notes were made in the field, and that he probably mistook some closely allied species for this one.

We sometimes found the parasitic *Melittobia* fly in the nests of *rubrocinctum*, and from two nests we reared the common fly *Pachyophthalmus aurifrons*.

We do not know how many nests are stored by the female in one season, in any of the species of *Trypoxylon*.

We are not as familiar with the habits of *T. bidentatum* as with those of the other two, but we have a few notes relating to the female. This little worker is the smallest of the three, and like her sisters is a confirmed spider hunter. Once, when out among the raspberry bushes, we had the good fortune to witness a capture. The wasp seized the spider as it rested on a leaf, by the top of the cephalothorax and, holding it firmly, curved her abdomen under and stabbed the under face of the cephalothorax. All her motions were deliberate, and after the operation she delayed a moment before picking it up by a leg and flying off. We often found raspberry stems which had been filled with spiders by this wasp, but we do not know the length of time required for the development of the egg nor how long the larva eats before pupation. The cocoon is very different in appearance from those of *rubrocinctum* and *albopilosum*, being excedingly long, slender, and almost white, instead of short, wide, and brown. The perfect insects come out in September and the last cocoon formed is the first one to hatch. This was also true of the cocoons of *rubrocinctum* formed in straws. The different habits of the hymenoptera in this respect are very interesting. In the case of *Ceratina dupla*, the small carpenter bee, the egg first laid hatches first, those above following in regular order. The lower ones wait patiently in their cells until the one in the top cell has matured, when they all come out at once. This is a very common species with us. Mr.

Comstock says that, so far as he knows, *dupla* is the only solitary bee that watches over her young until they become mature. In the case of some of the cuckoo-flies (*Chrysididae*), we have observed that the egg laid first hatches first, but that the mature insect, instead of waiting for the way to be clear, gnaws a hole through the side of the stem, and thus makes its entrance into the world.

Years ago, when we found that many of the *Epeiridae* laid enormous numbers of eggs (*A. cophinaria* from 500 to 2000), we wondered what became of the thousands of spiderlings. An acquaintance with *Trypoxylon* has shown us their fate, and has given us an illustration of how closely the two groups are related. To make a very modest estimate there must have been twenty wasps at work in our straw-stack. During the six weeks which make the busiest part of their working season each of these must have stored, at the very least, thirty cells, putting an average of ten spiders into a cell. It may then be considered certain that the straw-stack, with its working surface of 12x20 ft., was the mausoleum of six thousand spiders, and it is very probable that twice as many were interred within its depths. It must be remembered, too, that before the spiders have grown large enough to be interesting to *rubrocinctum*, *bidentatum* has had her turn at them, and that those that are allowed to grow too large for *rubrocinctum*, are preyed upon grade after grade, first by *albopilosum* and finally by *Pelopaeus*, *Pompilus*, and other genera.

The wasps of this genus lose their interest in family affairs after the second week in August, though after this time they may still be seen taking their well-earned holiday on the blossoms of the aster and the golden-rod.

CHAPTER IX.

THE BUG-HUNTERS.

Astata unicolor Say.

Plates IX., fig. 5; XI., fig. 3; XII., fig. 4.

This species varies much in size, the larger ones being about half an inch long. It is black, the thorax having some white pubescence while the abdomen is smooth and shining.

We had so often followed these wasps without seeing them capture anything that we had almost come to believe that they were chasing a will-o'-the-wisp, or something equally intangible. For a long time we could get no clue to their lives but at last a day came when we saw one drop into a hole in the ground which showed a good sized opening with earth heaped all around, more on one side than on the other. Within six inches was a second nest, more perfectly shaped, with a funnel-like opening exactly like that of *Cerceris clypeata*, and this was occupied by a second wasp of the same species. They were both busy carrying in nymphs of *Podisus modestus* Fabr., which they held by the base of the antennæ, venter up, grasping them with the mandibles and supporting them, more or less, while flying, with the second pair of legs. Every time that a bug was brought home the wasp alighted and walked around near the nest for a few minutes, and then went in head first. One of them paid no attention to us but the other showed much annoyance at our presence and buzzed about for some time before going in. Before taking their departure they almost invariably made a long locality study, first running about on the ground, flirting their wings nervously as they went, and then rising and circling all around the place. (Pl. XII., fig. 4.) Their periods of work evidently alternated with spells of idleness for after bringing in three or four bugs they would disappear and nothing would be seen of them for five or six hours at a stretch. After keeping these two nests under observation for a week we excavated them both but failed entirely to follow the tunnel and found none of the bugs that had been taken in.

This experience with *unicolor* took place in the middle of July and we saw nothing more of the species for six weeks. On the first day of September, however, one alighted almost at our feet on the bare ground of the garden. She was much smaller than the one that we had seen before, and the big, flat bug that she carried was inconveniently broad and stretched her legs apart as she ran about with it. After a moment she went into a hole which did not in the least resemble the nests of our earlier acquaintances, being much smaller and running in obliquely, with no earth heaped around. This little wasp proved to be one of the fearless kind and went on with her work without noticing us. She, too, had fits of industry. She sometimes found a bug in ten minutes, but was usually gone from thirty to forty when on a hunting expedition. After working for an hour or two she would amuse herself for the rest of the day, sometimes staying out until sunset and sometimes going to bed at half past one or two o'clock and remaining within until nine on the following morning. The nest was invariably left open when she went away but was always closed at night, and sometimes, also, when she went in for an hour's rest in the day time.

After we had watched this small *unicolor* for two days we opened the nest but found only one bug and no egg. On the next morning at nine o'clock she had nearly finished a new nest close to the old one. She did no hunting during the morning but made several excursions, and on returning from one of these spent twelve minutes in searching for the new nest, coming back again and again to the spot where the old one had been. She began to hunt at one in the afternoon and took in three bugs between that time and three o'clock, when she retired for the night. One of these bugs was laid down at the entrance of the nest while the wasp entered, turned around and then came up head first and pulled it within. As a usual thing *unicolor* walks straight in, carrying the bug in her mandibles.

Three of our four individuals of *unicolor* excavated their nests all at once instead of enlarging from day to day; but this one, after making her nest on the morning of September fourth, was found early on the morning of the fifth excavating from within. She worked in a very slow and dignified way, without the least hurry or bluster, loosening the earth and then lying quite flat and pushing it out with the end of her abdomen. Working backwards in this way she came out quite covered with dust, and still lying flat, pushed the loose material away from the entrance with her hind legs, but with a motion too gentle to be called kicking.

The nest was opened on September sixth and this time the tunnel was successfully followed, and four pockets, which led off from it half way down, were discovered. (Pl. XI., fig. 3.) Three of these pockets contained partly eaten bugs, and one of them had also a parasitic larva. The fourth pocket, which seemed to have been most recently stored, contained three bugs, and on the venter of the last one taken in, near the base of the first leg on the right side, and at right angles to the length of the body, was an egg. We were surprised to find that such a store of provisions had been taken into this nest, for if, as we had taken for granted, it had been freshly made on September fourth by the wasp whose nest we had destroyed on the previous day, she had filled three pockets on the fifth and sixth, and the bugs in two of these, as well as those carried in on the fourth, had been partially destroyed, not by the young of *unicolor*, but by parasites within their own bodies, before the sixth. We concluded, however, that this was the case, since our only alternative was to suppose that this nest had been made by another wasp, and that it had been partly filled before we saw it on September fourth, and it seemed extremely unlikely that anything could have been working there on the first three days of September without our seeing it. Moreover, if she was not the wasp that we had been watching right along, why should she have been attracted, as she evidently was, to the site of the old nest?

The egg which we took out on the sixth hatched just before noon of the same day, so that the egg stage in this species is probably not more than twenty-four hours. The larva ate the three bugs provided, and spun its cocoon on September tenth.

On September seventh we found our fourth and last individual of *Astata unicolor*. This one, which was much larger than any of the others, was making her nest when first discovered, pushing out great quantities of earth with the end of her abdomen. She was extremely tame at this stage of her proceedings, allowing herself to be caught and examined, and then resuming her work without the slightest sign of fear or perturbation. She worked slowly and deliberately for several hours and made a large round hole. The earth that was heaped up around the edges was not smoothed away and no effort was made to render the nest inconspicuous, excepting that the spot chosen was partly covered by a weed.

During the next few days our wasp did not spend much time in the neighborhood of her nest. We occasionally saw her going in or out but always empty handed. A beautiful big green *Chrysis* fly was watching the course of events even more closely than we were, spending her time around the nest or even inside of it. When the proprietor came home the intruder flew out and alighted close by. The wasp showed no resentment and the fly no fear. Thinking that she might interfere with our own designs we caught and executed the would-be malefactor, only to see her place taken by a smaller fly of the same family.

On September seventh our wasp was carrying in bugs, and now we found that a great change had come over her attitude toward us. Up to this time she had considered us as beneath her notice, but when she began to provide food for her offspring we at once became objects of distrust and suspicion, and nothing would induce her to go into the nest while we were near. She flew about the place, frequently alighting and seeming to hunt for it in different places. Sometimes she would go away for ten or fifteen minutes, and then reappear, still carrying her bug, to resume her circlings, and it was not until we had moved away to a distance of six or eight feet that she would go in. This excessive timidity was in striking contrast, not only to her former actions, but to the fearless conduct of the small *unicolor* spoken of before.

Of three bugs taken from *unicolor* as she brought them to her nest, two were quite dead, and the third, which responded to stimulation by a quivering of the tarsi and the antennæ when it was taken, died the next day. This bug and another which was taken dead from the nest excavated on September third, had parasitic larvæ within them which emerged after having eaten the softer parts, but died without spinning any cocoon. The three bugs taken intact from the nest opened on September sixth were all dead, although they had been carried in only the day before. So that although the sting that *unicolor* gives her victims does not always kill at once, it proves fatal within a very short time.

Astata bicolor Say.

Plates I., fig. 4; IX., fig. 6.

It was one o'clock in the afternoon on the sixteenth day of August. The mercury was trying some experiments up among the nineties and we knew from experience that the lower garden was the hottest place for miles around, yet thither we turned our steps without a moment's hesitation, possessed by the idea that something might be going on in that wonderful spot and we not there to see.

Sheltered by our umbrellas from the burning sun we promenaded up and down among the beans and potatoes scanning every inch of ground. An hour passed and our enthusiasm began to wane a little, yet we stayed on knowing that patient effort is almost sure to bring a reward. Suddenly our attention was arrested by a gleam of color. Was it a fly, this brilliant winged thing? Its actions awakened our interest; it had not exactly the *insouciant* air of a fly. It alighted near a weed, rose, circled about a little, came back to the same place, rose again, and—no, it was no fly,—dropped down into a tiny hole, hidden from above by a leaf. It was a wasp, and a very pretty one, with the abdomen soft, bright red, dark cephalothorax and gauzy wings. In a few minutes the little creature came creeping out and began to circle around the place but she evidently found it difficult to tear herself away from her home. Again and again she alighted near by, and finally she came close to the opening and, flattening her body so that she almost lay on the ground, gazed into it in a contented and contemplative manner. After a time she flew away. She was gone for ten minutes and when she came back we saw that she was carrying something in her mandibles. She did not go directly to the nest but alighted on a weed. After a moment she rose and circled about and then alighted again, this time on the ground. After she had repeated these actions several times she entered the nest, deposited her burden and almost immediately came out again. As before, some minutes were spent in circling about the spot before she flew away.

For two hours we sat by the nest watching her as she pursued the peculiarly even tenor of her way. She hesitated, delayed, and circled about whenever she left home and whenever she returned. Once on coming back to the nest, which was entered by a slightly oblique gallery, she walked in over the upper edge so that her back was down. On her return from her fourth journey we caught her in a bottle and found that she was carrying a small homopterous insect, which she held by the head, venter up. We shook the bottle but she would not drop it, and when released she resumed the business of the day with perfect self-possession. Twice on going in, she pushed up some earth, thus closing the hole behind her.

In the two hours that we watched her she made ten journeys. The stay within the nest was never more than two minutes but often as much more time was spent in going in and in getting away. We kept a record of the hours at which she returned which reads as follows: 2:42 o'clock, 3:03, 3:10, 3:18, 3:25, 3:30, 3:46, 4:00, 4:08, 4:15.

At fifteen minutes after four the wasp thought that she had worked long enough and as we were beginning to have something of the same idea it was a relief to find that having closed her door behind her she had gone to bed, or at least had decided to pass the evening at home. After awaiting for some time to see if she would reappear we placed a blade of grass over the nest, and covering all with an inverted tumbler, bade her good night.

At half past seven o'clock on the following morning we visited the garden to see if our little wasp was yet awake, but the blade of grass had not been disturbed. On a second visit, at nine o'clock, we found her flying about inside the tumbler and at once released her. She flew off and was gone for an hour and when she returned, bringing nothing with her, she circled about for a short time and then again departed without entering the hole. Ten minutes later she came back, still empty-handed, went into the nest, and pushed up such a quantity of earth from below as to make quite a high mound in place of the opening. When she came out again this accumulation of earth spread itself out on all sides. She now began to enlarge her nest, carrying out the dirt in little pellets, but this fit of industry only lasted for six minutes. A contemplative mood overtook her. She certainly felt no pressure of necessity, being quite contented to rest on a neighboring weed and meditate, varying the monotony by occasionally circling about her nest. It was two o'clock in the afternoon before she resumed her hunting expeditions.

This was our first acquaintance with *Astata bicolor*. A late arrival on the scene, it soon became a common species and between this time and the first of September scarcely a day passed without our seeing it. We never witnessed the making of the nest from the beginning but probably the earlier as well as the later part of the work is done with the mandibles, unaided by the legs. Supposing the excavation to be begun about ten o'clock in the morning the work is carried on without haste and with frequent pauses until two or three in the afternoon, when it is suspended. *Bicolor* goes in for the night at about four o'clock and nothing more is seen of her until the next morning when about an hour's labor completes the nest.

She invariably leaves the nest open when she goes away, but in every case that came under our notice the spot chosen was protected by the branches or leaves of some weed so as to be invisible from above. She is rarely fortunate in one respect, since we have never seen a parasitic fly in attendance upon her; but this fact makes it difficult to explain her wily and cautious approach to the nest. Why should she spend so much time in getting in, scarcely ever dropping directly down to it as other wasps do? On entering she often leaves the hole open and just as often closes it. The closure at night is doubtless to protect the nest from cold and dampness but in day-time it may be merely the result of her pushing back the loose earth which bars the passage to the nest. There is no attempt to clear away the earth from the outside. The appearance of the nest is almost identical with that of an ant-hole, a tiny opening with a circular heap of earth around it. The entrance tunnel is from two and one-half to three and one-half inches in length and the nest itself is from one and one-half to two and one-half inches below the surface.

In one of the nests that we opened we found three bugs. These we put into a glass with the wasp that had taken them in. She took each one in turn, and, standing over it, venter to venter, squeezed its neck very slowly for half a minute or more. We offered her several live specimens of the same species but she would not touch them. Of those that were taken from the nest, one was injured in being taken out, one was nearly dead and the third was very lively. The second one lived three and the third one five days after we disinterred them.

At another time, having found a wasp that was provisioning her nest, we waited until she went in with her load and then placed over the opening an inverted tumbler containing seven live bugs of the species that she preferred. When she came out she flew about in the glass for a short time and then, seizing one of the bugs by the head, in her mandibles, and holding it dorsum up, she curved her abdomen under it and stung the lower face of the thorax. We were close by, and could see the performance distinctly. She then, without relaxing her hold, walked with the bug into her nest. We tried to get her to take another, but without success.

Wishing to follow the fortunes of this wasp still further we came down to the garden early the next morning and stationed ourselves near her nest. It was nine o'clock before she made her appearance, and then she spent half an hour in the immediate neighborhood, walking around and around and frequently flattening herself down in the dust. She then went away, perhaps for breakfast, coming back an hour later without any load and spending twenty minutes inside the nest. At the end of this time (it was now eleven o'clock) she began the business of the day by working for ten minutes at enlarging her nest. Then, after circling about and alighting again and again, after standing just inside the doorway and looking out, and after lying down just outside the doorway and looking in, this most calm, deliberative, and unhurriable of all the wasps went away and caught one bug. After that the charms of home again asserted themselves and the circling performance was repeated. We tried to get her to accept a bug of our providing, but in vain. At half after eleven she took her departure and three hours later she had not returned. We then opened the nest (Pl. IX., fig. 6) in which we found eighteen bugs, thirteen of them being dead and five living as was shown by the quivering of their legs and antennæ in response to stimulation. They were all mixed with earth but had doubtless been stored in pockets like those of *unicolor*. We found no eggs nor larvæ. Of the five living bugs two died within twenty-four hours, while the others lived three days.

We saw another of these wasps carry in nine bugs during an afternoon and the following morning. Once, when she came out, we placed a large bug near her. She seized it promptly and stung it on the under side of the thorax as in the other case, and then carried it into the nest. We saw no malaxation, but this, perhaps, was done inside.

One afternoon we saw a little female of this species dig a very shallow nest, which she then entered, closing the door behind her. This was probably only a temporary shelter to be used for the night.

Astata bicolor, with her dreamy ways and reflective turn of mind seems out of place among our restless *Ammophilae, Sphegidae,* and *Bembecidae.* Her character is distinctly Oriental, and nothing of the hurry of the West is seen in it. As might be expected the individuals of the species do not differ from each other as is the case with other wasps. We found a remarkable unanimity in their hours for rising and retiring, and in the manner of digging the nest, in the result accomplished, and in their habits of departing and returning, each one was like all the rest.

So far as the habits of *bicolor* have a bearing upon the question of the stinging instinct, they show that there is no exact surgery involved in her method of dealing with her prey. She stings in the thoracic ganglion, and as a usual thing she stings to kill. It may be that in some cases malaxation is substituted for stinging, for a few of the bugs taken from the nests seemed too lively to have been subjected to so serious an operation. The second conclusion to be drawn is that the larva of *bicolor* subsists principally upon dead bugs. There is no wonderfully preserved store of fresh provisions for this little plebeian. Bugs can scarcely be considered dainty fare under any conditions and how much less so when they have been dead for days! Yet this is certainly a flourishing species, bearing no marks of degeneration or decay.

Astata Leuthstromii Ashmead.

It was on the fourteenth day of July that we saw this new species which is a little longer than *bicolor* and dark in color. The wasp stood with her head peeping out of a hole that seemed too large for it, and occasionally scrambled on the edges with her fore feet as though she were trying to get out, although it may be that her object was to draw loose dirt down into the hole. There was no heap of earth around the place as with the nest of *bicolor*. After a little the wasp came out and flew away but returned, without a load, in ten minutes, and after alighting and walking about for a while, flirting her wings as she moved, went in and closed the door. It was now three in the afternoon, and she did not open the nest until a little before nine on the following morning. The place was shaded and perhaps for this reason she did not go out at once, but she came up every few minutes and looked about, not jerking her head this way and that as is characteristic of some of our wasps, but frequently wiping in a little dust with her antennæ.

At the end of an hour she flew away without circling. In ten minutes she came back, flying lightly although she carried a bug in her mandibles, and after alighting for a moment on a blade of grass, flew into her nest, passing her burden backward as she entered so that for an instant it projected behind her.

Fearing that we might lose our wasp if we let her go again we captured her as she came out, and excavated the place, but failed to trace the nest or to find the hidden treasure.

CHAPTER X.

The *Diodonti.*

Plates X., fig. 5; XIV., fig. 3.

Along the fence that separates the garden from the woods beyond grows a row of choke-cherry bushes, among which are mingled wild roses and the tall stalks of the yellow coreopsis,—a touch of poetry amid the prose of beans and potatoes. It was while passing these bushes one day early in July that we saw, hovering over them, numbers of little black wasps. These were the *Diodonti*, and closer inspection showed that they were busily engaged in catching the aphides which swarmed on the undersides of the leaves. We were glad enough to seize the opportunity thus offered, and for this and several succeeding days we devoted ourselves to the study of this fearless and friendly little species.

Diodontus americanus is one of the tiniest of all the wasps, but having chosen for its prey something still smaller and weaker than itself it never lacks good hunting. Yet the wasps and the aphides were not the only actors in our modest drama of the choke-cherry bushes. The ants were also on hand, solicitously tending their little green cattle. As might be expected they did not look upon the destruction of the aphides with indifference but gave practical proof of their interest in the matter by driving away the attacking wasps. Had they combined, and sent out detachments to protect their flocks, the *Diodonti* might have hunted in vain, for the wasps invariably had the worst of it in their encounters with the ants; but their efforts were solitary and did not count for much, since a wasp that was driven from one group at once settled down upon another.

In Belt's "*Naturalist in Nicaragua*" there is an interesting account of a similar state of things existing among wasps, ants, and frog-hoppers. He tells of one species of ant which has adopted the role of protector, and which feels its responsibilities so thoroughly that it will bite the hand of any one who interferes with the young frog-hoppers. He says, "These leaf-hoppers are, when young, so soft-bodied and sluggish in their movements, and there are so many enemies ready to prey upon them, that I imagine that in the tropics many species would be exterminated if it were not for the protection of the ants.

"Similarly as in the Savannahs, I had observed a wasp attending the honey-glands of the bull's-horn acacia along with the ants; so at Santo Domingo another wasp, belonging to quite a different genus (*Nectarina*), attended some of the clusters of frog-hoppers, and for the possession of others a constant skirmishing was going on. The wasp stroked the young hoppers, and sipped up the honey when it was exuded, just like the ants. When an ant came up to a cluster of leaf-hoppers attended by a wasp, the latter would not attempt to grapple with its rival on the leaf, but would fly off and hover over the ant; then when its little foe was well exposed, it would dart at it, and strike it to the ground. The action was so quick that I could not determine whether it struck with its fore-feet or its jaws; but I think it was with the feet. I often saw a wasp trying to clear a leaf from ants that were already in full possession of a cluster of leaf-hoppers. It would sometimes have to strike three or four times at an ant before it made it quit its hold and fall. At other times one ant after the other would be struck off with great celerity and ease, and I fancied that some wasps were much cleverer than others. In those cases where it succeeded in clearing the leaf, it was never left long in peace; for fresh relays of ants were continually arriving, and generally tired the wasp out. It would never wait for an ant to get near it, doubtless knowing well that if its little rival once fastened on its leg it would be a difficult matter to get rid of it again. If a wasp first obtained possession, it was able to keep it, for the first ants that came up were only pioneers, and by knocking these off it prevented them from returning and scenting the trail to communicate the intelligence to others."

With our wasps there was no such struggle as this for the possession of the aphides. They made no resistance and we never saw them try to strike the ants from the bushes. We have been especially interested in Mr. Belt's opinion that some wasps are much cleverer than others as we have again and again noted the same thing.

We found that when a wasp secured an aphis she flew with it to another leaf near by, alighting, this time, on the upper surface. She then passed it back from her mandibles to the second pair of legs, and holding it, with them, under her body, she proceeded to make use of the first pair in giving herself a thorough cleaning. Her face, especially, was well washed and rubbed. We afterward saw other wasps put themselves in order and smooth their ruffled plumage after catching their prey. *Ammophila* was especially given to making her toilet on these occasions, but she had some excuse for it since she could not subdue her victim without going through something of a struggle. With *Diodontus* the performance became absurd, since the capture of the aphis required no combat, scarcely, indeed, an effort. The victim was merely picked up and carried off.

Her dainty person being put to rights, our little wasp brought the aphis forward, and squeezed its neck repeatedly between her mandibles. With *Diodontus* this malaxation is always accomplished delicately, so that the skin is not broken, but there is a considerable variation in the thoroughness of the work. In most cases the aphides are killed, since we afterward found that they were almost invariably dead in the nests, even in those that were freshly provisioned. In other cases the disturbance was so slight that they were able to walk about as soon as they were released, seeming to be scarcely injured.

To see the whole process more conveniently we repeatedly caught a wasp and placed her in a bottle with a leaf upon which were aphides. Using a glass, we could then see what passed very distinctly. The tiny wasp would pounce upon an aphis, and holding it with the first legs would squeeze its neck gently between the mandibles, rolling it over and over. After a few moments she would pass the aphis back to the second pair of legs and rest for a short time, usually taking this opportunity to wash her face. She would then bring the aphis forward and squeeze it again. After several repetitions of this process, the aphis would be dropped and another one picked up to be dealt with in the same way, twelve or fifteen being taken in succession before the wasp tired of her objectless industry. In the open, *Diodontus* often alights on one leaf and malaxes her victim and then flies to another and another, repeating the process several times before she finally flies off to her nest.

We were surprised to find that the wasp never used her sting. Since death is to be the result it would seem that the end could be attained more easily by the injection of a drop of poison than by the careful and laborious process which is used. This is not from any rigidity of the abdomen, since while we were handling the wasps they repeatedly tried to sting us, although they are such tiny creatures that they were unable to puncture the skin. It would be of interest to know whether *Stigmus*, which also captures aphides, and *Rhopalum* and *Crabro*, which take gnats, use their stings in killing their prey. We have seen the vigorous *Polistes fusca* descend upon a caterpillar and reduce it to a pulp by squeezing all the parts with her mandibles, not condescending to use her sting at all. It may be that this is the common method of capture in all those cases in which the difference in size and strength between the two actors in the play is such that the wasp need not sting her victim in order to reduce it to helplessness in her hands. This idea suggests that the object of the stinging is primarily to subdue, not to paralyze.

The next question that confronted us was, where were the nests of *Diodontus*? Here we met a difficulty that seemed absurd enough later on but which was very real at the time. We watched the wasps carefully as they prepared for flight, and bent all our energies upon keeping them in view—in vain. They rose upon their wings, and disappeared. Baffled again and again, we called the children of the household to our aid and offered prizes for the discovery of the nests, and these recruits, thinking that perhaps the wasps crossed the garden to the barn-yard, searched that enclosure thoroughly, and found in the straw-stack, nests indeed, hundreds of them, only they belonged to *Trypoxylon*. Not discouraged, our energetic assistants next scrambled over the fence to the north, invading the woods, and there in a worm-eaten weather-beaten stump they found more nests—but they belonged to *Rhopalum* and *Stigmus*. Three days passed before we dropped our eyes to the ground at our feet and found that there, close by, were the abiding places of *Diodontus*.

From the outside the nests show a tiny hole with some grains of dirt irregularly heaped around the edges. We had the greatest difficulty in excavating them, as the crumbling earth fell into the narrow gallery at every touch, making it almost impossible to trace. The nest that is shown in the drawing had been started in a small lump of earth which lay on the ground, and this made it easier to follow the entrance tunnel. (Pl. X., fig. 5.)

It takes the wasp about an hour to dig her nest. She carries the earth out with her mandibles and first legs, backing from the hole. The gallery runs in obliquely and ends in a pocket to one side. The nest is not closed until the provisioning is completed.

When an aphis is brought home the wasp remains within the nest only a few moments and then is off in search of another. The egg is not laid on the first one brought in since it is often lacking in nests which contain six or eight aphides. If the weather is hot and sunny it is not unusual for a nest to be made and completely provisioned on the same day, but when it is cool or cloudy *americanus* works very slowly or not at all. About forty aphides are necessary for the provisioning of a single nest.

On the same bushes with these wasps we constantly saw a slightly larger species of *Diodontus* which acted in every way like *americanus*. In spite of all our efforts we were unable to find the holes of this second and larger species. They were present in large numbers and it seemed improbable that they could have nested in territory so familiar to us as the garden came to be without being discovered. After close watching we concluded that these wasps flew over the fence into the woods while *americanus* settled down close by.

The month of July is evidently the working season of the *Diodonti* since they were very active from the seventh of the month, when we first saw them, until the first of August. From that time on we saw them less and less, although a few of them were still at work three weeks later.

On July twenty-fifth we first saw the males of this species, which, Mr. Ashmead tells us, had been unknown before. On this and on succeeding days we saw them mating with the females. As the females had been laying their eggs for about three weeks the males had probably been present all the time, but had escaped our attention.

The parasitic Chrysis fly, *Omalus corruscans*, is always in attendance upon *americanus*, both on the cherry bushes and on the ground near the nests. Brilliant and beautiful but full of evil intentions, she watches their comings and goings. There is no opportunity for her to lay her egg on the aphis outside of the nest. Holding it closely under her body and not exposing any part to attack, the wasp, without making the least pause, flies into her open doorway. When she comes out again the enemy is still lurking near, but no instinct warns her to cover her treasure. The door stands wide open as she takes her departure, leaving her young exposed to the foe. Perhaps the danger is not so great as it seems. The fly certainly penetrates into the nest, since we have found it in the gallery when excavating; and in one case we found a strange larva feeding on the aphides along with that of *americanus*; but it may be that the supply of food is so ample as to cover the needs of both. At any rate it must be confessed that the parasite has not prevented *americanus* from becoming a flourishing species.

Although as a rule, *Diodontus* worked for the coming generation, the captured aphis sometimes served not as food for the young but as a dainty morsel for herself. In these cases there was no malaxation, the aphis being held in any position while it was sucked dry of all its juices and then thrown away. This may be a further development of the habit described by Belt of stroking the frog-hoppers to get the drop of honey which they can yield without harm to themselves. It has little in common with the method of *Philanthus apivorus*, which, according to Fabre, squeezes the honey from its bee because if left, it would prove fatal to the young larva. It is rather like that of *Odynerus nidulator* which takes nothing from the caterpillars which are destined to feed the young, never storing up those from which it has sucked the juices.

Cerceris ornata offers us still another habit. The neck of *Halictus*, its prey, is brutally compressed, the skin being broken so that the juices of the body exude, and these juices are licked off by the wasp.* The object of the malaxation, however, seems to be to produce lethargy for the benefit of the wasp larva, since the bee is afterward stored up. The taste that the wasp gets of bee-juice is rather an accident than anything else. How is it that the honey is not fatal to the young of *Cerceris*, as it is to that of *Philanthus*?

As has been said, the excavation of the nest of *Diodontus* is a difficult matter, but in six cases we succeeded in finding the pocket with its contents. In these nests the number of aphides varied from five to forty, the provisioning being only just begun in some cases while in others it had been completed, and the nest closed up.

With a single exception the aphides in these nests were dead. They were usually green when first taken out but turned yellow

*Etude sur l' Instinct du Cerceris ornata, Archives de Zoologie Expérimentale et Générale, Deuxième Série, Tome V., 1887, p. 27.

by the second or third day and by the fourth or fifth were all dry and brown. The exception to the rule was a very lively little aphis found in a closed nest with about forty dead ones. We have no doubt that they are often alive when first taken in, from the fact that while watching the action of the wasps in the bottle we noticed that they not infrequently left the aphides almost uninjured.

In four of the nests we found the egg, which in one instance was on the under side of the body of the aphis, while in the other cases it was placed on the dorsum. Perhaps one of the eggs was laid by a parasite and this was the reason of the difference in position.

Only two of the eggs hatched. The first of these (No. 23) was taken from a nest which had been closed up at three in the afternoon on July twenty-second. At nine in the morning of July twenty-fourth we found that it had hatched, and it seemed to be a few hours old. The egg stage, then, probably lasts about thirty-six hours, although we judge that it may in some instances be less from the case of another wasp, No. 24. This nest was also closed up by the wasp on July twenty-second, and we dug it up on the afternoon of the same day. The larva, however, hatched at nine in the morning of July twenty-third, nearly a day sooner than the one in nest No. 23. This, to be sure, may have been due, not to a more rapid development of the egg, but to its having been laid earlier, perhaps shortly after the provisioning of the nest was begun, while in the other case it may have been laid after the aphides had all been carried in. We know that in certain other wasps (*Pelopaeus*) there is just such a variation as this in the point of time at which the egg is laid.

These two wasplings lived through the six days of their larval life. They ate the whole aphis, leaving no débris. At the end of that time one of them died and the other spun its cocoon. In the tube with this later larva we discovered, on the seventh day after the nest was taken up, a second smaller larva which was also eating the aphides. This one, which was probably the young of *O. corruscans*, disappeared two days later without having exerted any evil influence upon the destiny of the rightful owner of the nest.

Diodontus gracilis and *corniger* are said to provide aphides for their young, making their nests in holes in posts, while *minutus* and *tristis*, like *americanus*, burrow in the ground. *Americanus* seems to be the only American species of which anything is known.

CHAPTER XI.

SOME GRAVE DIGGERS.

Cerceris and *Philanthus.*

Plates I., figs. 3 and 8; VIII., fig. 6; IX., fig. 1; XI., fig. 2.

Dufour, in describing the fearful ravages of *Cerceris ornata* among the bees, says that the wasps of this genus are among other insects what eagles and hawks are among birds. While this characterization does not seem to fit the American species it is certainly true that the genus stands out as one of those in which the distinctive peculiarities are strongly marked. They might be considered the aristocrats in the world of wasps, their habits of reposeful meditation and their calm, unhurried ways being far removed from the nervous manners of the *Pompilidae* or the noisy, tumultuous life of *Bembex.* Their intelligence is shown by their reluctance to betray their nests, and by their uneasiness at any slight change in the objects that surround them. It is not necessary to attempt to catch them, or to make threatening gestures in order to arouse their sense of danger. If you are sitting quietly by a nest when the wasp opens her door in the morning she will notice you at once and will probably drop out of sight as though she resented your intrusion into her privacy. After a little she will come up again and will learn to tolerate you, but at the least movement on your part, almost at the winking of an eyelid, she will disappear.

Our three representatives of this genus all prey upon beetles that are injurious to vegetation, and therefore deserve the gratitude of the agriculturalist. They are from one-half to three-quarters of an inch in length, *clypeata* and *deserta* being banded with bright yellow, while in *nigrescens* the bands are much paler, being gray with a faint tinge of yellow.

The nests of our species are all deep, tortuous, and very difficult to excavate. We have never succeeded in finding their pockets and yet, for various reasons, we feel perfectly certain that *nigrescens*, *deserta*, and *clypeata* are like *C. ornata* in provisioning, successively, a number of cells which lead out of the main gallery. When one of these cells is filled with food and the egg deposited, it is probably closed up and thus separated from the runway. From our experience late in the season with the nests of another wasp (*Astata unicolor*) we are inclined to think that we made a mistake in looking for pockets at the lower end of the tunnel. Had we searched higher up, at the point of the curve, we might have found them, the lower part of the gallery probably being designed merely for a dwelling place for the mother of the family.

But although we did not get distinct pockets we found, in at least one nest, a supply of food that would have far exceeded the wants of a single larva. We did not succeed in finding different eggs on different groups of beetles but in a nest into which the wasp was still carrying food we found a half grown larva which was identified as being hers. The fact, too, that a wasp occupies a nest for so long a time as ten days or two weeks points to the conclusion that she uses it for a number of eggs which are laid at intervals.

Cerceris digs her nest, deep as it is, all at once. In this she is a contrast to her near relatives of the genus *Philanthus* who busy themselves for an hour or so every morning with fresh excavations.

Cerceris clypeata Dahlborn.

Plate I., fig. 8.

On the eighth of July the weather was so warm and bright that we went down to the garden at half past eight o'clock, knowing that it was rather early but hoping that the hot sunshine would tempt the wasps to industry. We had walked up and down several times when suddenly, right in the pathway, a nest appeared. A great quantity of loose earth had been taken out and heaped up, probably on the preceding day, and in the midst of this a little hole had been opened since we passed before. The place looked so promising that we sat down to watch it, and a few minutes later we were rewarded by a glimpse of some antennæ down the gallery, and then a little face with yellow markings appeared but quickly vanished. Now followed a very coquettish performance. The wasp came slowly creeping up again and again only to drop out of sight as soon as she had reached the opening. After a time she grew bolder and sat in her doorway, twitching her head this way and that in a very expressive manner as though she were planning the work of the day, but it was plain that although she was up early, business cares were not weighing heavily upon her mind, for forty minutes passed before she came out of the nest, and after making three or four circles about the spot, flew away.

How much livelier and more interesting it would have been if we could have followed her! We tried to guess at what she was doing, and imagined her hunting industriously. After fifteen or twenty minutes it seemed to us that she must have caught something and that she was surely returning. Most probably she was not working at all, but was breakfasting leisurely and exchanging compliments with her neighbors, for when she did come home after keeping us waiting for an hour and a half, she brought nothing with her and seemed quite unconscious of the fact that greater things had been expected of her.

We had placed a stone upon a dead leaf near by, to mark the neighborhood of the nest, thinking that even a *Cerceris* could not object to so simple an arrangement of natural objects, but our wasp noticed it at once, and evidently with much suspicion and disapproval. She began by circling several times just above it. Then she alighted on it and examined it carefully, walking over it and creeping underneath, perhaps to see whether it in any way menaced the safety of her nest, perhaps as the completion of a locality study made the day before. She then rose on her wings, and after a little more circling, dropped suddenly into her hole.

So far we had not been getting on very rapidly but from this time things took a turn. *Cerceris* is never in a hurry and yet she may be relied upon to do a certain amount of work every day. The one that we were now watching had probably come back for a final look at her newly made nest before beginning to provision it, for she soon reappeared and this time really went to work since in forty minutes she brought home a beetle (*Balaninus nasicus* Say.), which she carried by the snout, venter up, in her mandibles, supporting it while flying with the second pair of legs. She was much annoyed at our presence and circled about as before. Twice she alighted near by and walked about for a few minutes, and when she did this all her feet came down to the ground, the beetle being allowed to hang loosely. At last she made the best of a bad matter and went in. The rest of the morning was occupied with hunting, the capture of each beetle taking about forty-five minutes. Every time that she came home she spent fifteen or twenty minutes in the nest.

This species soon became very common and for two weeks scarcely a morning passed without our finding at least one newly made nest. The study of *clypeata*, however, consumes a great deal of time. For example we found, one morning, two nests within six inches of each other. It turned out afterward that these were inhabited by two different wasps, but at the moment we supposed that one of them had been dug and deserted and then a second one made, and wishing to know which one was occupied we resolved to watch and see. After waiting for three hours we saw one wasp returning but upon noticing us she veered off and began to circle about. She was heavily laden and her burden, instead of being supported by the second pair of legs, as is sometimes the case, hung down under the thorax and abdomen. After a moment she alighted on a plant near by and seemed to consider the situation, then circled a little more and flew away, remaining out of sight for fifteen minutes, then another return, more circlings and hesitations. She seemed to feel the weight of the beetle now, and alighted frequently on the ground and walked about, yet she would not go in, so reluctant was she to betray her nest. In this way she kept us waiting for a whole hour, although we were not sitting very close and were as still as statues. At last we retreated and stood as far back as we could and still keep the hole in view. She now came closer, and, after hanging poised on her wings for a moment, dropped into her nest.

We once found a nest of this species in process of construction. A large heap of fresh earth had been pushed out and this entirely covered the spot, but at intervals there were upheavals from below which betrayed the presence of the wasp. When we saw it first it was half past eight o'clock, and we judged, from what had been accomplished, that she must have been at work at least an hour. It was half past nine before the excavation was complete. We had not been certain, up to this time, as to what we were watching, but now we had the pleasure of seeing her open her doorway from below and stand in the entrance while she washed her face, very prettily. When they rest at the mouth of the hole the first legs, which are yellow, are bowed in a semi-circle on each side of the yellow face, the distal joints being bent up so that the wasps seem to be standing on their elbows. This attitude, which is often seen in *Bembex spinolae*, gives them a delightfully amusing, bow-legged appearance. They usually open their nests in the morning at about nine o'clock,—a little earlier or later according to the time at which the sun strikes the spot. They then spend from forty minutes to an hour in taking a survey, the least movement on the part of a watcher causing them to drop out of sight as if the earth had given way beneath them. Sometimes there is a little way-station an inch or two within the tunnel, and the wasp only falls back to this point, and here she may be seen, if one peeps in cautiously, either quietly awaiting the retreat of the intruder or, perhaps, performing her toilet in a leisurely and elegant manner, using her fore feet, like a cat, to wash her face.

Whenever she leaves her nest she makes three or four rapid circles around the spot. This is doubtless to freshen her memory of the locality. We once saw *clypeata* make a thorough study of the neighborhood. This was in the case of the wasp mentioned before, that was so long in carrying her beetle in because of our being on the ground. When she finally did go in she stayed only an instant—just long enough to deposit her load—and then came out and spent a long time in a thorough investigation of all the surrounding objects, flying in and out among the plants, now high, now low, and circling again and again around the spot. It looked as though she had been puzzled and disturbed by the presence of unaccustomed things. As soon as the survey was over she went inside and closed the door, as though its object had been not so much to strengthen her memory as to correct former impressions.

The work of bringing in beetles goes on very irregularly, and as a rule not more than two or three are stored in the course of a day. It is not unusual for *clypeata* to spend three or four hours away from home and then come back without anything, and often, even in the middle of the day, she passes an hour or two in the seclusion of her nest. We had several nests under observation for a week at a time without ever once seeing the owners, although they were evidently occupied since they were sometimes open and sometimes closed. The outer entrance is always left open when the wasp goes away, although possibly access to the pockets may be barred below; but when she enters she closes the door unless she means to come out again at once. The closing is sometimes effected by pushing the earth up backwards, with the end of the abdomen, but the hole is rather too large for this method and more frequently the wasp comes up head first, carrying a load of earth in her front legs. This is placed just within and to one side of the entrance, and then more armfuls are brought up, until, after two or three trips, the opening is entirely filled.

We once captured the wasp in a bottle, as she returned, loaded, to the nest. She dropped the beetle but soon picked it up again and stung it vigorously, *with intention*, as the French say, first under the neck and then further back, behind the first pair of legs. After this it was dropped while the wasp fluttered about for a few minutes, but it was then picked up again, and stung as before. We both saw this operation repeated in exactly the same way, four different times, with intervals of five or six minutes between.

In a nest which we excavated after watching it for nine days, we found nothing until we had gone six inches down, and at this point the tunnel was lost, but mixed with the crumbly earth that we took out of the hole, we found eight beetles and a half grown larva of *clypeata*. The destruction of this nest was accomplished one morning, and when we came back to the spot twenty-four hours later we found that a new one had been made close by, doubtless by the same individual. We had expected to find her bringing beetles and dropping them foolishly on the ground like Paul Marchal's *Cerceris ornata*, and were gratified that she showed an advance in intelligence over that species, although to be sure she would have been still wiser had she chosen an entirely new neighborhood. Another individual was so much disturbed by our scrutiny that she dropped her beetle at the entrance to her nest. She did not pick it up again and utilize it, although it lay for three days in the dust at the threshold.

As to the condition of the beetles stored by *clypeata*, in the first nest that we opened we found eight, seven of which were dead, while the eighth, which we had just seen stung several times, was alive but died on the following day. The second nest gave us five beetles, all of them dead and dry. In the other nests that we opened we found nothing, although we knew that the beetles were there had we only been skillful enough to discover them.

Cerceris deserta Say.

Of this species, which closely resembles *clypeata* but appears later in the season, we had only a single example. We chanced to see her dropping into a crevice among some lumps of earth and at first could scarcely believe that this was the dwelling place of a wasp, as there was nothing whatever about it to indicate a nest, and even after we had removed the rough pieces of earth above, we could see nothing of the loose material that must have been carried out.

She was much like *clypeata* in her manners, with the same habit of surveying the world from her doorway and manifesting the same annoyance at our presence when she was returning to the nest, but she carried in more beetles in the course of the day and worked much more rapidly. Between nine and eleven o'clock one morning she brought in five loads, and some of the journeys occupied only ten minutes.

The first time that she found us sitting by her nest she circled about for nearly an hour, seeming unable to make up her mind to enter. At length we withdrew a little way but still her suspicions were not entirely allayed, and after a further study of the situation she dropped, not into her own nest but into a large cricket hole near by. Taken aback by this manœuvre, and thinking that perhaps we had a second individual to deal with, we stealthily approached, and peering in, could see the cricket inside, the wasp having slipped beyond. It did not seem possible that the little creature could be endeavoring to deceive us, and yet what other explanation could be offered for her conduct? We again took up our distant position, and after ten minutes more had the satisfaction of seeing the wasp slip out of the false nest and drop instantly into the true one. After a little she became quite accustomed to us and entered her nest without the least delay.

The prey of *deserta* (*Conotrachelus posticatus* Boh.) is held in the mandibles, and while we were watching her she did not support it with the second legs, even when flying. We took one of these beetles from her and found that it moved the tip of the abdomen freely whenever the body or legs were touched. On the next morning only the tips of the legs responded, by quivering, when the body was touched, and two days later it was unquestionably dead.

This species sometimes makes quite a thorough study of her nesting place before leaving it, and then, again, she will fly off without pausing at all. She has the habit of making a number of half circles in front of the spot, and then, after rising a little higher, of flying several times completely around it.

The observations on *deserta* were made between the twenty-fifth and twenty-ninth of August.

Cerceris nigrescens Smith.

We had long been familiar with the sight of *nigrescens* flying about over the purslane plants, now alighting and now circling again, before we succeeded in getting close enough to see what she was doing. What we had sought for in vain, however, came to us unasked. We had just entered the garden, one afternoon, when we saw her, bearing some kind of a burden, drop into an open hole almost at our feet. After a few moments she came out and flew away, and we, making ourselves as comfortable as circumstances permitted, settled down to watch the course of events.

Forty minutes passed before we saw her returning. She was evidently carrying a load which she seemed to hold in her mandibles. She seemed much annoyed by our proximity to her nest, and it was fifteen minutes before she could make up her mind to go in. During this time she circled about within from five to ten feet of us, alighting frequently on the weeds. Once when she alighted her victim seemed to struggle, for she pounced on it and grasped it afresh. She finally dropped into her nest and at once pushed up a large quantity of earth behind her. As she had not done this the first time that we saw her go in we took it as an indication that she meant to remain at home for the rest of the afternoon, and this proved to be the case.

We watched patiently but she did not come out, and at the end of half an hour we covered the spot with a glass, first marking the nest by scattering grass seed over it. These seeds had not been disturbed at sunset, and as the nest had been closed at half after two o'clock it was evident that she had finished her day's work at that hour.

On the following morning we were on hand at an early hour, but *nigrescens* did not appear until nearly nine o'clock, and then it was only to put her head outside the door for an instant and hastily retreat as though she had forgotten some important part of her toilet. At nine she came to the doorway again and took a survey of the world, turning her head this way and that with an air of elegant leisure. There she stood in placid enjoyment of the morning scene for just half an hour, when she came outside. Fearing to let her go, lest she might not return, we caught her and at once excavated the nest. This consisted of a tortuous passage three and a half inches long, which ended in a pocket. It contained eighteen small beetles, all of which were stiff and dead excepting two. These two were doubtful, since although they gave no response to stimulation, even with alcohol, they were flexible and had a general appearance of life. Three days later these too were stiff.

These observations were made on the twenty-eighth and twenty-ninth of August.

Philanthus punctatus Say.

Plate I., fig. 3.

This is a pretty little yellow banded species much resembling *Cerceris* in appearance. The nest consists of a main gallery with pockets leading from it, each pocket being stored with one egg and enough bees to nourish a single larva. When the wasps emerge from the cocoon they find themselves in the company of their nearest relatives and in possession of a dwelling place, and they all live together for a time before starting out independently to seek their own fortunes. On the fifth of August we discovered on the island a happy family of this kind, consisting of three brothers and four sisters, the females, with their bright yellow faces and mandibles, being handsomer than the males. They seemed to be on the most amicable terms with each other, their only trouble being that while they were all fond of looking out, the doorway was only large enough to hold one at a time. The nest was opened in the morning at about nine o'clock and during the next thirty or forty minutes their comical little faces would appear, one after another, each wasp enjoying the view for a few minutes with many twitchings of the head, and then retreating to make way for another, perhaps in response to some hint from behind. Then one by one they would come out, circle about the spot and depart, sometimes leaving one of their number to keep house all day alone. They usually left the hole open but if there was a wasp within, it was soon closed from below. During this playtime period they did not return until they were ready to settle down for the night, the first one coming home at half after two or three o'clock and the others arriving at intervals, none of them staying out later than five. Most commonly they found the right spot without trouble, scratched open the hole and then either closed it behind them or stood waiting in the doorway for the next arrival. Occasionally they had difficulty in locating the nest and worked at two or three different places before finding it.

We kept these wasps under close observation, often watching the nest from the moment it was opened in the morning until it was closed at night. On the twelfth of August, a week from the time that we first saw them, one of the females felt the responsibilities of life settling down upon her. At half after four in the afternoon she began to enlarge the nest and worked with a great deal of energy for forty minutes. After a long disappearance within the hole she would come up backwards, kicking behind her a quantity of earth which was not only taken outside but was then spread out far and wide. She worked with the front pair of legs which were curved inward, after the manner of *Bembex*, and when a pebble or some such object came in her way she either dragged it to a distance with her mandibles or pushed it before her with her head in a way quite peculiar to herself. In distributing the earth that was taken out, she went five and one-half inches from the nest—a distance which is much greater than is common among wasps, but which accords well with the habits of *punctatus*, since she continues the work of excavation from day to day.

On August thirteenth, at half after eight in the morning, we found that a second female, perhaps inspired by the example of her sister, had made a new nest within two inches of the first one, and had flown away, leaving it open. Presently the other wasps began to appear, one after the other, in their doorway. Two of the males flew away and one of the females, doubtless the one that we had seen digging the night before, began to work afresh at making the nest larger. Probably she was excavating a pocket for the reception of an egg, and the amount of labor required was enormously increased by the great length (about twenty-two inches), of the main gallery by which the displaced earth must be carried out. She worked for an hour and in spreading the dirt about, inadvertently filled in the opening of the second nest. At length she flew away.

At ten o'clock a female arrived carrying a bee of the species *Halictus disparalis* Cr., and tried to find nest No. 2. She came to the wrong place and worked about, here and there, for some minutes, holding the bee under the thorax, clasped by the second pair of legs. Being unsuccessful she dropped her burden and flew away for a few minutes. While she was gone we removed a leaf that had fallen over her nest, and on her return she at once descended upon the right spot and began to scratch open the entrance, the bee being kicked backward with the rejected earth. When the way was clear, however, she picked it up, brought it toward the hole, dropped it, ran in and out, brought it nearer, ran in again and turning around in the tunnel seized the bee in her mandibles and pulled it down. This performance was due to the accidental obstruction of the gallery, for we afterward found that *punctatus* ordinarily flies directly into her nest, or, when it is closed, pauses on the wing to scratch an opening with the first legs. The bee is pushed backward a little as she goes in but does not often project from under her abdomen.

At fifteen minutes after ten the worker from nest No. 1 brought in a bee, and from that time the two worked industriously. They showed some individuality in their ways, for No. 2 always closed her door when she went away and never circled at all, while No. 1 invariably circled before leaving and always left her nest open. To be sure, there was a female left on guard, so that perhaps she did not feel the need of caution.

Our wasps had not far to go for their victims. Forty feet away, on the eastern side of the island, was a steep declivity, and here, in the soft crumbly soil, was a great *Halictus* settlement. No prettier sight can be imagined than is presented by this colony on every sunny summer day. The whole bank is riddled with nests and at the entrance of each stands a male bee, his tiny head exactly filling the opening. The females are constantly arriving, laden with pollen, whereupon the males politely back inward to make way for them. Into this scene of contented industry descends the ravaging *Philanthus*, taking males and females alike.

On the afternoon of the fourteenth of August our two workers were in the full tide of affairs. No. 1 took in eleven bees within two hours, but her record was somewhat confused as two other females were going in and out at the same time. We felt sure that neither of these was hunting, but one of them shared in the labor of the nest by helping with the work of excavation.

No. 2, however, was alone, so that we could keep a definite account of her comings and goings. Her record is as follows:

Left.	Returned.	Left.	Returned.
1.48	2.07	3.38	3.55
2.08	2.11	3.56	4.03
2.12	2.19	4.04	4.22
2.20	2.30	4.23	4.25
2.31	2.37	4.26	4.55
2.38	3.07	4.56	4.57
3.08	3.28	4.58	5.20

At this last return she brought in no load and at once closed the nest for the night, after having stored thirteen bees in three hours and nine minutes. It will be noticed that in some cases the capture of the bee occupied only one, two, or three minutes, while at other times she was gone much longer. At each return she stayed only an instant—just long enough to deposit the bee—inside the nest, the minute that elapsed before she flew away being occupied in carefully closing the hole. The wasps that were going in and out of nest No. 1 sometimes closed it when they went away, but this was done in an untidy fashion, quite different from the nicety and precision of No. 2.

At half after five o'clock the wasp that had been digging for some little time at nest No. 1, flew to nest No. 2, opened it, and attempted to enter, but was quickly driven out by the owner. She then dug a little in several other places, finally returning to sleep in the family home. On the next day we found that No. 2 was tolerating in her nest one of the females that had not yet begun to hunt, but whether it was the one she had rejected the night before or the fourth member of the sisterhood we could not tell. On the eighteenth, three days later, the wasp had left this temporary home and made a nest for herself four feet away on the hillside. The males were still living in the first nest with two females.

When the weather was cold and cloudy *punctatus* remained closely housed within the nest, or, at most, came out to do an hour's digging and then again disappeared. The warmer the weather and the more brilliant the sunshine the more rapidly they worked. When leaving the nest they would often creep out and walk around it three or four times before rising on their wings, and even then would sometimes alight once or twice before flying away. The males, especially, liked to stand about for a time, watching their more industrious sisters at their work. The females usually began the day with digging, and frequently closed it, toward night, in the same way.

In order to see the method of stinging we at one time provided ourselves with a number of bees, and putting one of them into a bottle, introduced a wasp. She seized it almost immediately, with great vigor, and stung it once, under the neck, and then dragged it up and down the bottle by one antenna which was held in the mandibles. After a moment she shifted it and held it with the second legs in the usual way. We now put in another bee which she also caught, stung in the same place, and then dropped without relaxing her hold of the first one. As she seemed to have nothing further to show us we released her, and after circling a little she took into her nest the bee that she was carrying.

In our next experiment we used a larger glass, thinking that with more space we might see malaxation. The instant that the wasp was introduced she grasped the bee with one rapid powerful motion, and stung it just under the neck as before. Then holding it with the second legs she began to fly about in the glass. We now introduced another bee, whereupon the first one was relinquished, and the second was treated in exactly the same way. The stinging was the beginning and the end of the operation, and when we released her she at once took the bee into the nest. There was no malaxation outside and certainly there was none within, as was shown by the rapidity with which the wasps issued from the nest after storing the bees. We were only successful in getting the wasps to sting when we tried the experiment with those that were hunting. When those that had not yet begun to store their nests were put into the glass they paid no attention to the bees.

The victim of the sting of *punctatus* is killed at once. Life is extinct from the instant that the stroke is given. This is true also of the honey-bee that is the victim of Fabre's *Philanthus apivorus*, but the explanation that he gives of the action of his wasp in thus dealing sudden death instead of paralysing its foe—that the honey must be sucked out of the bee before it can be safely used as food for the larva—does not hold good in our case, since the honey that *Halictus* carries to mix with the pollen upon which her offspring are fed, is not removed.

As time went on we found on the island two other *Philanthus* colonies, although that is rather too large a word to apply to them, since one consisted of four nests and the other of only two. When we came to excavate the nests of this species we were greatly astonished at the length of the gallery, and not until then did we properly appreciate the industry of these little wasps. It is no small undertaking to follow one of their tunnels for twenty-two inches, even when, as in this case, the greater part of it is parallel to the surface of the ground. (Pl. XI., fig. 2.) We did not find distinct pockets, as the soil was very crumbly and fell in as we worked, but we came upon clumps of bees an inch or so to one side of the gallery and about three inches apart, with larvæ in different stages of development. In one nest we found twenty-six bees in two clumps, some of them half-eaten and some of them fresh, but all quite dead. We have no doubt that *punctatus* completely provisions one pocket and closes the opening from it into the gallery, before she starts another, making a series of six or eight independent cells. The provision for one larva is probably twelve or fourteen bees, the capture of which, in good weather, would be a fair day's work.

That the males do not always stay on in their ancestral home is shown by an observation that we made on the only occasion that we ever saw this species in our garden. Nothing was stirring at half past three o'clock in the afternoon and we had given up work and started for home, when, in going up an inclined part of the field, we noticed something in motion within a ragged-edged hole which ran obliquely into the ground. It seemed strange that a wasp should be beginning its nest at so late an hour, but a wasp it was, as we could plainly see when we took an attitude sufficiently humble. It was loosening the earth with its mandibles and then pushing it backward with its hind legs and abdomen. We had scarcely settled down to watching it when a second one of the same species appeared, and with a good deal of fuss and flutter began to dig its hole close by. The spot chosen by this second one proved unsatisfactory and another beginning was made in a new place. Again something was wrong, nor was a third choice any better. At last, however, the work was started in earnest and might have been carried to a conclusion if we had not caught the little creature to satisfy a suspicion that had been growing in our minds. Yes, we were right. The worker was not a female making a nest for the rearing of her young, but a male *punctatus*, preparing a shelter for the night.

In the meantime the first wasp had pushed back such a quantity of earth that the hole was entirely closed, but every few minutes he came backing out to clear the way. At the end of half an hour all became quiet. The door remained closed, and doubtless the wasp was fast asleep. Putting a blade of grass and then an inverted tumbler over the nest we left him for the night.

On removing the glass at half past seven the next morning we found the nest open but the wasp not visible. At half past eight the head appeared just inside the hole, the long antennæ twitching now to this side, now to that, as if an inspection were being made. Soon the head came out. The wasp stood for some minutes making a survey, looking to right and left with lively jerks of the body. Then, apparently concluding that the day was not far enough advanced, he came out, whirled around, and ran head-first into the nest. He probably took another nap, for all was quiet until just before ten o'clock when the antennæ appeared again. The survey was taken as before, first from within and then with the head in view. At last he flew out and making three circles, each one wider than the last, about the place, flew away. He staid out all day and had not returned at half past three in the afternoon, but on going down at half past four we found that he had gone in and closed the door from below.

It is clear, then, that these males do not construct a new lodging every night but return to the same spot to sleep. Other wasps creep into crevices. We have often found them, in the morning, in the holes of the posts of our cottage porch; but we are glad to be able to put it down to the credit of one male that he had sufficient foresight and industry to provide a sleeping place, and sufficient intelligence to return to the spot when the declining sun warns him that evening is approaching.

CHAPTER XII.

THE SPIDER RAVISHERS.

Pompilus and *Agenia.*

Plates I., figs. 1, 2 and 7; V.; X., figs. 6, 7 and 8; XII., fig. 5; XIII., fig. 1.

While *Ammophila* feeds her larva upon caterpillars, and *Bembex*, after the manner of the social wasps, feeds her young from day to day on dead flies, the *Pompilidae*, so far as their habits are known, all prey upon spiders. The family is a large one in the United States, one hundred and twenty-seven species having been described. The members of the group differ in size, color, and habits, and the individuals of the same species show the very considerable amount of variation which seems common to all those groups of animals which have been carefully studied. Happily the old notion that habits and instincts, unlike structural peculiarities, are always uniform, is no longer insisted upon, and there is ample evidence for the opinion that functional variations are as common as morphological. We have studied five species of this family and have found their respective rôles of great interest.

According to Fabre the French members of this genus, although they do not make their own nests, still exercise some foresight in the matter by selecting a suitable crevice before catching their prey. Among the species that we have studied *quinquenotatus*, *biguttatus*, *fuscipennis*, *marginatus*, and *interruptus* first catch the spider and then make the nest; while *calipterus* and *scelestus* prepare the nest before capturing their prey.

Pompilus quinquenotatus Say.

Plate II., fig. 7; Pl. X., figs. 6, 7, 8.

This wasp is usually rather less than half an inch in length and is black, the abdomen having a variable number of white bands and a white tip.

It was on the last day of July that, as we were walking through the bean field, we saw a cloud of fine dust which came spurting up out of the ground like water in a fountain. By watching intently we saw that the cause of the commotion was the rapid action of the legs of some little creature that was almost hidden in the earth, and this proved to be our first example of *P. quinquenotatus*.

She was working away as furiously as though she had studied the poets and knew her *carpe diem* by heart. Faster and faster went the slender little legs, higher and higher rose the jet of dust above her. Then suddenly there was a pause. The burrower had met with some obstacle. A moment more and she came backing out of the hole, her feet slipping on its crumbling edges. In her mandibles she carried a pebble which was taken to a distance of four or five inches. Then, moving quickly, she swept away the dust that had accumulated near the mouth of the nest, re-entered the hole, and resumed the labor of excavation.

We thought that the rate at which she worked was too violent to be kept up very long, and sure enough, before ten minutes had passed the nest was deep enough for her purposes, and we afterward learned to our chagrin, that it was too deep for ours. The wasp came out, circled round the spot three or four times, and then flew off like a hurricane. Never have we seen a creature so fiery, tempestuous, cyclonic. Before we knew her proper title we took to calling her the Tornado Wasp, and by that name we shall always think of her.

Her flight was too rapid to follow but in a minute we saw her returning. She was carrying a spider, a good sized specimen of *Epeira strix*, which she had evidently deposited somewhere in

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TORNADO WASP (POMPILUS QUINQUENOTATUS) DIGGING NEST.

the neighborhood before beginning to dig. Alighting near by she left the spider lying on the ground while she ran to her nest and kicked out a little more earth. Then seizing it by one leg she dragged it, going backward herself, into the nest. She remained hidden for about two minutes, then reappeared, and, seeming to be in as great a hurry as ever, filled the hole with dirt. To disguise the spot and render it indistinguishable from the rest of the field was her next care. Hither and thither she rushed, now bringing little pellets of earth and placing them above the nest, now sweeping away the loose dust which might suggest the presence of the *cache*, and now tugging frantically at a stone which she wanted to place over the hidden treasure, but which was too deeply embedded in the earth to yield to her efforts. She did her work faithfully although with such eager haste that all was completed at the end of twenty minutes from the time we saw her first. So well was the place hidden that it was only by careful orientation that we could be certain of its exact locality.

Her task accomplished, away flew our little tornado as though she were pursued by the avenging spirits of all the spiders that she had murdered, although more probably she was off in quest of another of those meek and helpless victims.

"Now," we said, "we will trace out the nest and make a drawing of it. We will take the spider home and note its condition from day to day, watching, at the same time the development of the larva."

Enjoying this little air-castle we began to excavate. Having had experience with the nests of *Ammophila* and *Diodontus*, and knowing that the task might not be so easy as it looked, we went to work with all possible care. It seemed however that some magician's trick—some deception of the senses—had been played upon us. We saw the spider interred, we at once dug up the place and found nothing. Slowly and carefully we enlarged our circle. We went down deeper until the opening was large enough to hold a thousand spiders,—still nothing. Then we tried another plan. Gathering all the earth that we had taken out we sifted it through our hands—in vain. At last we acknowledged ourselves beaten, and trudged home empty-handed.

Our pride was destined to be still further humbled. Three times within that same week we saw the Tornado Wasp bury her spider, and three times we failed, just as incredibly, to find it. On the last of these occasions we did not let her fill the nest, attempting to follow the tunnel and get out the spider as soon as the egg was laid, but the lose unstable character of the soil defeated us.

Our fifth example, however, dug her nest, not among the beans but lower down in the potato field, where the ground was firmer, and here we made our first successful excavation,—successful only up to a certain point, since in getting out the spider we dislodged the egg, and although it was at once replaced it never developed. The spider was placed three inches below the surface but we could not trace the tunnel. At our next opportunity, wishing to make good this failure, we placed a blade of grass in the opening just after the wasp began to fill it. On being disturbed she assumed the most comically threatening aspect, whirling around, lifting her wings, and then circling about us. As soon as we moved back she dashed at the grass-blade and pulled it out with great energy. A few minutes later we made a similar attempt and again she frustrated our plan, but when we inserted the grass-blade for the third time, the nest being now half filled, she let it remain. Some hours later, with this to guide us, we succeeded in tracing the nest, but much to our disappointment found it transformed into a banqueting hall. Scores of tiny red ants had discovered this rich store of food. They had eaten the egg and were rapidly finishing the spider.

Twice afterward, in opening these nests, we found the same ants in possession before us. It is probable that they are a formidable enemy to this and other species of *Pompilus*, but they seem to find the spider by burrowing beneath the surface, so that the elaborate hiding of the nest from above cannot be meant as a protection against them.

Pompilus quinquenotatus has a decided preference as to the spider that she takes. While *Pelopaeus* and *Trypoxylon* are entirly indifferent both as to size and species, and the more nearly related *Pompilus marginatus* takes *Thomisus, Drassus, Attus, Agalena* or *Lycosa,* this more fastidious wasp will not be tempted from the spider of her choice. In more than fifty examples the victim in the play was invariably *Epeira strix.* If she must confine herself to one species she has made a fortunate selection, since there is no other spider so common in our neighborhood, not only in the woods, but around the barns, and outbuildings. Most frequently it was the female that was taken, but this does not imply a preference for that sex, since the females are more abundant than the males. We have never seen the spider captured and do not know where the sting is given, but certainly this wasp wounds her prey very severely. The spiders that we took from her were either dead or so completely paralyzed that it required great care and the use of a magnifying glass to determine that they were alive.

The next stage of her proceedings we are familiar with, as we have frequently seen the wasp carry the spider. Unlike her sister, *marginatus,* she usually flies with it, and seems not at all encumbered by its weight. In many cases, however, she drags it, holding it by one leg and running rapidly backward.

A suitable place for the nest being found the spider is very prettily taken care of while the work is in progress. A plant, usually a bean or a sorrel, is chosen, and the *strix* is hung in the crotch of a branching stem, where it will be safe from the depredations of ants. (Plate X., fig. 8.) This precaution is not always taken. We have many times seen the spider left on the ground, although there were plenty of plants at hand.

The next point is to decide upon the precise spot for the nest, and here our wasp shows herself very uncertain and hard to please. Never have we seen one settle down and complete her work in the spot first chosen. She dashes at a place and scratches and digs away with furious energy for a few minutes, and then starting up, she darts wildly hither and thither until a new place, near by, is fixed upon and another beginning made. In one instance eight different nests were started and some of them half made, the little worker seeming to be beside herself with excitement. After the decision is finally made the tunnelling is a rapid process. In one case it took the wasp a whole hour to complete the work, but out of the thirty nests that we saw made, nineteen were finished in from twenty to twenty-five minutes. Like Fabre's *Sphex* the wasp interrupts herself three or four times to visit her spider and make sure that it is safe. When all is done she brings the *strix* to within a foot or two of the opening, runs to the nest to take a final look, and then, going backward herself, pulls it inside. In two instances we saw the fidgety little creature go through a most comical performance, which again recalls the *Sphex* of Fabre. Leaving her treasure on the ground she ran to the nest and kicked out a little more earth; hastening back she dragged it an inch nearer; then away she went to the nest again for more digging, and so on, dropping her spider half a dozen times before she at last brought it home. In two other cases in which there was no such anxiety about the size of the nest, there was, in reality, more reason for it. Indeed in one instance the opening had to be enlarged before the spider could be taken in.

The laying of the egg takes only two or three minutes and then the hole is filled up. In this part of her work *quinquenotatus* shows a great deal of variation, sometimes coming out of the hole and sweeping in the dirt with her first legs and sometimes standing in the tunnel while she draws the earth in with her mandibles and then jams it down with the end of her abdomen. The former plan was in vogue in the garden while the latter was more common with the wasps on the island. After the hole is filled the spot is covered with pellets of earth and pebbles brought from a little distance, very much as is done by *Ammophila*.

When we found that *quinquenotatus* was a very common species, and that nearly every day brought us a fresh example, we thought that we had the question of its stinging habits in our own hands. What could be easier than to carry a *strix* about with us and to exchange it, when opportunity offered, for the paralyzed spider of the wasp? The good results obtained by Fabre and Marchal from this manœuvre made us confident of success. We did not doubt that when the wasp came for her spider and found it livelier than it ought to be, she would repeat the stinging operation before our eyes.

Accordingly, the next time that we saw *quinquenotatus* digging we made a diligent search for her spider and soon found it on a bean plant five feet away. Just as we discovered it, however, the wasp swooped down and carried it to some purslane, close to the hole, where she hung it up again, while she went to make her final preparations at the nest. We seized our chance and quickly substituted a fresh *strix* for the one that had been paralyzed. Acording to the habit of its species when danger threatens, it kept perfectly quiet, and when the wasp returned it was hanging there as motionless as a piece of dead matter. How she knew the difference was a mystery, but she would not touch it. She seemed to think that she had made a mistake in the locality and that her own spider must be hanging somewhere close by, for she hunted all over that plant and then over several others near to it, returning continually to look again in the right spot. After five minutes she gave it up, circled about three or four times, and flew off in the direction of the woods to catch another spider. Why did she go to the woods? When she realized that the *strix* she had stung was gone and that she must have another, why did she not take the one that hung there in plain view? Our failure could not have been due to the fact that we had handled the spider, since when, on other occasions, we took one that had been paralyzed, examined it and then returned it to the wasp, she accepted it without hesitation.

Disappointed though we were at the irrational conduct of our wasp, we resolved to await her return and to try again. In forty minutes she came back with another spider, but instead of taking it into the nest she hung it upon a bean plant near by (Plate X., fig. 7), and then proceeded to dig a new hole a few inches distant from the first. Foolish little wasp, what a waste of labor! Truly, if you are endowed with energy beyond your fellows you are but meagerly furnished with reason.

Again we availed ourselves of our opportunity and substituted our spider for hers. This time it had grown weary of playing its motionless rôle and frequent readjustments were necessary in order to keep it in position. At the moment that the wasp came back to take it the spider scrambled from its place and began to make its way along the stem. The wasp evidently saw it for she hovered over it a moment. She then flew to the next plant where she hunted about over the leaves and branches in search of her lost treasure. After a time she returned. The spider had now come to a standstill and the wasp examined it attentively, although without touching it. She then flew away without circling at all, which might, perhaps, be taken as an indication that she had no intention of returning to a place where she had fared so badly.

Just at this moment we chanced to see another paralyzed *strix* hanging near by. Again the exchange of our specimen was accomplished, but when the second wasp came to find her spider she gave us no more satisfaction than the first. The substitute hung there quietly enough. We ourselves could not have distinguished it from the original, but *quinquenotatus* took a good look at it, decided that something was wrong, hunted about a little for her own spider and then flew away.

We had then, as the fruit of our morning's work, gained nothing in regard to a knowledge of the stinging habits of our wasp, but at least we had secured three freshly paralyzed spiders to add to our laboratory collection. As to the *strix* that had so kindly assisted us in our experiments, we placed it on a bush in the pleasantest and most secluded corner of the garden and left it there, wishing it a long and happy life.

Later on in the season we tried the same experiment. Taking her spider from *quinquenotatus* as she was dragging it to her nest, we offered her a very lively *strix* in its place. She would not notice it at all, and soon flew away. Half an hour later she reappeared and seemed to be looking for a place to dig. As she ran about on the ground we offered her another spider, dropping it on the ground in front of her. This one behaved admirably, drawing up its legs and keeping perfectly still, not moving even when she felt of it and turned it over, but it was left without any display of interest or emotion.

One day we saw a *quinquenotatus* finish her nest and go after her spider. She was absent for some time and when an ant passed by dragging a paralyzed *strix* that had evidently been stolen from some wasp we thought that the one we were watching had been robbed, and rescuing the spider, placed it in the doorway of the nest. We had judged wrongly, for a moment later our wasp came back bringing her own spider, and dropping it near by, ran to look at her nest. She was disturbed at finding the way blocked, and dug out a little earth to one side of the *strix*. Then she flew to some holes in the ground not far away and dug a little, first in one and then in the other. After this she took a look at her spider and then went back and dug a little more at her own nest. Finally she seized the impeding *strix* by a leg and dragged it out of the way and paid no further attention to it, storing her own spider and then flying away, although the one she had rejected might have saved a hunting expedition.

At another time we saw two wasps digging their nests two or three feet apart. One of them finished before the other and being unable to find her own spider (probably it had been carried away by the ants), she seized that of her neighbor and bore it away. The rightful owner saw, from a distance, what was happening and ran to the rescue. A violent scrimmage ensued, the two wasps clinching and rolling over and over together. The robber escaped and made off but was followed and caught again. She fought so well for her ill-gotten treasure, however, that she finally conquered the other and hurried off with her prize. She showed by her manner that she felt the need of haste, for instead of laying the spider down and looking at the nest, she dragged it directly in, as though she feared another attack. This was the first time that we had ever seen these wasps fighting over their prey and we were surprised to find that they would take spiders which they had not captured themselves, since when we had tried to exchange with them they had refused to carry out our scheme. This was clearly an intelligent (immoral?) act and could not be an affair of instinct.

Once again we witnessed a similar struggle. One of these wasps was laboriously dragging her *strix* up a steep hillside when a much bigger one of the same species descended upon her and seized the spider. She was loth to give it up and they both pulled until it seemed as though the poor creature would be dismembered. The highway robber came off victorious and after flying to a distance hung the spider up while she finished a partly made nest, and then stored it away. It may be said in extenuation of her conduct that since she had a nest started she had probably been robbed herself, and therefore felt that she was entitled to a spider.

The nests of *quinquenotatus* vary considerably according to the kind of soil in which they are made, the firm clay of the garden giving a result quite different from the fine dry earth of the island, in which they are usually much larger and scarcely to be distinguished from the holes of *Bembex spinolae*. In both localities, however, the nest consisted of a short tunnel, running obliquely downward, with a slight enlargement at the end, but with no change in the direction of the gallery. (Plate X., fig. 6.)

In the loose sand of a steep hillside we found that the wasps had a different method. Their tunnels in this place, filled up nearly as fast as they could dig them, and when they had reached a depth of half an inch they turned off at a right angle, and excavated in an entirely new direction. They probably derived some advantage from this variation for we saw four in succession follow the same plan, which certainly appeared to be an intelligent adaptation of means to ends.

We once saw a wasp of this species digging her nest on the *Bembex* field. When finished it was a large hole which could not have been distinguished from those of *spinolae*, which were open all about, for the weather was bright and sunny. She went away and soon reappeared with her spider, which was dropped three feet away while she ran to make sure that all was right, and now followed something that we had never seen before—she could not find her nest. She flew, she ran, she scurried here and there, but she had utterly lost track of it. She approached it several times, but there are no landmarks on the *Bembex* field. We have often wondered how they find their own places. After five minutes our wasp flew back to look at her spider, and then returned to her search. She now began to run into the *Bembex* holes, but soon came out again even when not chased out by the proprietor. Suddenly it seemed to strike her that this was going to be a prolonged affair, and that her treasure was exposed to danger, and hurrying back she dragged it into the grass at the edge of the field, where it was hidden. Again she resumed the hunt, flying wildly, now, all over the field, running into wrong holes and even kicking out earth as though she thought of appropriating them, but soon passing on. Once more she became anxious about the spider, and carrying it up on to a plant suspended it there. Now she seemed determined to take possession of every hole that she went into, digging quite persistently in each, but then giving it up. One in particular that was close by the spider, seemed to attract her and she worked at it so long that we thought she had adopted it, for it seemed to be unoccupied. At last, however, she made up her mind that all further search was hopeless and that she had better begin *de novo*, and forty minutes from the time that we saw her first she started a new nest close to the spider, as though she would run no more risks. This nest was successfully completed and the spider was stored away without further misadventure.

The egg of *quinquenotatus* can be but lightly attached to the spider, for only once, out of many attempts, did we succeed in getting it out without displacing it. In this case three days elapsed before it hatched. The larva ate for a day or two but then pined away and died. Another nest was opened on the tenth day after the egg was laid, and in this the spider had been entirely eaten and the larva was just spinning its cocoon, so that the larval stage probably occupies about a week.

To show as accurately as possible the effect of the sting of *quinquenotatus* upon her spider, we quote from our notes:

No. 32. August 6. We brought in three freshly paralyzed specimens of *E. strix* taken from *quinquenotatus* before they were buried. For purposes of comparison we killed another *strix* by compressing the head and thorax. We have numbered the spiders 1, 2, 3, and 4, No. 4 being the one that we killed, and have placed them in separate saucers. No. 1 is alive. Nos. 2 and 3 give no response to stimulation and we believe them to be dead.

August 7. Nos. 1, 2, and 3 are all alive.

August 8. Nos. 1, 2, and 3 are alive and in good condition.

August 9. The three spiders are alive but look a little shrunken. So far as we can see there is no difference between the abdomens of those stung by the wasps and the one we killed; but the cephalothorax of this last was a little broken and hence has become shrunken.

August 11. Nos. 1 and 2 are still alive. No. 3 is dead and is evidently decomposing, since the abdomen is soft and stays indented when touched. This is also true of No. 4.

August 17. Nos. 1 and 2 are still alive.

August 19. The spiders are not only alive but are becoming more active. When touched, No. 1 raises the first pair of legs to the posture of attack or defence. It can almost turn itself over when placed on its back. To move the saucer is a sufficient stimulation for this one, but No. 2 does not respond unless touched. While No. 1 moves the first pair of legs most readily, No. 2 moves the second pair more than the first.

August 21. The two spiders seem to be regaining their health. No. 1 moves the body and all the legs without stimulation, and almost turns itself over. No. 2, when touched, moves first, second, and fourth pairs of legs.

August 22. Both spiders have lost power since yesterday. No. 1 moves only when touched. No. 2 scarcely responds at all, and has its legs drawn up.

August 24. Both alive. No. 1 is better again—indeed very lively. One touch makes it move the four anterior legs up and down twelve or fifteen times, without stopping. No. 2 looks like a dead spider, but when it is touched there is a feeble quivering of the legs.

August 29. No. 2 is dead. No. 1 is as lively as ever. When touched it struggles for more than a minute. It can almost turn over.

September 2. The spider gains strength, and now moves its legs without being stimulated.

September 6. The spider succeeds in turning over when placed on its back.

September 15. The spider is still in good condition.

No further record.

No. 43. August 8. Took *strix* from a nest of *quinquenotatus*. It is barely alive.

August 10. When the spider is stimulated the tip of the left anterior leg quivers a very little.

August 12. The spider is oead.

August 16. The body is beginning to soften and stays indented when touched.

August 19. Spider quite dry and hard.

No. 59. August 26. Took spider from wasp as she was dragging it to her hole. It was plainly dead, the cephalothorax having been badly squeezed.

No. 52. August 16. Opened nest of *quinquenotatus* and took out the spider. We cannot determine whether it is dead. Under the glass there seems to be a slight quivering of the legs.

August 17. The legs quiver.

August 26. There is still a slight quivering in response to stimulation.

August 28. The spider is dead.

A summary of our notes shows a very wide variation in the condition of the spiders. Out of eleven that were stung three were killed at once, two lived four days, one five, one eleven, one twenty-three, one twenty-five, one thirty-one, and one at least forty days and probably longer.

Fabre bases his very strongest arguments for the exactness of the method by which wasps sting their victims, upon the actions of one of the *Pompilidae,** but certainly *P. quinquenotatus* can make no claim to nice workmanship, for if she occasionally stings in such a way that life is preserved for some time it seems to be a matter of chance rather than of skill. In one respect, however, looking at the matter from Fabre's point of view, she is very successful. Her victim is left so motionless as to be a perfectly safe repository for the egg. Even in the case of the spider that lived forty days the power of motion did not return, to any extent, during the first ten or twelve days, and before this time in the natural course of events, there would have been nothing left to move.

We look back with much pleasure upon our acquaintance with this gay, excitable little wasp. She was so full of breezy energy that it was always delightful to meet her, and she showed so wide a variation in individual character that we seldom watched her without learning something new.

Pompilus biguttatus Fabr.

This wasp varies from one-quarter of an inch in length to three times that size, and is marked with one or two interrupted white bands on the abdomen. It is extremely common upon the island in our lake, the males especially appearing in swarms about the first of August, when they may be seen attempting to mate not only with females of their own kind but also with those of *quinquenotatus,* which is sometimes described as a variety of the same species. Their habits are certainly much alike although *quinquenotatus* is distinctly the more excitable of the two, and preys solely upon *Epeira strix,* while *biguttatus* is occasionally seen with *Epeira labyrinthea,* a much less common spider. One peculiarity of *biguttatus* is her passion for washing herself. After she has caught her spider and bestowed it safely, she flies to an adjoining plant and falls to brushing off her wings and legs, and washing her face again and again, as though

*Souvenirs Entomologiques, Quatrième Série, p. 267.

she would never finish. When at last she is satisfied with herself she searches for a nesting place, starting and abandoning a number of holes before she settles down. After a little work she becomes anxious about her spider and goes back to look at it, but instead of going to the spot she usually flies to the place of her washing operations, and hunts about for five or ten minutes before she finds the right plant. Under like circumstances *quinquenotatus* would be wild with excitement and anxiety, but it is not so with *biguttatus*—she is even calm enough to stop and sip nectar from the flowers. After she has rediscovered her treasure she does not leave it until she has circled about the place to impress the surroundings upon her memory. As a result, when she next visits the spider she finds it without difficulty. She often comes back to look at it four or five times before the nest is finished, the process taking anywhere from fifteen minutes to an hour. The tunnel runs in obliquely for an inch or an inch and a half and ends in a slight enlargement. The filling is sometimes done from within, the wasp standing in the hole while she draws the earth in with her mandibles and jams it down with her abdomen; and sometimes from without, the earth being kicked in and the surface then smoothed over. When we once interrupted the process in order to dig out the spider, the courageous little wasp alighted upon the knife with which we were working, in her effort to protect her nest.

We have never seen *biguttatus* make a long flight while carrying her spider, as is commonly done by *quinquenotatus*, her most common habit being to run backward, dragging it by a leg. In three instances that came under our notice the wasp seemed resolved not to take one step on the ground, and made her way along by climbing backward up on to some elevated place and then flying forward in the direction that she wished to pursue. These flights were short, covering only from two to fourteen inches. As soon as she alighted she began to climb again, perhaps only to the top of a stone or a lump of earth, if nothing higher were at hand, but oftener scrambling up the stem of some plant or blade of grass. This mode of progress was not well adapted to getting across the onion field, and a wasp looked very absurd trying to go backward up the slippery stalks for five minutes at a time without making the slightest advance. In other cases she kept patiently to her feet until she came to a plant that was not only easy to climb, but high enough to give her a real advantage.

In taking the spider to its final resting place, *biguttatus* drops it once or twice by the wayside while she inspects the nest and perhaps adds a few finishing touches. At the last she backs in, dragging it after her.

An egg that we took from a nest just after it was laid, was fastened to the spider on the right side of the abdomen. It hatched at the end of forty hours, and had a healthy larval life of eight days, spinning its cocoon on July twentieth. On the fifteenth of August we found that it had flown.

Of three spiders stung by *biguttatus*, one was dead when taken from the wasp. The second, taken on July sixth, seemed to be quite dead until the eighth, when it gave a slight response to stimulation. From this time it improved, at first slowly and then rapidly, until on July fifteenth it drank water and moved all its legs without stimulation. On the eighteenth it began to walk, and by the sixth of September it had entirely regained its health and was released. The third spider, which was taken with the egg upon it, lived until it was destroyed by the larva.

Pompilus fuscipennis St. Fargeau.

Pl. I., fig. 2; Pl. XII., fig. 5.

This species, which is a little smaller than *P. quinquenotaus*, is black, with the red girdle that appears so frequently among the solitary wasps. The first time that we ever saw this wasp she was running rapidly backward over the bare ground, the brilliant red of her body flashing in the sunlight as she dragged along a little spider of the genus *Thomisus*. Presently she carried it up on to a leaf and began to bite at it, but being disturbed by an ant, hurried on with a much agitated manner.

Soon she stopped again and resumed her attack, biting savagely at the legs near their junction with the body and now, looking closely, we saw that two of them had been completely cut off. While occupied in this way the wasp was evidently intensely excited. She lay on one side with the abdomen bent under, turning the spider over and over as she worked. After a time she carried it onward to the potato-field, where the plants afforded some shelter, and placing it upon a leaf, well above the ground, began to dig near by. She worked almost entirely with her mandibles, lying sometimes on her side and sometimes on her back as she cut away the earth, which was pushed out with the end of her abdomen. When she had worked for ten minutes and had gone in the length of her body, she picked up the spider and made rapidly off with it, several times rising on her wings and flying backward for a few inches. A little further along she again deposited it on a leaf and began to dig in a fresh place. At the end of twenty minutes the nest was ready but in bringing the spider she missed her direction and carried it to one side. Dropping it on the ground she began to hunt about for her hole, but was distracted with excitement and ran so far afield that we feared she would never find it. At last, however, she came to the place, ran in for a moment, brought the spider nearer, dropped it and ran to the nest once more, caught it up again, and tried to back in with it. She was holding it by the under side of the body, the venter being toward the hole, and the legs spread out and stopped its entrance. A moment's tugging convinced her that this would not do, and she then turned the spider over, holding it by the back, whereupon the legs at once folded themselves across the underside of the thorax and the spider was drawn out of sight.

After the egg was laid the wasp came up to the edge of the hole and drawing in some earth with her mandibles began to dance up and down upon it, jamming it into place with her abdomen. Afterwards she came up higher and drew the dirt in with her first legs, not getting out of the hole until it was entirely filled up. Then began a remarkable performance.

Bracing herself firmly on her legs she used the end of her abdomen as an instrument and with it she now pounded the earth, now *rubbed* it, like a pestle in a mortar, and now used it as a brush to sweep away loose dust. Sometimes she would throw a little earth back under her body with her mandibles and rub it down with her abdomen. This part of the work being finished she spent a few minutes in sweeping the ground with her first legs, and then brought a quantity of small objects and placed them over the nest,—a little stick, the petal of a faded flower, a scrap of dead leaf, and so on, until ten or twelve things had been collected. This artistic finishing up of her duties recalled *Ammophila*, but among our subsequent examples of *fuscipennis* we never saw one do her work with such nicety. They were usually contented to fill in the nest more or less compactly, sometimes doing much of the work from the outside, to brush off the surface without any rubbing or pounding, and then to bring two or three little pebbles or lumps of earth to place over the spot.

So far as we were concerned this was one of the most fearless of the wasps, not even interrupting her work when we once placed a glass over her as she was filling her nest, but the approach of an ant would throw her into a perfect panic and seizing her spider she would make off with every sign of terror. It is difficult to understand why wasps of this species, as well as of *biguttatus*, never offer combat to the ants that rob them right and left, but invariably seek safety in retreat.

P. fuscipennis rarely circles about when leaving a place, and this is unfortunate since her sense of locality semes to be particularly weak. She nearly always has to hunt for the plant upon which she has placed her spider, and always loses track of her nest when she tries to bring the spider to it. (Pl. XII., fig. 5.) We once caught her as she was carrying her spider, and then released her on the same spot, but she became so much confused that without our assistance she would never have found it again.

P. fuscipennis fastens her egg to the abdomen of the spider. An egg that was taken from the nest just after it was laid hatched at the end of forty-nine hours, but the larva died on the following day, so that we have no record of this stage of its existence.

Of eight spiders taken from this wasp, two were dead and the others were badly paralyzed, responding only to careful stimulation. One of these improved after a time but the gain was not permanent as it died on the ninth day.

One nest was made in a large lump of earth and ran in horizontally; but all the others that we saw, went down almost vertically.

Of ten spiders that we saw in the possession of *fuscipennis*, nine belonged to a single species of the genus *Thomisus*. The tenth was a very small, immature, male *Lycosid*, and had been captured by a tiny wasp of rather less than half the ordinary size.

The most interesting thing about *fuscipennis* is her habit of biting the legs of her victims. The instinct is very irregularly developed since four out of ten spiders had not lost any legs, while the others had been deprived of one or two. No one who has watched the wasp can doubt that the habit is related to the fact that she makes a very small nest in comparison to the size of her prey. The spider never went in easily, always requiring to be shifted and turned and tugged at. There was an especial tendency to bite at the legs at this point of time, when the wasp, standing within the tunnel, was trying to drag the spider down. In one instance she managed to get it past the entrance, but it stuck in the gallery, and after working at it in that position for a time she brought it out, subjected the legs to a severe squeezing, and then tried again. It was still a very bad fit, but by turning it about and pulling at it she succeeded in getting it in. It may be that the object of biting the legs is not to remove them but to render them limber so that they will bend easily. Whatever the process may be it is carried on at intervals, from the time the spider is captured. As she carries it, the wasp pauses again and again, now on bare ground, and now in a sheltered place or on some plant to renew her efforts at getting the legs into a satisfactory state. The details of the condition in which we found them may be interesting. Four spiders retained their full complement of legs but in one of these they had all been badly squeezed, the marks of the mandibles being plainly visible on the trochanters; one had lost the three distal joints of the third leg on one side; one had lost a leg of the third pair, and two others showed signs of having been bitten; another had lost a leg of the first pair, another one of the second, and still another, one of the fourth, while the most seriously mutilated spider in the series had lost the third and fourth legs on one side. *P. fuscipennis* was to be seen in our garden from the twenty-first of July until we left the country on September tenth.

Pompilus calipterus Say.

It was on the fifth of August that we saw this good sized, dark gray wasp, walking up and down a fence post. A little scrutiny showed that she was carrying pellets of earth from the ground into a hole four feet above, in the wood, and very odd she looked, making this journey again and again on foot instead of using her wings. Upon cutting away the post we found that she was just partitioning off the second apartment in what was doubtless intended to be a long series. Both cells contained female spiders of the species *Xysticus ferox*, that in the inner one being twice as large as the other, and each spider had an egg on the side of the abdomen. The large one was dead, but the other responded feebly to stimulation and lived in this state for four days. One of the eggs, the one that had just been laid when we opened the nest, hatched at the end of sixty hours, but the larva did not live.

Pompilus marginatus Say.

Plate I., fig. 1.

Our acquaintance with this remarkable wasp began in the middle of July. She is a small creature, only half an inch long, and is dressed in black, with a bright orange spot on each side of the anterior part of the abdomen. We were watching the pretty little *Diodonti*, as they filled their holes with aphides, when we saw her going backward, dragging along a medium-sized spider. Soon she came to an onion flower that was lying on the ground. Here she stopped and, after a moment's hesitation, drew her prey in among the blossoms of the cluster so that it was hidden from view. It was not long before she came out and began to fly about near the ground, frequently alighting to poke her head into cracks and to run again and again into little chance holes. Never did an insect behave in a more demented manner, and although there may have been a method in her madness it was difficult to discover it. No hole nor cranny pleased her and back she flew to the onion to see whether her booty was safe. For fifteen minutes she ran and flew now here, now there, hurry and anxiety in every movement, returning frequently to reassure herself about the spider. Several times she entered a hole at the base of a weed, not a made nest, but an accidental crevice, and this spot was at length chosen either as a temporary or a final resting place for her spider, since she dragged it from the onion and deposited it here. We tried to capture the wasp, but having failed in this, we dug out the spider. It was three inches down, the hole being deeper than it looked from the outside. There was no egg upon it. Evidently the work had not been finished for the restless creature returned fifteen times within an hour to the broken nest, either for the purpose of laying her egg or to remove the spider to another resting-place on her homeward way.

The spider, which was an *Agalena naevia*, about two-thirds grown, was dead. We reached this conclusion only after most careful investigation and are satisfied that there was no mistake. We thought, though we may have been mistaken, that both head and abdomen appeared slightly crushed. On the following day, July fourteenth, we re-examined it, and found the legs drawn up to the body and quite stiff. In the next two days it became dryer and somewhat shrunken, and by the eighteenth it was quite dry. As late as the twenty-third, however, it was in sufficiently good condition to have served as food for any of the nurslings to which we have played foster-mother.

This was our first specimen of *marginatus*, and a month passed before we met another. It was while watching some *Bembecidae* that we saw the pretty little orange-spotted worker dragging a small *Thomisid* across their nesting ground. The spider was so small that she held it in her mandibles well above the ground, and we only speak of her as dragging it because she walked backward and acted as though she were obliged to exert herself. Quite often the spiders taken by this species are too large to be carried, and then it is necessary to drag them, and this habit is so ingrained that when it would be much more convenient to go straight ahead they stick to the ancient custom, and seem unable to move in any other way. This little wasp was in a frantic hurry, running backward into the *Bembex* holes and then scrambling out again until she had crossed the field and had turned to one side, having gone, since we first saw her, about fifteen feet. Here she dropped the spider and began to skim over the ground—it could not be called running and yet it was not flying,—until she found a circular hole in the black earth, which looked as if it ran vertically downward. At the time we thought that this was a nest that she had made for herself, but we afterward concluded that it had been excavated by some other creature, that she had found it and determined to make use of it, and that she was bringing her prey to the spot with that end in view. Without entering she rushed back to the spider, but after carrying it a few inches, dropped it and ran to take another look at the nest. By this time, however, she was too much excited to know what she was about, and for five minutes she scurried over the ground without finding it. During this time she picked up the spider four times, carried it a little way and then dropped it. The last time she carried it to the edge of the grass and stored it there, this being her first attempt at concealment. She now found the hole again and brought the spider nearly to it, but by this time she was perfectly beside herself. The spider was seized again and again, only to be dropped the next second, while the wasp rushed back and forth between it and the hole. In time this method of procedure brought it close to the nest, but it was carried around the edge once or twice even then. At last, accidentally as it seemed, it fell in, when the wasp quickly ran in also and pulled it down. For half an hour she remained inside and when she came out we caught her to make sure of her identity. As we set her free immediately we expected her to go to work at covering her nest, but in this we were disappointed for she did not return. We left the place undisturbed from the thirteenth to the fifteenth of August, when we dug up the nest. We found the spider, but if there was any egg upon it we lost it. The spider was alive, as was shown by a quivering of the legs. This quivering grew fainter and fainter until upon the nineteenth it was scarcely perceptible, and on the twenty-first the spider was dead. Our first spider had been stung to death at once, while this one lived seven days and a half after being stored.

A third *marginatus* was discovered at noon of the nineteenth. She had dragged her prey from a distance, frequently leaving it to hunt about after the manner of her kind. We found no egg on the spider—a *Drassus*—which was paralyzed, the anterior pair of legs quivering. On the morning of the twentieth we felt sure that it was dead, still we re-examined it on the twenty-first and twenty-second to be certain that there was no recovery.

On August twenty-sixth we found a fourth specimen of *marginatus*. She was running rapidly backwards dragging a young *Phidippus tripunctatus* which she grasped in any way that was convenient, sometimes one side being up and sometimes the other. When she reached the grass at one side of the field she left the spider on the ground and began to hunt about for a place in which to bestow it. About six feet away she discovered a cavity made by the piling together of two or three lumps of earth. This she examined carefully, first outside and then within, going in by one opening and coming out by another. All seemed satisfactory for she went back for the spider and after the usual amount of fluttering to and fro between it and the hole, brought it into the hiding place. Then she came out and began to hunt far and wide. All about the place she went, over a circle of thirty feet in diameter, her manner bespeaking the utmost anxiety and hurry. Twice she visited her spider to see if all were well. Finally, ten feet up the hillside, she ran into an opening among some stones, staid a few minutes, hurried down the hill and dragged the spider up toward this new resting-place. On the way she dropped it and hunted around in great agitation until she found it again. At last she disappeared with it under the stones. After watching the place for

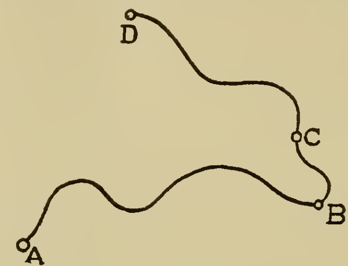

Diagram of road over which a spider was carried by *P. marginatus*. The wasp was first seen at A; B, C and D are the spots at which the spider was hidden while she hunted about for a final resting place.

nearly an hour we went away for a time, confidently expecting that when we returned we should find the spider with an egg upon it, but we had been deceived. On our return the hole was empty, and we concluded that it had been only another resting-place, the third, on her homeward march. The diagram of the road over which the spider was carried may aid in giving an idea of her movements.

Our fifth specimen of *marginatus* had caught a small *Thomisid* which she held in her mandibles entirely off the ground, walking backwards, nevertheless, as if she were dragging it. Unlike any of the others that we had seen, instead of hiding the spider in a hole or under something on the ground, she carried it up into a purslane plant and hung it there. After some hunting she came back and carried it a little way, and then, climbing a bean plant, deposited it upon a leaf which was closely covered by another. Then she ran off again and was gone thirty-five minutes. We remained with the spider, since the plants were so close together that it was impossible to follow her. When she returned she seized her treasure and started off among the plants where, in spite of our efforts to the contrary, we soon lost her. A sixth example added little to our knowledge. She carried a small *tripunctatus* in her mandibles as she ran backward. She was as frantically anxious to accomplish something, and as helplessly incompetent to accomplish anything as the others. Once her victim was hung up on a sorrel plant, and once it was hidden within a hole, where she remained with it for some minutes. When she came out and flew away we dug it out, but there was no egg upon it, so we had taken it too soon. It was severely paralyzed so that for three days there was scarcely any quivering in response to stimulation. On the fourth day it was a little better, but on the seventh, it died.

On September first, while out in the bean patch, we saw a large *Lycosid* running madly, first in one direction and then in another. Hovering eagerly and excitedly just above, was our *marginatus*, dashing down at the spider again and again as it came into view for an instant, and then circling wildly around until it appeared once more. Now she pounced upon the frightened spider but missed her aim, now she really grasped it but was shaken off. At last the end came. The wasp descended upon the doomed spider and there was a violent struggle, both the combatants rolling over and over upon the ground, while all that we could distinguish was the flashing of the red upon the body of the wasp. In an instant it was over, and the wasp rose, leaving the spider limp and motionless, upon its back. In our other examples of *marginatus* the spider taken had been so small that the wasp might easily have held it and thrust her sting into any spot that she pleased, but this *Lycosid* was a different antagonist. In the fierce battle where the two were so nearly matched, there could have been but slight opportunity for skillful surgery. In point of strength the wasp was at a disadvantage, and she must have come off victor by the quick use of her sting. Under these circumstances she must have struck when and where she could, without any selection of a particular spot. That she quite realized the power of her foe was shown by her next action. With the utmost circumspection she settled down upon the spider and made a prolonged and careful examination of the mouth parts. The investigation was satisfactory and without any further stinging she seized the spider by one leg and, this time, really dragged it off. It was a good load for her and it evidently required all of her strength to pull it along. Not far away was a lump of earth and under this the treasure was stowed and then began the usual hunting performance, which soon resulted in the discovery of another cavity which had a very small opening. She crept in, remained a minute, and then came out and brought her spider to this new hiding place. The head went in easily but it took a great deal of tugging to get the rest to follow. At last both spider and wasp were out of sight and everything remained quiet for so long that we began to think that this time we were really to see the final act in the play. But no, when the little wasp came creeping out it was only to start off on another extended tour in which we did not attempt to follow her. She doubtless selected another halting-place, for when she returned it was to try to get the spider out of the hole by pulling at one of its hind legs. The task, however, was not an easy one. She exerted all her strength, so that we expected to see the poor victim dismembered before our eyes, and still it did not come. At last she seemed to realize that there was more than one way to accomplish her end, and turned her attention to cutting away the earth to make the opening larger. After a few moments' work she tried again, and although the passage was still much too small for convenience the spider was at length dragged forth, looking much the worse for wear. As she moved away we alarmed her by lifting some vines that prevented our keeping her in view, and she flew up, leaving the spider on the ground. We seized the opportunity to bend and twist the plants this way and that so that the ground might be left uncovered. The changes that we made probably disconcerted her for she seemed to lose track of her prey. For over half an hour she hunted about, circling above the place and running around and around over the ground. She often came so close to the spider that we could not understand why she did not see it. At last it was recovered and again she started off. We tried to follow her but the vines were so thick that, in spite of our efforts, she soon disappeared into the undiscovered country which we thus far had been unable to penetrate.

Up to this time we had been entirely unable to understand the actions of *marginatus*, and each new example added to our confusion instead of clearing it away. We were inclined to think that she never made a nest for herself but caught her spider and then hurried about for a good place to store it, and that her absurd conduct was the result of an indecision of character which made it extremely difficult for her to choose a place and be contented with it. The last part of this judgment holds true, even now when we know her whole history, but we have at last learned that she does dig her own nest.

We had watched a wasp for some time as she carried her spider from place to place, and finally saw her take it into a crevice among some rough lumps of earth which she had previously examined. We expected one of the long spells of eventless waiting to which she had accustomed us, but on lying down and peering into the hole we found that there was an opening on the further side, for a ray of light feebly penetrated the interior. Moving about in this dim illumination was our wasp, and after a little, we could see, quite distinctly, that she was digging a hole. This then is her method—to find some sheltered hiding-place where she may secretly make her nest, that no creature may know where her treasure is hidden.

We have twice seen a *marginatus* pick up her spider and fly with it backward for a long distance—as much as four or five feet. This recalls the wasp which is said to fly backward before a moving horse and catch the flies that are hovering over it.

P. marginatus is not troubled by any notion as to the family connections of the spider that she takes. Anything will do provided she is strong enough to overcome it and carry it to her nest. The effect of her sting is quite variable since in some cases the victim was killed at once while in others it was but little affected in the beginning and lived for eighteen or twenty days.

Although we have made observations upon thirteen individuals of this species we have never succeeded in getting the spider with the egg upon it.

Pompilus interruptus Say.

Early in the afternoon of the fifth of July, we saw this small, yellow-banded wasp, flying slowly about from leaf to leaf and from plant to plant, dropping to the ground, now and then, to run a little distance on the tips of her toes, in a peculiarly dainty manner as though the ground were not good enough for her to walk upon. She came back, again and again, to a spot under a weed where there was a round shallow hole in the ground, and presently she began to work at this, showing that it was a partly made nest. She carried the earth out in her mandibles depositing it at the edge of the hole, and, after a little, pushed away the accumulation with her feet. As she went deeper the dirt was passed under her body and pushed up to the surface with her legs. There was no kicking and all her motions were slow. Every few minutes she flew up to a twig where she stood very high on her legs, holding her wings up stiffly at a right angle to her body. This manner of lifting the wings was very peculiar, and gave her somewhat the look of the wasps of the genus *Vespa*. When she had gone her own length into the ground she came out and looked at her prey, a large *Epeira strix*, which was hanging in the crotch of a weed close by. After this she flew off toward the west and was gone five minutes, then came back and, taking a look at the spider, passed on toward the east and began to run about on the ground as though she were looking for something. At length she started a fresh nest, about eight feet from the first one. She dug slowly but persistently, working more like *fuscipennis* than any other of the *Pompilidae*, turning around and around in the tunnel so that her back was sometimes up and sometimes down. As a result of this method her hole was perfectly circular. After twenty minutes, when she had gone in rather more than her own length, she flew to her spider, which she found without any trouble, seized it by one leg and ran rapidly backward with it directly toward the nest. When within ten inches she dropped it and hurried on to see if everything were right, returned, picked it up again, and carried it to within two inches, where it was left while she took one more look. Everything was in order, and seizing the spider she backed in with it and disappeared. After two minutes she came out and began to cut away the earth near the entrance and to push it in, and then, after a little, to fill the hole with the dirt that had been taken out, which she pushed down with her legs. The whole operation occupied about forty-five minutes but before she was quite done we caught her and opened the nest. This proved to be only a little more than an inch deep with a slight enlargement at the bottom. The spider was dead and exuded a fluid from its mouth. The egg was placed on the right side of the abdomen, near the middle. Forty-eight hours later it looked as if just ready to hatch but at this point it died.

Pompilus scelestus Cresson.

At eleven o'clock on the morning of a warm day in the middle of August we saw this steel-blue *Pompilus* dragging a big *Lycosid* across a field. The spider was 16 mm. long and wide in proportion while the wasp was but 13 mm. long and very slender, so that the weight of the spider was at least three times that of its captor. The necessity for going backward was evident in this case, but the wasp moved rapidly considering the load that she was dragging. As she worked her way along she made frequent pauses, stopping for two or three minutes at a time in some little hollow, or under leaves or weeds. She spent a good deal of time, during these pauses, in cleaning herself, and a good deal of time also in doing something to the spider which we could not understand. She seemed to be biting the legs, near the body, beginning with an anterior leg on one side and working backward and then repeating the operation on the other side. She went through this squeezing process again and again, and to us it looked as though she might be trying to force back the juices from the legs into the body preparatory to cutting them off, but after a time she would seize her prey and start on again. She had made her way along in this fashion for some ten feet, when a second wasp appeared and alighted on a weed near by. This interloper was a trifle smaller than the other, and from her actions was evidently greatly interested in the paralyzed spider. When the *Pompilus* stopped for a moment the other moved from stem to stem in a stealthy manner just as a cat stalks a bird. The rightful owner of the prey was disturbed and dashed at the invader, driving her away again and again, but she flew only a short distance and was soon back, always creeping nearer and nearer to the spider. We, too, were watching with closest attention, but our desire was to see the speedy home-coming of *Pompilus* and to learn whether she cut off the legs of her victim, and so, interesting as was the contest between the wasp and the wasp-inquiline, we decided to interfere and remove the intruder. This was very easily accomplished since the little insect was so intent upon getting near to the spider that she was oblivious to our presence and allowed us to place a bottle over her as she stood eagerly looking for a chance to advance. Her removal gave great relief to the other wasp as was manifested by an entire change of manner. Before, she had been constantly on the lookout, moving only with the greatest circumspection, but now she relaxed her vigilance. With the *Ceropales* in our vial we, too, felt relieved, and now the path of discovery seemed clear before us, but scarcely had things assumed their old status when a second enemy, a much larger and bolder *Ceropales*, threw both the *Pompilus* and ourselves into consternation. Again we took the side of our wasp and drove the other one off, but only to see it return a few moments later. The *Pompilus* now flew at it in a most gallant fashion and pursued it far afield, but when she came back the enemy was but a few seconds behind her. Here we again interposed and removed the second *Ceropales* from the field of action.

All cause for anxiety being over the wasp now resumed her journey. Before long she came to a shallow depression in the ground which was partly sheltered by an overhanging lump of earth, and under this covering she dropped the spider and again began to squeeze its legs. After a moment she removed it to the other side of the depression, where it was subjected to further manipulation. Next, her toilet was attended to, and then the spider was carried back and placed again under the lump of earth. At least ten times was that limp and helpless creature dragged from one side to the other of the little depression, a distance of about two inches, the time between being filled in by the wasp with cleaning herself and squeezing the legs of her victim. After forty minutes of this tedious delay the moment came when she picked up her burden with renewed determination and started rapidly on her way. We kept very close to her but she did not allow our presence to interrupt her work, and, indeed, paid no attention to it. After she had gone along for a distance of about eight feet there was another pause, of only five minutes this time, and when she resumed her onward march it was in a new direction. Thus far she had gone almost due south but now she turned and went six feet toward the west. Suddenly the spider was dropped. There was no hole in sight but the wasp seemed to feel that some important crisis had arrived. Her whole manner was excited and flurried and we thought that surely we had reached the neighborhood of the nest. How little we understood her! Her nest was still far away, and it may be that she had just begun to realize that the task she had undertaken was too heavy for her accomplishment—that at her present rate of progress her strength would be exhausted before she could reach her goal. At any rate something was wrong. The spider was left unprotected on the ground while she made a number of long excursions without it, sometimes being gone as much as fifteen minutes. On coming back from these trips she would return to the task of squeezing the legs with such energy and persistence that we expected to see them drop off. Then she would run over the ground in all directions, looking under lumps of earth and stones and poking her head into every little hole. Was she trying to find some suitable spot near at hand to take the place of the one which she had prepared or selected at a distance?

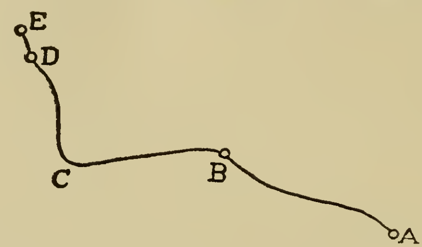

Diagram of road over which spider was carried by *P. scelestus.*

One hour from the time of her arrival at this place, and two hours from the time that we began to watch her, she flew away and was gone for an unusually long time. We can only suppose that when she absented herself in this way she was visiting the spot to which she wished to convey her booty. On her return she seemed to be filled with a new idea, for after climbing to the top of a tall stout weed that grew near by, she came down, seized the spider, and tried to drag it up the stem. Perhaps she meant to lift it to such an elevation that she could fly with it, but it was too heavy for her and fell after she had raised it to a height of three inches. She then flew away again, and on her return we caught her, fearing that she was becoming discouraged and that she might presently depart to be seen no more. Had there been any prospect of her solving the difficulty that beset her our patience might have held out to the end, but this was evidently a case in which there was a failure of instinct, or intelligence, or whatever faculty was concerned.

More than a year passed before we had another opportunity of solving this problem of *scelestus*, and the pleasure with which we hailed her second appearance in our garden may be easily imagined. This time the wasp had made her nest but was not ready to fill it, and when we first saw her she was running about, without any particular aim in view, although at the time we supposed her to be hunting. Before long she went and took a look at the nice round hole which she had made near the fence that separates the garden from the woods. The earth that had been taken out had either been carried to a distance or had been swept away after the digging was completed, for there was no pile to be seen. This was at two o'clock of a cloudy afternoon. It may be that she needed the stimulus of sunshine to make her hunt, or perhaps she realized that what was left of the day would not give her sufficient time to capture her spider and bring it home. At any rate she spent the remainder of the afternoon in making short excursions around her nest. We could find no reason for these from the utilitarian standpoint, unless she was making a careful locality study of the neighborhood, and this seems improbable since they were all in the direction of the garden, while her hunting expeditions, when the time came for them, carried her in the opposite direction, into the woods.

Whatever their object, the trips took her from ten to twenty feet from the nest, each occupying from fifteen minutes to half an hour. At every return to the nest she flattened herself out on the ground and wriggled in the dust, and then dragged herself all around it in the strangest manner. Perhaps these actions were indications of pleasurable emotion. We had seen them once before, in *Priononyx atrata* just before she carried a locust into her nest.

At a little after four o'clock she began to investigate, very carefully, the plants and grasses that immediately surrounded her hole, showing an especial interest in one bunch of clover that grew four inches away. Into this she finally vanished, and peering curiously among the greenery, we discovered her hanging to a leaf, which was sheltered by thick foliage on all sides. Here she remained motionless and probably fast asleep until sundown, when we left her for the night.

When we went to the garden at eight o'clock on the following morning, *scelestus* was still sound asleep in her leafy bower. We thought it best to awaken her, for a large *Agalena naevia* had spread her web just below, and if the wasp should drop upon it nothing could save her. We therefore aroused her gently, whereupon she crept slowly up the stem and taking her stand on the highest point, surveyed the world. Then, after stretching herself sleepily, she made her toilet, cleaning off her wings and legs, and washing her face with her feet like a cat. When these duties were finished she walked slowly about for an hour, visiting her nest every now and then. Suddenly, at half past nine o'clock, her whole manner changed, and seeming very much excited she ran rapidly along, parallel with the fence, for fifteen or twenty feet, and then, rising on her wings, flew far away into the woods. She had evidently gone hunting at last, and we watched eagerly for her return. She was not successful at once, however, for at half past ten she came back without anything, stayed at the nest for a few minutes, and then flew to the woods again with the same excited manner as before. Perhaps she had already caught her spider at some far distant spot, and was getting her bearings preparatory to bringing it home, but it was half past one when she suddenly appeared, five or six inches from the nest, coming backward through the fence, and dragging a large *Lycosid*. This she laid down close by, and began to bite at the legs quite after the manner of the wasp we had seen the year before. Her movements were full of nervous excitement, in marked contrast to those of the previous day. Presently she went to look at her nest and seemed to be struck with a thought that had already occurred to us—that it was decidedly too small to hold the spider. Back she went for another survey of her bulky victim, measured it with her eye, without touching it, drew her conclusions, and at once returned to the nest and began to make it larger. We have several times seen wasps enlarge their holes when a trial had demonstrated that the spider would not go in, but this seemed a remarkably intelligent use of the comparative faculty. Her method of work was peculiar. Standing in the tunnel with her head down and her abdomen curved under, she bit the earth loose with her mandibles and pushed it under her body and beyond the tip of the abdomen. When a little had accumulated she backed out, holding it in this way.

While she was thus employed the spider was attacked by a very tiny red ant, that could not by any possibility have stirred it. When the wasp caught sight of this insignificant marauder she fell into a fit of wild fury and bending her abdomen under, seized the ant again and again in her mandibles, and flung it backward against the tip of her sting. The little creature finally escaped, seeming none the worse for the rough handling to which it had been subjected, while the wasp, still trembling with excitement, grasped her spider and rushed off to a distance of several feet, carrying it up on a weed and depositing it there. The labor of excavation was then resumed and after a half hour's work, was completed to her satisfaction. Coming up head first she flattened herself out on the ground, and sprawling thus, dragged herself all around it. The spider was now brought to the nest, being left once on the way while she ran in and out again, and was taken in after a new and original fashion. Backing in herself she seized it by the tip of the abdomen and dragged it down without any trouble, since the legs were gently pushed up over the head and made no resistance.

In two minutes she emerged from the opening, and standing on the four posterior legs, with her abdomen hanging down into the hole, scratched the earth backward with the front legs and mandibles. As it fell in she pushed it down with the abdomen, and as the hole filled she raised herself higher and higher on her legs, still using the tip of the abdomen to work the material into place.

When the operation was nearly completed we caught the wasp and opened the nest. The egg, which was placed upon one side of the abdomen of the spider, did not develcp, because its intended victim, not being held in place by the earth of the nest, knocked it off on the second day. We transplanted it to the abdomen of an *E. strix* which had been more thoroughly paralyzed by *quinquenotatus*, but in vain.

Among the French wasps the yellow-winged *Sphex* first makes her nest and then captures her prey, which is so small that she can carry it easily. The Languedocien species on the other hand takes a very heavy victim and digs her hole near the place of capture, wherever that may be. How much better is this adjustment than the one that we see among our *Pompilidae*, where *quinquenotatus* first catches her *strix* which is so small that she can easily fly with it, and leaves it exposed to many dangers during the time that she is excavating its resting place, while *scelestus* digs her nest and then goes far away to capture the great spider, which she must drag painfully along for hours before she can bring it home.

The victim of *P. scelestus*.

When we picked up the spider that had been stung by our first example of *P. scelestus*, at a little after one o'clock in the afternoon, it was limp and appeared to be dead. A careful examination resulted in the same verdict. No stimulation brought a response. At five o'clock, however, we succeeded in getting a slight quiver of the tarsi, when stimulating the legs at the articulation of the femur and trochanter. At nine o'clock on the following morning, August eighteenth, the spider, which was a full grown female, had almost recovered; she was so active that when she was touched with the forceps she ran several steps, and when the instrument was brought in front of her she seized it with her falces and held it so firmly that she could be lifted up and dragged about. She could co-ordinate her movements, since she brushed off anything that touched her by means of her tarsi. She was unable to see, since when threatened in front she paid no attention until she was touched, when she threw up her first legs in the way that is characteristic of spiders, and snapped with her falces. When picked up she bit the hand severely. She was evidently a good deal affected by the poison and did not act like a normal spider. Voluntary movement was not abolished but she had little initiative and remained quiet unless disturbed. A little later in the day she ran a few steps without being touched.

On the nineteenth there was but little change. When the tip of one of the legs was touched it was drawn up toward the body, and by touching the first, second, and third in succession they would all leave the ground, but when the fourth was stimulated and drawn up one of the others came down so that she always had one to support her. On August twentieth, when placed on her back she was unable to turn over, although she made a great effort to do so. On the twenty-second she ate a fly, and on the twenty-third she caught an uninjured fly which was put into her glass. From that time on she caught anything that was put into her glass and seized with her falces any object that was used to touch her. One day we gave her a large stink-bug, one of the *Pentatomidae*. She at once caught it but when it sent off its terrible odor she dropped it and drew back in haste. The odor was so powerful that the spider fell over on to one side throwing up all the legs on the side toward the bug, in the most comical fashion. We now feel quite confident that stink-bugs are protected from spiders.

Up to the thirteenth of November our captive changed but little. She caught flies when they came in contact with her, turning so quickly that they were seized before they could escape, but when they walked in front of her she evidently did not see them, being quite blind. She ran rapidly and had command of all her parts, and yet voluntary movement was not quite normal. Perhaps her condition might be expressed by saying that she was more sluggish than is usual in her species, moving about in her glass much less than other specimens of her kind have done when we have kept them in confinement.

The result of the sting of the wasp, then, was in the first instance completely to paralyze and to render the spider incapable of any movement whatever. This condition lasted from about eleven in the morning to five in the afternoon, or six hours. In the second stage she slowly recovered, the effect of the poison passing off gradually, so that by the next morning she was able to move about and to defend herself with considerable vigor. Within a few days she was in fair condition, being able to walk or run, to bite and to catch flies, but she remained permanently blind. Taking these facts into consideration it is plain that the ganglionic mass in the cephalothorax was seriously affected by the poison of the wasp. The whole mass was involved since all the parts were perfectly paralyzed. The paralysis could not have been the result of injury to the ganglionic structure since recovery took place within twenty hours, therefore the disorder was functional not structural, excepting as regards that part of the nervous mass that was actually pierced by the sting, and in which the tissue was destroyed. To judge from results, the part which was thus affected was that which supplies the nerves of sight. In regard to the general paralysis from diffusion of the poison, we should expect it to be of brief, or of permanent duration, according to the amount injected, and our experiments upon spiders and crayfish have given these results. A crayfish many times as large as this *Lycosid* was completely paralyzed when stung by a wasp at a point remote from any ganglion, but in a few minutes the effect of the poison passed off and movement was restored. A repetition of the sting either killed the animal or reinstated the paralysis. The table given in the chapter on *Pelopaeus* should be consulted in this connection.

The spider under discussion having made an almost complete recovery, except as to vision, we determined to try the effect of a severe wound of the nervous mass in producing paralysis. At three o'clock in the afternoon of November twenty-ninth a fine needle was pushed through the center of the thoracic ganglion of a spider from the ventral side. Paralysis at once ensued although the legs twitched and responded irregularly to stimulation. Fifteen minutes later the first, third, and fourth legs on the right side kept quivering as the spider lay on her back. At the end of an hour she turned over, after some struggling, and took two or three staggering steps. When picked up for examination she bit the finger so that the fang penetrated the skin, and as the hand was raised she held on so that she was lifted from her feet. She regained her strength gradually and by ten o'clock of the same evening she moved about, but as the legs on the two sides did not act together she went sideways instead of straight ahead. There was but little change from this condition until the second December when the second leg was drawn up to the body and never moved again. On the fourth she was less active, growing weaker and weaker through the day, and on the afternoon of the fifth she died. She had lived for six days with only partial paralysis after being wounded in the ganglion by an instrument six or seven times as thick as the sting of a wasp. During this time she had been able to turn over, to run when touched and to bite violently. One drop of wasp-poison seems to have more potency in producing paralysis than any ordinary wound of the nervous system.

Our second example of the victim of *scelestus* was, when taken from the nest, perfectly limp and motionless, givirg no response to stimulation. Within twenty-four hours the effect of the poison had largely passed off, and by the third day the spider had recovered her normal health and was released.

This spider and the one taken by our other *scelestus*, belonged to the same species.

When we take the rapid recovery of the spiders into consideration we see that the comparatively small size of the nest is an important factor in the drama. The prey is buried alive in the fullest sense of the term but is wedged in so tightly that not the slightest movement is possible, and thus the egg is protected.

Agenia bombycina Cresson.

In the literature of the hymenoptera references have been made from time to time, to certain wasps that cut off the legs of spiders or other creatures before storing them away, but observations on the subject have been rare and not very definite. Kirby and Spence* quote from M. Cassigny to the effect that he has seen species of *Sphecina*, in the Isle of France, drag into their holes dead cockroaches, and that when one happened to be too large to enter, the elytra, and some of the legs were removed so that it could be drawn in without difficulty. Brehm, in the "Thierleben," says that *Agenia punctata* builds nests of mud and places in each cell one moderately large spider from which she has first removed all the legs. The most interesting notes on the subject have been made by M. Goureau* who gives an account of finding two spiders that had been mutilated by wasps, one of them having had all of the legs cut off and the other, all but the first pair. At another time a wasp that was flying near him let fall a spider which he captured before it could be recovered by the owner. The wasp escaped so that he could not determine the species, but the spider's legs had been removed. He concluded that instead of stinging the spiders the wasps had mutilated them so that they could not run away. He does not seem to realize that death would certainly result from such an operation.

Vespa germanica often cuts off the wings of a dead wasp or even cuts its body into two parts, before flying away with it, but this is only when the captured insect is too large to be handled in any other way; and *Pompilus fuscipennis* sometimes cuts off one or more legs from her spider, although without any regular method of procedure.

We once saw a wasp of the species *Agenia bombycina* carrying a spider (an adult female *Maevia vittata*) from which all the legs had been cut off excepting those of the first pair. She

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*Introduction to Entomology, 7th edition, p. 562.

*Ann. Soc. Ent. de France, 1839. Tome VIII., pp. 539–542.

held it by one of the remaining legs and went forward, sometimes half flying. We took the spider from her and found that it was dead.

We have recently received from Mr. George Dimmock a very interesting account, together with the specimens, of a find of a set of cells of *bombycina*. We give the description from the notes that he has generously placed at our disposal:

September, 16, 1895. Found a wasp nest under a stone at Canobie Lake, N. H. It consisted of sixteen small mud cells about 15x8 mm. (Pl. IX., fig. 3). Eight of these cells contained spiders—each cell a single spider—and all the spiders were of one species, *Lycosa Kochii*. Two were immature females, three mature females and three, mature males. In the other cells were the remains of single spiders more or less eaten. With one exception these spiders were deprived of all their legs but not of their palpi. One spider retained, in addition to the palpi, its anterior pair of legs (Pl. IX., fig. 2). One cell contained a spun-in-pupa, and in the remaining cells (i. e., eight) the spiders were so far devoured that the species could not be readily determined. In one cell was an egg fastened upon a spider and in others larvæ in various stages of development. Thus all stages of the young, from egg to pupa (and imago) were represented, only a single imago being found. She did not attempt to defend the nest but hid in the grass near at hand."

Thus the statements of Goureau and Brehm are confirmed and there can be no doubt that some of the solitary wasps have the remarkable habit of cutting off some or all of the legs of the spiders that they use for storing their nests. When Mr. Dimmock sent us the spiders and cells, we found, upon examination, that a single spider was just large enough to fit comfortably one of the cells. If the legs had not been removed the victim would have been too large for its coffin. The habits of this wasp prove that in this instance at least, a dead and considerably mutilated spider serves the larva for food quite as well as a paralyzed caterpillar does in the case of *Ammophila*.

Agenia architecta Say.

For a few days before the fourth of July our flag stood in the corner of the porch, and when we unfurled it, on the national holiday, we found fastened to it, and hidden in its folds, three dainty little mud nests, eight millimeters long by five wide. Each nest contained a wasp larva and a dead spider. The nests were probably made one day apart since the larvæ spun their cocoons on the seventh, eighth, and ninth of July, giving a shorter larval stage than we have ever known excepting in the case of the little grasshopper wasp, *Tachytes* sp.? On July twenty-ninth a male of *A. architecta* issued from one of the nests, and before August second two females had appeared from the others.

On the seventeenth of July we found two nests of *architecta* fastened to the inside wall of the boat house. The larvæ had already pupated and by the twenty-eighth of the month the wasps had flown away. From its rapid development it seems probable that this species has two generations in one season.

CHAPTER XIII.

THE ENEMIES OF THE ORTHOPTERA.

Tachytes sp.?

Plate XI., fig. 5.

Early in September this little black wasp suddenly became very common in the garden. The first one that we saw was going forwards in a series of long jumps, carrying a small grasshopper which was held by the base of the antennæ. She soon doubled on her tracks and it became evident that she did not know her way, but after going around in circles for two minutes she ran into her nest. When she came out she spent a long time in circling around, flying close to the ground in wavy, snaky lines, occasionally alighting to run a few steps, but in spite of this locality study, ten minutes later, when she came jumping along with her second grasshopper she had lost her nest again and hunted about just as before, twice going directly over it without seeing it. While she was thus occupied another wasp of the same species attacked her and tried to get possession of the grasshopper, but the rightful owner was able to defend it. At last it was stored away and she proceeded to fill the nest, scratching the earth in with her first legs and working it down with the tip of the abdomen. She worked quietly but steadily for ten minutes, closing the place neatly, and then brought bits of leaf and pieces of earth to cover it all over.

On the same afternoon we saw another of theses wasps digging her nest, but she was so much disturbed when we came anywhere near her that we were obliged to retire. On the next day we saw her astride of a small grasshopper jumping along like the one of the day before. She too had great trouble in finding her way. When she reached the nest she laid her prey down while she went inside for a moment, and then, coming out, seized it by the antennæ and backed in with it, instead of taking it in forwards as was done in the other case.

Another wasp of this species carried a much larger grasshopper which was so heavy that she could not jump with it, but was obliged to keep to the ground. In this case only one was used instead of two, which is the usual number. This wasp was first seen at a distance of twenty feet from her nest, and yet she went straight to the right spot without the least confusion, showing that some individuals of the species have a better idea of locality than others.

The nest of this species is a short, shallow tunnel with an enlargement at the end, within which are placed the grasshoppers, on their backs, with their heads in. (Pl. XI., fig. 5.) Earth is packed solidly into the tunnel but not into the cavity at the end.

We took two eggs of this species. Each was placed across the thorax of the grasshopper at the base of the neck, on the ventral side. Both hatched at the end of thirty-six hours from the time they were laid, ate for three days, and then spun their cocoons. One of them ate only one small grasshopper, leaving a second one untouched, while the other finished the large grasshopper that formed her sole provision.

The grasshoppers taken from the nests, five in number, were in all cases alive, there being a quivering of the mouth parts, and in some cases of the legs also, without any stimulation. This condition lasted for twenty-four hours from the time the poison was injected. After that they became quiet but remained alive until they were destroyed by the larvæ.

It is a curious thing that in these wasps is found the perfection of that method of paralyzing the prey which is so much dwelt upon by Fabre, although from their habits this fine workmanship is not of the slightest use to them. They entomb their victims underground, where the conditions are favorable to their preservation, and the extremely short period that elapses between the laying of the egg and the spinning of the cocoon makes it a matter of indifference whether the grasshopper is alive or dead, since in any case it would be eaten before decomposition set in.

Lyroda subita Say.

In our summer work we often found ourselves wishing that we could be in half a dozen places at once and could chase several wasps at the same time, and never did we feel these desires more keenly than on the twenty-ninth of July, when, after spending the best part of an hour in watching the hunting of an *Ammophila* we were obliged to choose between following her to a possible conclusion, and giving our attention to a little black wasp which we now saw for the first time. This wasp was running around a bunch of clover in a nervous, agitated manner, as though she were oppressed by some great anxiety. The chance of discovering something entirely new decided us to relinquish our Ammophiline hopes and we sat down at the feet of our new teacher.

We could not see anything remarkable about that bunch of clover but certainly the spot had some strong attraction for the uneasy little wasp. She ran off first in one direction and then in another. She circled about and made short flights now this way and now that, but always returned. At last she betrayed the secret of her interest by descending to the ground and picking up a small black cricket which had been lying close by all the time. She flew up into the air with it but even now did not leave the neighborhood, continuing to fly about from place to place, alighting now and again on the bean plants.

After this performance had lasted for five minutes she brought her burden back to the same spot that it had occupied before, laid it down, and without vouchsafing to us any explanation of her conduct, began to burrow into the soft earth. She went down head first, backing out with the dirt, which she carried with the front legs. While she was thus occupied we defended her booty against two hunting parties of ants which, at different times, fell upon it and would certainly have carried it off if we had not been at hand.

It took the wasp twenty minutes to open the burrow, although, as we afterward learned, it had been excavated before. At the end of that time she turned around inside, came out head first, and dragged the cricket within.

We at once opened the nest but found it impossible to follow the tunnel on account of the crumbling of the earth. Indeed we almost concluded that we were doomed to complete failure for it was not until we had gone down between six and seven inches that we found, in a little pocket, our wasp in company with three crickets upon one of which was a larva a day or two old. At the time we knew nothing of the habits of *Bembex spinolae* and we were much astonished to find a wasp which evidently fed her young from day to day.

The contents of the nest were carefully conveyed to our wasp-nursery at the cottage. The cricket that we had seen taken in was dead as was also the one upon which the larva was feeding. The third one was alive as was shown by a rhythmic movement of the palpi on the right side. By the next day, however, this one also was dead.

On the morning of the third day, July thirty-first, the larva had eaten all of the first cricket and the greater part of one of the others, leaving only the large hind legs. Supplying the place of the mother we killed two more and put them into the tube. One of these was eight millimeters long, this being about the size of those which the wasp herself had caught, while the other was of another species and much larger, being thirty millimeters long. Its size and kind however made no difference to the larva, which attacked this one next although there were two small ones yet untouched. It ate only half of this big one, however, and then passed on. On August second we gave it two more small crickets and for that day and the one following its good appetite continued, but on August fourth it stopped eating. We thought that its larval life must be completed, and expected to see it spin its cocoon, but something was lacking which we were too ignorant to supply and on August fifth it died. It had eaten six small crickets and half of the large one, which was equal to about two more. Thus ended our only acquaintance with this interesting little wasp.

Priononyx atrata St. Farg.

Pl. XIV., fig. 4.

It had rained heavily in the night, and when we went down to the garden at a little before noon of August fourteenth, although the sun was shining brightly, we found that everything was still too damp to suit our fastidious friends, the wasps. One of them, however, had begun a task on the day before and felt that she must go on with it whether the weather suited her or not, for in walking through the strawberry bed we disturbed a big black *Priononyx* that flew up from her nearly completed nest at our approach. At one side of the opening was a pile of freshly excavated earth, and beneath this was the material that had plainly been taken out the day before, since the pellets were wet and beaten together by the rain. Our wasp did not go far but settled down on the ground near by and remained quiet for some minutes. Then she flew over the adjoining row of plants into the next space and, after running about a little, found her prey—a big brown locust (*D. carolina*) which had been deposited there while she went to give final touches to the nest. She was satisfied now with merely taking a look at it, after which she rose on her wings and circled widely about, alighting here and there, but not going back to the nest. When on the ground she flattened herself out, in an odd way, lying so that the ventral surface of the body was in contact with the earth. We had never before seen just this action in a wasp, but afterward we observed the same thing in *P. scelestus* when she was in the neighborhood of her nest. After ten minutes had passed in this way she went back to her burrow and took out half a dozen loads of earth, running down and then backing out with it in her mandibles, and not using her legs at all. Then she went back to her locust, which, in the meantime, had been jerking its legs up and down and showing plainly that it was not in a state of suspended animation. She caught it by one antenna, straddled it with her long legs, and ran along briskly, very much like an *Ammophila* until she had reached the open space between the rows of plants in which her nest was situated, but here, at a distance of about three feet from the nest itself, she dropped it, and walked deliberately away, past the nest and considerably beyond it. Now again she flattened herself out close to the ground, and remained in that attitude for five minutes. Whether because she was not quite ready to lay the egg, or for some other reason, it was evident that she was in no hurry. At last, however, she approached the locust again. Just before she reached it, it gave a jump as if in normal health, but did not attempt to fly. We certainly expected that she would sting it again, but no, she straddled it as before, holding it at the base of the antennæ, and carried it to the nest. Here it was dropped while she ran in for a moment, came out, and then backed in again, caught it, still by the base of the antennæ, and dragged it out of sight. When, after a few minutes, she came out, we caught her and put her under a glass with another locust, but she would not touch it.

The nest was not excavated until two days later, exactly forty-eight hours from the time the egg was laid. It ran in obliquely for two inches, and had no pocket. The locust had been pulled in head first with its long third legs stretched out behind, and the earth had been pressed in around it so closely that it could not move. As soon as we began to remove the earth we were conscious of a violent kicking down in the dirt. The position of the head was indicated by a long antenna which stuck up through the covering. As the earth was gently pushed away the egg was revealed. It was fastened to the upper side of the body (the locust lay on its right side) in the skin just above the third leg, so that the long curved free end extended over the thigh. As soon as the locust was uncovered it jumped away and would have departed entirely if we had not caught it. We held its legs so that it could not kick, but it twitched the muscles of its skin so violently that the egg jumped up and down. It probably could not move at all in its narrow prison but now that it was taken out the only chance of saving the egg was to kill the locust, and therefore its grotesque head was removed, not without sympathy for its hard fate. Before the operation the mouth parts, antennæ, and first and third pairs of legs seemed in perfect condition. The second pair did not move unless touched and then only feebly. The wings were motionless.

In spite of our precautions the egg never hatched. Probably it had been too violently shaken up already.

This species is evidently one of those that first prepare the nest and then catch the wherewithal to fill it. She stings it in such a way that it cannot fly, and the poison temporarily affects its legs also, but there is at no time a condition of immovability excepting from mechanical causes, the wasp relying upon tight packing to secure the necessary degree of quiet.

We afterward saw this wasp occasionally in the garden, apparently looking for a place to dig her nest, but flight always carried her beyond our power of following before she found a spot that suited her.

Chlorion coeruleum Linn.

Pl. II., fig. 3; Pl. XI., fig. 4.

As we climbed the steep slope that leads to the level ground on the top of the island, one morning late in August, we saw a magnificent great steel-blue wasp coming from the grass that fringed the edge of the cliff, carrying in her mandibles a good sized cricket. After running a little way she rose and flew lightly for about eighteen feet, and then, after pausing long enough for us to overtake her, ran forward again to a large hole on the bare hillside. To one side of the opening was a pile of earth made up of large pellets. Into this hole went our wasp, without any hesitation.

When she came out, at the end of five minutes, we secured her and at once opened the burrow. The tunnel was large and ran down to a pocket (Pl. XI., fig. 4), in which were seven crickets (*Gryllus abbreviatus* Linn.), neatly arranged on their backs with their heads inward and their long hind legs projecting somewhat into the tunnel. They varied in length from fourteen to seventeen millimeters. All of them were alive and moved without any stimulation. On the fifth one taken out was the long, cylindrical egg, which was placed on the right side of the body at right angles to its length, the free end being directed upward. It was now only nine o'clock in the morning, so that it seemed likely that the egg had been laid the day before, on August twenty-seventh. It hatched on the morning of the thirty-first. The larval stage occupied ten days, during which time five crickets were eaten, the cocoon being spun on September ninth.

The cricket to which the egg was fastened kicked violently through the first two days after the hatching, striking the larva continually. The other crickets died from day to day but were accepted without question by the larva.

Harpactopus abdominalis Say.

Pl. II., fig. 1.

Warm air, brilliant sunshine, and the wide expanse of the onion-bed made the conditions for wasp-hunting quite perfect on that fifth day of July when we first saw *Harpactopus abdominalis.* The large, handsome wasp, dressed, after the fashion of so many of her relatives, in black with a red girdle, was hunting about among the plants with an anxious, hurried air, which seemed to indicate that she was looking for a nesting-place, but when she came to the spot that she wanted, a few rapid scratches opened a burrow that had already been made, showing that this species, like *Ammophila,* first digs her nest and then hunts for her quarry. If she had first secured her prey and then made the nest it would have been open.

As soon as she had opened up the way she began to hunt about as before, running hither and thither with great rapidity and showing by the excitement of her manner that some important crisis in her affairs was at hand. After three or four minutes she stumbled upon a large dirt-colored locust (*Disosteria carolina*), which was lying on the ground about two feet away. She seized her bulky prize by the base of the antennæ and carried it, right side up, to the edge of the hole, where it was dropped while she backed in. Then, grasping it in her mandibles, she dragged it out of sight. When she reappeared we tried to catch her, and she flew away. A few minutes later she returned and began to fill the hole but again we disturbed her, and this time she was, perhaps, impressed with the idea of danger, for she stayed away from the place for at least half an hour. At the end of this time we gave her up and turned our attention to something else, but when we came back later in the day we found that the hole had been filled and the spot neatly smoothed over. We dug out the locust and found the long cylindrical egg fastened on the right side, just above and overlapping the articulation of the third leg with the body. The locust was quiet but the abdomen pulsated and under stimulation the antennæ quivered. By the next day it had partly recovered, and from the seventh to the tenth of July it was quite lively, kicking vigorously when touched. On the eleventh it began to lose strength and on the fourteenth it died. The egg never hatched.

CHAPTER XIV.

THE MUD-DAUBERS.

Pelopaeus.

Pl. II., fig. 5; Pl. X., figs. 1–3.

This genus is widely distributed, being found in all regions of the earth, and contains a large number of species. Of these, two are common in this locality, *Pelopaeus cementarius*, or Yellow Mud-dauber, and *Pelopaeus coeruleus*, or Blue Mud-dauber. The latter is much the more common of the two, and its irridescent steel-blue color makes it one of the most beautiful of our wasps. For a number of years we have given a great deal of time to the habits of this genus and we are far from agreeing with that most distinguished observer, Fabre, in the opinion that its rôle is one of mediocre interest. The large measure of individuality that we have found in the habits of the different individuals that we have studied, may, it is true, be only the natural result of the large number of our observations. Perhaps all of the solitary wasps would be found to vary as widely as the mud-daubers if several hundred examples of each species were carefully studied. Be that as it may, it is certainly true that our mud-daubers possess all the charm of marked individuality, with few defects of temper, and that they lead most industrious and interesting lives.

We have not been able to determine how many generations there are in a year, but there are certainly two, and perhaps three. In May or June the female makes her appearance and begins the work of establishing a home. Almost invariably she decides to build for herself, although now and then she uses an old nest. This habit of occasionally renting an old house is common to a large number of wasps that under ordinary circumstances prefer to construct their own domiciles. We have, in several instances, seen two or three queens of our *Polistes fusca* join together and utilize a nest of the preceding year, each one clearing up three or four cells wherein to start her colony, while close by other queens were starting new nests, each building one for herself, being unable to find anything that suited her among the numerous old ones that hung about the place. This intelligent use of old habitations on the part of *Pelopaeus* is not very frequent, the instinct to build seeming well-nigh imperative.

The spot chosen for the nest may be in a barn, up among the rafters, in an out-house, under the roof of a porch, or indeed in any sheltered place where it will be protected. Originally they built under over-hanging rocks and in hollow trees, as they still do if better places are not to be found, but when near human habitations they make use of the more convenient positions which they offer. Fabre says that the *Pelopaei* in France build on chimneys inside of houses, and he even believes that they examine a chimney to see whether it is in use, so that they may be assured of sufficient warmth for their young during the winter. Our wasps are less provident, perhaps because they are entirely able to withstand a low temperature, and so have not had their intelligence so highly cultivated as is the case with their French cousins.

Having selected a place the wasp goes off for her building material. She will use almost any kind of earth if only it be damp. We once found a nest consisting of a group of fifteen cells, four of which, in the center, were constructed entirely of pure white plaster, making a striking color contrast with the mud colored cells which surrounded them. In gathering her load of mud, the wasp forces her head down into the soil, raising her body into a nearly vertical position. While she works she gives vent to her feelings in a loud contented hum. She ceases to sing as she rises, with a lump of mud held in her mandibles. On arriving at the scene of her building operations she places the soft mud in position, using her mouth, mandibles, and feet, patting it both inside and outside as the wall grows. The layers are put on in a more or less oblique position, and each load makes about half a ring in the larger parts, or a whole ring near the bottom of the cell. From thirty-two to forty loads complete the cell, which is composed of from sixteen to twenty layers. As a usual thing one cell is placed against another until a large mass is formed. The wasp adds nothing to the mud, depending upon its drying for the necessary firmness, and if, by some accident, the rain strikes it the whole becomes soft and falls to pieces. Since one wasp builds in several different places in a summer it is difficult to say what should be considered a fair amount of work for a season. Most commonly there are five or six cells in a group. The largest number that we have ever found was twenty-one. Probably we should have found the average number higher if we had not collected while the work was still going on, instead of waiting until the season was over.

The cells, when first finished, are elegant affairs, and with the blue or yellow wasp standing on the rim, they present a very pretty picture; but soon all this is changed, for when a few cells are done she brings pellets of mud and plasters them all over the outside, hiding the contour of the rings and making it, in very truth, the nest of a dauber. What it loses in beauty, however, it gains in durability and strength, and as the later cocoons must remain within through the winter we will hope that the thickness of the walls serves as a protection when the mercury goes down below the zero point. One wasp had too much artistic sense to spoil the appearance of her work, but she compromised with her instinct by bringing the extra amount of mud and attaching it in lumps here and there over the whole of the group (Pl. X., fig. 1.) We, ourselves, preferred this style of architecture to the other. The chief interest of *Pelopaeus* lies in instances like this, of marked variation in an important instinct.

Almost all the cells that we have collected during the past six years, or, to be more exact, five hundred and forty-six nests out of five hundred and seventy-three, had their openings at the top, the longitudinal axis being nearly vertical, while twenty-seven were placed horizontally, with the opening at the side. (Pl. X., figs. 2–3.) Fabre found that in France, *Pelopaeus* always gave the cell a horizontal or slightly oblique direction with the opening out or a little up. With our wasps the variation in the position of the cells was an individual affair, since one would sometimes change the direction of the cells she was making. One fickle-minded worker built two with their openings directly up, and then placed a third cell at right angles to these with the opening out. Another made sixteen vertical cells and then, changing her plan, placed two horizontally. We found another group of six, of which four opened up and two out, and still another with five up and four out. So far as we could see the one direction possessed no advantage over the other. Maindron, in describing the habits of *Pelopaeus* in the Indian Archipelago, says that what strikes him most in the aspect of their nests is their great variability. He has never found two alike in exterior form, in volume, or in the number of cells, and these also vary greatly, although they are almost always oblong.*

So soon as the cell is done, even if it be late in the afternoon, the wasp begins to lay in the food supply for her offspring. In this she differs from most of her relatives, as few of them will work after four o'clock. In favorable weather the blue wasp often builds and stores a nest in a single day. The prey that she seeks is spiders, and this seems to be true of *Pelopaeus* all over the world. They take spiders of many different kinds but always spiders. If a wasp begins to put a common species into her nest she is very likely to continue with it until the cell is full, but she exercises a wise eclecticism in her choice and saves herself all the trouble that she can. In spring and through mid-summer our wasps most frequently take *Epeira strix, vul-*

*Ann. Soc. Entom. de France, Tome VIII., p. 338.

garis, and *juniperi*, which are very common at that time, but their depredations are not confined to these species, as representatives of several families are often found in the same cell. Hentz, the well-known arachnologist, said that he made some of his rarest finds in mud-daubers' nests. Sex plays no important part in determining the choice since when the males are abundant they are commonly seized. In September, when many of them mature, the proportion of the males to the females increases. Dr. McCook, in his work on American spiders, says:* "It is, however, true that in the gatherings of any individual wasp there is apt to be a preponderance of a single species of spider. Thus it would seem that a wasp starting out with *Epeira strix*, for example, is apt to devote herself chiefly to collecting that particular species." But after all the preference, if any exists, is but little developed and propinquity is the important factor in determining what arachnid is taken.

An extract from our notes will give an idea of the contents of these cells.

Nest taken July 17 contained 9 *Theridion tepadariorum*.

Nest taken July 17 contained 16 *E. strix*, 1 *Thomisid.*

Nest taken July 17 contained 10 young *A. riparia*, 4 *Steadota marmorata*, 1 *E. insularis*, 1 unknown.

Nest taken July 21 contained 5 *E. insularis*, 3 *Phidippus rufus* (1 male and 2 females, all mature), 1 *A. riparia*.

Nest taken July 22 contained 9 *Thomisus ferox*.

Nest taken July 22 contained 9 *A. riparia*, 5 *Steadota marmorata*.

Nest taken July 22 contained 15 *E. labyrinthea*, 1 *Dendryphantes militaris* males, adult.

Nest taken July 23 contained 12 *Xysticus* sp.?

Nest taken July 23 contained 7 *Phidippus* 3-*punctatus*, 1 *Xysticus* sp.?

Nest taken August 18 contained 9 Orbweavers, (*E. insularis* and *juniperi*).

Nest taken August 18 contained 15 *A. riparia*.

Nest taken September 14 contained 1 *Misumena oblonga*, 2 *E. vulgaris* (1 male), 2 *E. juniperi* (1 male), 4 *M. asperata*, 4 *E. strix*, 1 *E.* 3-*punctatus*.

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*American Spiders and their Spinning Work, Vol. II, p. 386.

We might add to these notes but it is not necessary as they are fair samples of the hundreds of cells that we have examined. The number stored is as variable as the species. We have found as few as four in a closed nest, and Hentz once counted forty. They pack in as many as the nest will hold, using the head to push them as close together as possible, the legs of the spiders being bent in all directions without regard to either their comfort or their life. They order their food by the pound rather than by the dozen, as it is said very thrifty people do with their eggs.

The method of capture is the most interesting as well as the most important part of the life history of the solitary wasps. One can scarcely overestimate the value of the observations of M. Fabre in this field and the longer we study his experiments the greater becomes our admiration of him and of his work. In one of his chapters, while estimating the value of his own achievements in different lines, he says that while the zoölogist will prefer one part of his work and the embryologist another, that the philosopher who is concerned with the nature of instinct will give the palm to his study of the predatory wasps. He then goes on to say: "I am with these last. Without hesitation I would abandon all the rest of my entomological baggage for this work, which, moreover, was the earliest in date and which has for me the dearest associations."

During the last three years we have tried many ways of discovering the manner in which the *Pelopaei* sting their prey. One plan after another has been thought out, tried and abandoned as useless. The quality of patience is worth cultivating and we have found that unless one is possessed of a large stock of that virtue together with a firm belief in Darwin's sentiment, "it is dogged as does it," he had better abandon the study of the habits of animals.

Having failed entirely in our experimental efforts to discover the method of *Pelopaeus* we resolved to follow them in the field. We jealously guarded the spiders that spun their webs on our cottage walls, in the hope that their enemies would come there to seek them. No devastating broom was allowed to disturb them and they increased and multiplied wonderfully, but the unreasonable wasps never came near them. We scarcely knew what to do next, but just at this juncture a friend who lived several miles away, sent us word that his cottage porch was a favorite hunting-ground of the *Pelopaei*, and, thankful for the opportunity, but wondering much why his cottage was preferred to ours, we made haste to go over to the scene of their operations.

The questions to which we wanted answers were these: How was the spider seized? When and how many times was it stung? Was the wound given with discrimination, a certain point in the ganglion being pricked so that the spider might be paralyzed but not killed, or was it given after the manner of a novice in the art? Was there any malaxation?

To make sure of all these points during the brief instant of turmoil that covered the capture of the spider was, perhaps, asking too much. At any rate we had to content ourselves with partial success. We had scarcely arrived at our friend's cottage, when, to our great delight, a blue *Pelopaeus* came flying along, alighted on the wall, and began her search, creeping into corners and cracks and investigating cottony lumps of web. In a few moments a small *Epeira strix* (the only species to be found on the cottage), was dislodged and at once dropped to the floor of the porch. The wasp paid no further attention to it but went on with her search. Three more spiders, one after the other, were disturbed and dropped to the floor without being followed. The fifth one discovered was a little larger than the others and was seized by the jaws and first legs of the wasp before it had time to escape. It was then rolled into a ball, or at least so it appeared, and stung, then rolled a little more, and stung again, and then carried off. We had scarcely drawn reath after this performance when a second wasp appeared. This one dislodged two spiders, and then caught a third which was seized and stung without any rolling and then instantly borne away. A third wasp seized the first spider that she found and started on her flight at the same moment, stinging it on the wing.

So the game went on while the three of us, for our friend soon became infected with our enthusiasm, waxed warm with the excitement and fascination of the chase. As the hours went by some of the yellow mud-daubers appeared, adding to the interest of the scene, although we could not see that their method differed in the least from that of *coeruleus*.

Rarely did they succeed in catching a spider until they had dislodged two or three. Sometimes the spiders were followed as they dropped, and were caught on the floor, but oftener the wasp let them escape and continued her search on the wall. At the moment of capture we could see that she bent her abdomen under and inflicted a sting, but although we concentrated our attention on the point we could not be sure as to just what part was touched. Sometimes it was the under part of the abdomen that seemed to be stung, but more commonly it was the cephalothorax, underneath or at the side. Once, when the three of us were watching the same wasp, we all agreed that the thrust was given in the dorsum of the abdomen, but the whole thing was done with such a rush that we cannot make any positive statement. It is, however, our impression that this first sting was given anywhere, at random, with the object of producing a condition of temporary quiet in the victim so that the next part of the operation could be carried on with deliberation.

The second step in the procedure was commonly for the wasp to alight upon some neighboring object, usually the branch of a bush or tree, and sting the spider a second time. She now had every opportunity for the operation of learned surgery, and she was evidently in no haste, but the difficulty of following her as she flew, and her habit of alighting above our range of vision made it almost impossible to see just what she did. She certainly remained on the branch for some moments, either resting quietly or rolling the spider around and around.

As the fruit of that day's labor we saw twenty-six assassins capture and poinard as many victims, and with their actions as a basis we may assert that the wasp very commonly stings her prey twice, first at the moment of capture and again after she has alighted near by, and that the method of operation gives her every opportunity for the exercise of any skill that she may possess.

Having failed then in our plan of studying *Pelopaeus* under artificial conditions, and having met with only a moderate degree of success in watching the wasps out of doors, we found ourselves obliged to rely mainly upon a third method, that of studying the condition of as many of the spiders as we could gather, in the hope of deciding whether these wasps are so wonderfully skilful as they are reported to be, or whether they are novices in the art of paralyzing their prey. To the layman the results of a surgeon's work are much more important than the method of his procedure, and the test of his skill is the percentage of recoveries among his patients. Since the wasp, then, has been held up as an adept in the art of producing paralysis without death, we thought it fair to adopt a similar test with her, and so we set for ourselves the task of examining spiders from the cells of *Pelopaeus*, to see how many were killed at the moment of capture, or were so much injured that they died shortly after, and how many had been stung with such discrimination as to preserve them for many days alive, but motionless, a store of fresh food for the larva of the wasp. It may be urged that dead spiders serve this purpose as well as living ones, but this is a separate question. The point to be first determined is whether the instinct to sting a certain place is much or little developed in these wasps.

We examined in all five hundred and seventy-three cells. Of these, forty had been freshly sealed up with the egg just laid, or were still open, the process of storing not having been completed. Under these circumstances the spiders were from one to three days old and gave valuable information as to the point in question. A detailed account of all our observations would be too tedious but we select a few typical cases under each head.

August 15. Took a nest containing fourteen specimens of *Argiope cophinaria* from 1-4 to 1-3 grown. Egg on anterior part of abdomen. The spiders were very closely packed together and although plump and fresh were all dead.

July 23. Found nest with fourteen spiders, four alive, ten dead. Of the dead ones four looked plump and fresh, and six were dry. They were packed together even more tightly than usual, so much so that the abdomens of the dry ones were crushed and glued together and also to the walls of the nest. One spider was partly plastered into the top of the cell where it had been closed. Those near the top were the freshest. A second nest gave us fourteen specimens of *Epeira juniperi*, including many varieties of this variable species. There was no egg, although the nest had been closed. This was the finest looking and best conditioned lot of spiders that we have ever seen. Thirteen of them were alive and one dead.

July 28. On re-examining the spiders of the second nest taken on July 23, we found that nine of the thirteen were dead, three of these being partly dry.

September 14. We took a nest of which the provisioning was not quite completed. It contained fourteen spiders, eleven of them being dead and three alive. Twelve of them were very plump and fresh looking, while two had their abdomens crushed and looked old. The egg had not yet been laid. We repeatedly examined the spiders very carefully with a magnifying glass and even tried them with alcohol, which causes a good deal of movement in those that are only paralyzed, but they were certainly dead.

September 15, 8 P. M. Have spent two hours in working over the spiders taken yesterday. The three are still alive, but there has been no recovery among those that we pronounced dead.

September 26. The three are still alive. Four of the others are very dry.

This will suffice to give a fair idea of the surgical skill of our ravishers. It is plain that the most of the spiders are killed at once, while a quarter or a third of them live for a period varying from one to twelve days, dying in the nest from day to day. Among those taken from other nests were some that were so slightly injured that they lived all the way from twelve to forty days.

We have tabulated below the results obtained from our study of the forty nests above referred to:

TABLE No. 1.—*Showing condition of spiders found stored in 40 nests— 1-4 days old.*

No. of nest.	Condition of Spider.		Total No. in nest.	No. of nest.	Condition of Spider.		Total No. in nest.
	No. dead.	No. alive.			No. dead.	No. alive.	
1	1	1	2	21	8	2	10
2	9	....	9	22	1	1	2
3	14	....	14	23	7	3	10
4	10	5	15	24	6	2	8
5	12	....	12	25	3	16	19
6	8	....	8	26	13	12	25
7	20	1	21	27	....	15	15
8	28	1	29	28	13	1	14
9	20	5	25	29	10	4	14
10	17	1	18	30	1	13	14
11	12	5	17	31	10	4	14
12	3	6	9	32	2	3	5
13	15	2	17	33	7	1	8
14	5	8	13	34	....	15	15
15	1	2	3	35	....	5	5
16	9	4	13	36	2	11	13
17	5	6	11	37	1	5	6
18	13	6	19	38	1	13	14
19	8	10	18	39	6	4	10
20	4	1	5	40	11	3	14
					316	177	493

The table shows that about thirty-three per cent. of the spiders are so skillfully stung that they are only paralyzed, while the remainder are so poorly stung that they are killed. After death they begin to dry up but remain in good condition for at least twelve or fourteen days. As compared with other species of the same genus our wasps excel those of France, which, Fabre has found, almost invariably kill their prey at once, but they fall far below some of those that are found in other parts of the world. Monteiro, in his work, "Angola and the River Congo" (p. 323), says that he has opened many of the nests of *Pelopaeus spirifex* and has always found the spiders alive, though unable to crawl away when taken out. "Whilst at Bembe," he says, "I fortunately witnessed a fight between a large specimen of these wasps and a powerful spider which had built its fine web on my office wall. The spider nearly had the wasp enveloped in its web several times, and by means of its long legs prevented the wasp from reaching its body with its sting, but at last, after a few minutes' hard fighting, the wasp managed to stab the spider right in the abdomen, when it instantly curled up its legs and dropped like dead to the ground. The wasp pounced down on it, but I interfered, and picking up the spider placed it under a tumbler to ascertain how long it would live. * * * It lived for a week, and, although moving its legs when touched, had no power of locomotion, showing that the poison of the wasp has a strong paralyzing effect." Eversmann gives similar testimony in regard to *Pelopaeus distillarius*. He has opened forty cells of this species and has always found the spiders alive.* Thus we have, in the different species of this genus, the widest variation in the habit of stinging the prey. Some kill almost all of the spiders, others kill more than half, while yet others, it is claimed, put up all their victims in a living but helpless condition.

Our wasps did not share the habit of those observed in France, in laying the egg upon the first spider placed in the cell. Indeed we found that it was only after the nest was completely provisioned that the egg was laid, on the abdomen of one of the last spiders brought in. The importance which Fabre attaches to the early laying of the egg seems to us a little exaggerated as the difference in time in the two methods of procedure cannot be enough to give much advantage either way. We have often counted the number of journeys that a wasp makes in an hour, and have found that it averages from twelve to

*Bulletin Mosc., Tome XXI., 2, 1848, p. 248.

fifteen. At this rate the nest could be filled in about sixty minutes, and even if it took two or three times as long the change in the condition of the spiders would be insignificant. If, in stocking her larder, *Pelopaeus* had to hunt as long for her spiders as *Ammophila* does for her caterpillars, we might find in the deposition of the egg upon the first one secured "the happy arrangement" so much dwelt upon by M. Fabre. We quote the following notes kindly made for us by Mr. S. N. Dunning, on *P. cementarius.*

Pelopaeus cementarius.

July 13, 1896.

"Four cells finished. Nest formed on wall near ceiling in home at Hartford, Ct.

"Cell No. 1 contained pupa surrounded by a glutinous membrane and the legs of spiders.

"Cell No. 2 contained pupa surrounded by glutinous membrane but no spiders, legs or leavings of any kind.

"Cell No. 3 contained a larva just ready to pupate and a few remnants of legs of spiders.

"Cell No. 4 contained a young larva 1-4 in. long and 11 medium sized spiders (oblong shaped and 3-8 in. long) of what appeared to be two species of which 8 were black and 3 grayish. Of these the legs of ten could be made to quiver but one was apparently quite dead.

"A fifth cell, finished all excepting the entrance, contained one spider which was easily made to quiver its legs. There was no egg."

After the egg is laid and the nest closed up the duties of the mother are over and that cell and its contents are abandoned to their fate. More mud is brought, more nests are built and more eggs are laid, but further responsibility for her offspring she knows not. If all goes well, in from two to three days, depending on the temperature, the larva hatches and begins to eat the spider to which it is attached, finishing the abdomen in one day if it is of medium size. Quite commonly the larva eats only the abdomens of the first four or five spiders that it attacks, but after this it eats the cephalothorax and even the legs of one before passing to the next. Later on, it may return to the harder parts that were neglected at first and devour them also, finishing up, last of all, with any broken pieces of legs that may have been overlooked. There are exceptions to this order, for some larvæ do not leave the first spider until the whole body is consumed, but in all instances where the supply of food is plentiful, many of the legs, and sometimes whole spiders are left. Our study of the eating habits of these larvæ has led us to the conclusion that they are not in the least fastidious as to whether the food is hard or soft, fresh or dry. Their habit of eating only the abdomens of the first spiders comes about from the fact that when the abdomen is consumed it is broken from the cephalothorax and in squirming around in search of another piece they are likely to come into contact with another abdomen. As they grow larger and stronger they eat the whole spider at a sitting, be he alive or be he dead. Perfectly dry spiders furnish as much proteid matter as the same number of fresh ones. On several occasions when playing nurse-mother to a number of growing larvæ, which we kept in little glass saucers, where we had not provided a large enough food supply we made good the deficiency by adding a number of dead and dry spiders that we had had on hand for some three weeks. These were accepted by our infants, and were greedily devoured.

For from nine to fifteen days the larvæ pass both days and nights in eating. They consume, in that period, from five to twenty spiders, the number being determined by their size. As we are writing this, two larvæ on our table are just entering the cocoon stage. One of these has eaten six spiders, leaving a few legs, while the other has devoured fourteen with the exception of half-a-dozen legs and the cephalothoraces of two, but in the second case the spiders were young and small, while in the first they were nearly full grown, so that this one is really the bigger glutton of the two. Whether the spiders used are large or small depends primarily upon accident. The wasp takes whatever she happens to run across, provided always that it is not too heavy for her to carry nor too big to be pushed into her cell. We have not a spider in our fauna that would not fall a speedy victim to our *Pelopaeus* should she attack it. When experimenting on the mating habits of *Attidae*, some years ago, we kept large numbers alive in our mating-boxes, and we found the females of *Phiddipus tripunctatus* so vicious and powerful that they had to be kept in solitary confinement to prevent their killing the other spiders, and yet our slender mud-daubers used these very females, even when they were full-grown. The small and feeble spiders then, are not taken because they are small and feeble but because they are so very abundant as to make them a convenient source to draw from. All spider collectors know that for each adult specimen taken in collecting there are at least twenty that are immature. Among certain species it is almost impossible to get an adult specimen at certain parts of the season although the immature forms are found on every bush. In the latter part of August or early in September the female of *A. riparia* lays from five hundred to two thousand eggs. The young spiders remain in the nest through the winter, and in the following May begin to spin their little webs everywhere. Through June and July the mud-wasps on their hunting expeditions meet them frequently and use them freely. As they grow larger and scarcer other crops of young and common spiders take their place. Interpolated all through the season, we find the larger and rarer kinds in just about the proportion that they bear to the smaller ones in nature.

Fabre's chapter on "Les Vivres du Pélopée" bears so strongly upon our subject and is so interesting in itself that it seems well to repeat some parts of it here. He says that so far as discovering the method of attack in *Pelopaeus* is concerned his efforts have not been crowned with any great measure of success. He has seen the wasp swoop down upon a spider, clasp it, and carry it away, almost without pausing in her flight. Other hunters alight on the ground, make their fastidious preparations sedately, and distribute the strokes of the sting with the calm deliberation which a delicate operation demands. This one darts down, seizes her victim and departs, something after the manner of *Bembex*. So rapid is the abduction that it may be presumed that the mandibles and sting are only used while the wasp is on the wing. This impetuous method, incompatible with learned surgery, explains to us, he thinks, even better than the narrowness of her cells, the predilection of *Pelopaeus* for small spiders. A larger and more powerful victim might put the wasp in danger. The faultiness of her art makes a weak victim necessary to her. We must suspect that a spider so hastily and carelessly taken, may be killed.

As a matter of fact careful and repeated scrutiny of the contents of these cells, when the egg was not yet hatched, confirms these suspicions. There is never any trembling either of palpi or tarsi, and in about ten days they decompose. This then is what is stored in the cells of *Pelopaeus*, spiders dead or nearly dead. Is the learned art of paralyzing practiced by *Calicurgus* upon the tarantula, which keeps it fresh for seven weeks, unknown here? Have we here to deal, not with a delicate operator who knows how to abolish movement without destroying life, but with a brutal worker who kills for the sake of rendering the victim immovable? Both the withered aspect and the rapid deterioration of the victims bear witness that this is the truth.

This, M. Fabre goes on to say, should not surprise us; later we shall see wasps giving instant death by one stroke of the sting with a science not less astonishing than that of the paralyzers. We shall see the motives which demand this and we shall recognize under all its aspects, the profound anatomical and physiological knowledge which a rational act would require to rival the unconscious act of instinct. He then adds that he cannot even suspect the cause which makes it necessary for *Pelopaeus* to kill her victims but that he can easily understand her logical method in turning to account these spiders, menaced with early decomposition. In the first place the prey is multiplied in each cell. The piece actually attacked by the larva is soon a disorganized mass, likely to decay speedily, but it is small and is consumed before decomposition can advance, for when a larva once attacks a spider it does not leave it for another. The others then remain intact which is enough to keep them fresh during the short period of larval life. When, on the contrary, the prey consists of a single large piece, it is necessary that the organic life should be maintained, and a special art must also be observed in eating it. It is well then that *Pelopaeus* is inspired to take numerous small pieces. The egg, moreover, is always placed on the first spider brought in, whether the storing of the nest is completed within a few hours, or whether, as in some cases, it occupies several days, and this M. Fabre considers a very happy arrangement.

This account of the habits of *Pelopaeus* and the explanation offered for the several facts is exceedingly important, because the French *Pelopaei* differ from ours at nearly every point. Ours kill only about two-thirds of their victims, many of the others being paralyzed so perfectly that they live for two or three weeks. Again, ours, instead of placing the egg upon the first spider, almost invariably lay it upon the last one brought in. Another point of difference is that our larvæ frequently eat only a part of a spider at a time, returning to finish it later on, a rash and reprehensible course of action of which their better-taught French cousins are never guilty. When one comes to compare the two sets of facts furnished by the two groups of species the deductions which Fabre has drawn as to the importance of the instincts of the French group are seen to be unfounded. The American species violate nearly every principle which he considers necessary to their existence, and yet they flourish and multiply. It is just possible that our learned author has put a trifle too much philosophy into his interpretation of the actions of these wasps. For our part we find nothing in the actions of *Pelopaeus* that needs to be explained—nothing that is not well adapted to the conditions under which each species works. The measure of praise or blame which we mete out to these depredators is merely a way of saying whether we would or would not follow their methods in provisioning our houses and rearing our children. Perhaps we should always use large spiders and should always have them fresh, but it is evident that tastes differ and the matter is so purely a subjective affair that it will have to go unsettled. In any event whether her victims be strong or feeble, old or young, big or little, fresh or dry, they certainly serve admirably in enabling *Pelopaeus* to rear brood after brood and to people the different parts of the earth with abundant representatives of her kind.

If any conclusion can be drawn from our observations it is that there is no importance to be attached to the number of spiders stored, to whether they are large or small, to the placing of the egg on the first or on the last victim, nor even to the state of the spiders, since those that are killed at once by the stroke of the beautiful assassin serve their purpose just as well as those that are paralyzed, and lie collapsed and powerless, all unconscious of their approaching fate.

At the close of the period of alimentation the larva spins its cocoon, which, light-colored at first, turns darker in the course of a few days. Here it remains, perhaps for a few weeks, or perhaps until the following spring. When it is ready to emerge there exudes from its mouth a quantity of watery fluid which serves to soften the cover of the cell so that it may easily gnaw its way out. While watching a number of young wasps both of the yellow and the blue species just as they were leaving the nest, and even before their wings were ready for flight, we noticed that when touched they at once attempted to sting. This would seem to prove that the stinging habit is congenital and instinctive.

We have made a number of experiments on different invertebrate animals to determine the effect of the venom of the wasps when injected into different parts of the body. Our first effort was to discover whether animals could be killed by allowing them to be stung several times at a point remote from the central nervous system. For this, we took a small crayfish, two and one-half inches long, and removed the first ambulatory leg at the basal joint, and then held an individual of *Polistes fusca* in such a way that it thrust its sting into the exposed end of the limb. Two stings were given at each of which the crayfish straightened out violently. After a few seconds the legs relaxed and their tips began to quiver just as we have seen them do in spiders found in mud-nests. In a moment the crayfish became perfectly limp and remained lying either on the dorsal or the ventral side, as it was placed. From eleven in the morning until two in the afternoon, when it died, the maxilipedes and ambulatory legs kept moving irregularly. The sting could scarcely have reached a ganglion, so that the death of the crayfish was due to the diffusion of the poison. This experiment we repeated several times, substituting *Pelopaeus cementarius* in place of *Polistes fusca*, and always with the same results.

We next took a large spider, *E. strix*, and breaking off the second leg at the femur let the wasp sting it at the point of fracture. This was at nine o'clock in the morning and the spider remained limp and unable to move until five in the afternoon when it partly recovered and began to move about with difficulty. On the following day it still moved about slowly but was far from appearing normal, and on the morning of the third day it was dead. On the eighth day it was still plump and in good condition although the sixth and seventh days had been very hot, 90° Fahr.

On July fifteenth we let *Polistes fusca* sting a spider, *E. labyrinthea*, in the middle of the upper surface of the abdomen. The spider remained in a motionless state with the legs drawn up, until the next day, when it died. On July twenty-fourth the spider was shrunken but the legs were still flexible and the body soft.

We next let *P. cementarius* sting *Marptusa familiaris* twice at the spinnerets. The spider was paralyzed at once, all the legs being limp although they quivered at the tips, but in five minutes it recovered somewhat and was able to stagger about. This continued for ten minutes when the wasp was allowed to sting it again in the same place with the same immediate result as before but this time there was no recovery and in thirty minutes the spider was dead. We repeated this experiment with a large *Thomisus*, and with *Dolomedes tenebrosus* and in both cases the stinging resulted in death at the end of twenty hours. All of these spiders and many others were killed by the general diffusion of the poison through the system and not by any wounding of a ganglion. When we allowed a considerable amount of venom to be injected death followed almost immediately but if a smaller amount was used the spider lived a day or more.

One experiment was tried upon a large caterpillar, the sting of our large hornet, *Vespa maculata*, being forced out and pushed into the last segment, and some of the poison squeezed into the wound. The effect of the venom was immediately visible in the posterior third of the body. The anterior two-thirds moved normally, dragging the end of the body along. Perhaps this worked the poison forward for after a little all the anterior parts became affected. An hour later the caterpillar seemed slightly better, but on the next day it was so much affected that it could not turn over when placed on its back, moving only when stimulated. On the third day it was alive but very sluggish, moving slowly when touched, and on the fourth day it died. This was on the fourth of July. On the seventh it was still soft and in good condition, but by the eleventh it was quite dry.

A large number of spiders that were killed in our experiments were kept that we might note the time at which decomposition began. We found that on the average they kept fresh for ten or twelve days after death. We had only one which began to decompose as early as the ninth day, and even in this case the spider was in what a wasp larva would have considered an edible state three or four days longer. All of our experiments were in complete agreement with the condition of things found in the nests, where many of the spiders were alive when first stored but died from day to day, and whether dead or alive, plump or dry, were eaten eagerly and with apparent relish.

The following table shows for eleven nests, of which we preserved the contents, the rate at which the spiders died. In all these instances the nest had not yet been closed, as in numbers four and eleven, or if closed, the egg had not hatched, showing that the spiders could not have been stored more than two or three days. Of eighty-four spiders forty-three died in from two to five days while only fifteen lived from thirty to forty days.

TABLE No. II. *Showing the length of life of spiders found in wasp nests.*

No. of nest.	Condition of the spiders when found.		No. of days that the spiders lived after nest was opened.																							Remarks.
	Dead.	Alive.	2	3	4	5	7	8	9	10	12	13	14	15	16	20	25	29	30	31	32	35	36	38	40	
1[1]	7	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	3	..	..	..	..	[3]1	..	Egg not hatched.
2	12	12	..	..	7	..	..	1	..	..	1	..	..	..	..	..	1	..	..	1	..	1	..	..	..	Egg not hatched.
3	7	12	..	..	9	..	..	..	..	..	1	..	..	..	2	..	..	..	..	..	..	..	..	..	..	Egg not hatched.
4	11	3	..	..	..	..	..	..	..	1	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	Nest not closed.
5	1	13	..	..	..	9	3	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	Spider fresh looking.
6	7	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	1	..	1	..	..	Egg not hatched.
7	2	3	..	..	..	1	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	Egg not hatched.
8	3	6	2	..	..	2	..	..	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Egg not hatched.
9	2	15	..	7	2	..	3	..	..	..	1	..	..	2	..	..	..	..	..	..	..	..	..	..	..	Egg not hatched.
10	12	5	..	2	2	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	Egg not hatched.
11	11	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3	..	..	..	[2]1	Nest not closed, Egg not laid.
Total	75	84	2	9	20	12	6	1	2	2	3	1	1	3	3	1	1	2	7	1	3	1	1	1	1	

[1] Nest number 1 was *Pelopaeus cementarius*.
[2] This spider was so slightly injured that it moved about and moulted once.
[3] Very little hurt, moved freely.

Fabre has found the members of the genus *Pelopaeus* exceedingly unintelligent and absolutely lacking in rational discernment,* but evidence of quite another character is found in some

*Aberrations de l' Instinct, Souvenirs Entomologiques, Quatrième Série, chap. III.

experiments made on a mud-dauber many years ago by Mr. P. H. Gosse, from whom we quote the following:*

"June 30. I watched with much interest the proceedings of a Dauber in building her mud-cells; it is a pretty species (*Pelopaeus flavipes*). She has chosen the ceiling of a cupboard in my sitting room, where, previously to my observing her, she had made one cell and the half of another parallel to it; the former was closed, the latter had got its contents of spiders, and only wanted closing. Such was the status quo.

* * * * * * * * * *

She then flew off and returned with a similar load, which she applied upon the last to make it thicker. When she was gone the third time, in order to observe her behavior, I thrust the head of a pin through the newly laid mortar, opening a hole into the cell. On her return, she at once perceived the hole, and deposited her lump upon it, spreading it about as before. I played her the same trick several times, at all of which her proceedings were the same, save that at length she seemed to become very angry and endeavored to catch the house flies that were flying and crawling near. I have no doubt that she suspected them of having a hand in it. At all events, she jumped at them very snappishly whenever they came near, and sometimes even with the load in her mouth, but I did not see that she caught one. Once, too, a large Ichneumon was lurking about, at whom she fiercely flew, and I think they had a short struggle. At times she would linger at a little distance, after depositing her load, apparently hoping to catch the insidious house-breaker, 'in the manner' as lawyers say.

"At length I broke off a large piece from the side and bottom of the old part, exposing the spiders to view; this, however, she speedily built up as before, at two or three loads, adding to the standing part all around the hole, and not at one side only. After this I did not put her industry to the task any more, but suffered her to finish her work, which she did by adding another layer or two to the end. I, however, made a hole in the first cell, which was quite hard and dry, to see if she would observe it, which she did at once, and clapped her load of mortar on it. I noticed that while working, though the wings were closed incumbently, she kept up a shrill buzz, like that of a bee when held in the fingers; her antennae, which were usually carried nearly straight, were during the plastering curled up and continually vibrating and moving on the surface of the work, evidently trying it by

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*Letters from Alabama on Natural History, London, 1859, pp. 239-241.

touch, which seemed to me adverse to the theory that calls the antennae 'ears.' In seeking her materials, she was gone often more, never less than a minute, and always brought a lump similar in appearance, which was invariably carried in the jaws, without any aid from the feet.

"The Dauber built another cell today, on the other side of the first, which is now therefore in the middle. I again pestered her by sticking a small tin tack in the newly laid mud, just where she would have to deposit the next load. When she came, she appeared quite bothered; she ran back and forward, and round and round over the cells for some time with the mud in her jaws, as if at a loss what to do in so novel an exigency. It was a different case from the former; a hole could be stopped up, but here was an intruding substance just where she wanted to deposit; should she lay it on, the incumbrance would be more firmly imbedded; should she place it elsewhere, it would be wasted, not being needed, or perhaps be positively injurious; should she attempt to remove the evil, her mouth was occupied, and she was unwilling to lose her burden. At length, however, as the least of the evils, she seized the tack with her jaws and drew it out, dropping her mud in the effort. When she was away the next time, I bundled up a worsted thread, and pressed it on the soft work, which presented a still more serious obstacle, as she could seize only a small part of it which would yield without coming away; however, by taking hold of several parts of it successively and tugging at them for a long time and by walking round and round with it in her mouth, she at length got it out. These instances of sagacity and perseverance greatly pleased me. After laying on the load, she always cleans her antennae with her fore feet, and her feet with her jaws; on arriving she never alights at the nest, but always on the inside of the cupboard-front and crawls along the ceiling to it."

Summary.

Our *Pelopaeus*, then, builds her nests of plain mud, in sheltered places. The food-supply of the larva consists of a variable numbers of spiders, a few if large ones are taken, many if they are small. Size, sex, and kind are unimportant, the wasp showing the greatest variation in these matters, probably, indeed, taking the first thing that comes in her way. If the weather is fine the work of building and provisioning is completed in one day. Her skill in the use of the sting is all that is required for her purpose which is rather to overcome any resistance that she may encounter than to paralyze the spider and thus keep it fresh. To her it is a matter of indifference whether the spiders are killed or paralyzed, and either result may follow. The examination of cells recently provisioned shows that while most of the spiders are dead, many of them, although motionless, are alive and will respond to stimulation by a quivering of the tips of the legs. These living spiders die from day to day, the death rate depending upon the amount of poison that has been injected. It is probable that the spiders are usually stung in the under side of the cephalothorax. We base this opinion upon what we ourselves have seen and also upon the fact that many of the *Pelopaei* take spiders of the genus *Gasteracantha*, in which this is the only part soft enough to be penetrated, all the rest of the spider being enclosed in horny plates; and it is commonly the fact that among the solitary wasps all the members of a group sting their victims in the same way.

CHAPTER XV.

EXTRACTS FROM MARCHAL'S MONOGRAPH ON CERCERIS ORNATA.

The memoir of Paul Marchal on *Cerceris ornata** contains so much that is of interest that a series of short quotations from it would quite fail to give an idea of the thoroughness of the work upon which it is based and of the importance of the results. We therefore take the liberty of transcribing freely a considerable part of the paper.

The nest of the wasp consists of a tortuous gallery from which lead a number of rounded cells. In each of these is deposited an egg with enough bees of the genus *Halyctus* to nourish it through the larval stage. The provisioning of one cell is completed before that of another is begun, so that in a single nest there may be found one cell partly provisioned, one with an egg and others in different stages. The egg is placed diagonally on the ventral face of the thorax. A single cell contains a variable number of victims—some seven or eight, others four or five. Probably those of a small number are destined for the males. The species of *Halyctus* used are numerous, and male bees are often found among the victims, some cells having nothing else.

Cerceris ornata is one of those wasps that are not disturbed by artificial conditions. When placed with a bee under a bell-glass her method may be studied in detail. It is only necessary to have patience—in a quarter or half an hour she comes near *Halyctus* and engages in combat. If one has laid in a sufficient

*Etude sur l'Instinct du *Cerceris ornata*, Archives de Zoologie Expérimentale et Générale, Deuxième Série, Tome. Cinquième, 1887.

supply of bees he may continue to assist, as long as he wishes, at the manœuvre of *Cerceris*. It is not even necessary to take the wasp with her victim; it is enough to shut in together an *Halyetus* and a female *Cerceris*, always with the condition that the latter has been captured while hunting. "Five successive times," says Marchal, "I saw *Cerceris* return to the assault and recommence the same manœuvre on the unhappy bee. To speak truly the immediate result obtained by this succession of operations did not appear to me to correspond with the energy employed, and after the fifth operation the immovability was scarcely greater than after the first. Moreover the one which received the assault five times, taken at two o'clock, still moved its legs the next morning after the abdomen was excited; this is precisely what resulted from a single operation."

The instinctive act of *Cerecris*, then, may be considered a reflex due to the sight of the bee and able to be accomplished an indefinite number of times so long as the wasp is in chase.

At the moment of capture *Cerceris* seizes the bee brusquely, clasping the anterior part of the body with her mandibles. Her recurved abdomen darts the sting into the neck at the articulation of the head and thorax, the stroke being given vigorously as though it were of capital importance. For a few moments the two combatants roll on the ground; one or two quick strokes are given under the thorax, principally between the prothorax and the mesothorax, and the bee becomes motionless; then *Cerceris* holds her victim face to face with her, looks at it a few seconds, and turns it around so as to bring the neck opposite her mandibles. The bee being thus adjusted the wasp proceeds to dig at the nape of the neck, squeezing it for from two to four minutes. This process is usually performed within the nest, and it is noticeable that *Cerceris*, after the malaxation, does not drag her bee by an antenna as she would do if the operation usually preceded the entrance into her hole. On the other hand the wasp sometimes gives the strokes with her sting and then, not proceeding to malaxation, at once begins to drag the bee as if seeking to regain the nest.

Marchal does not agree with Fabre in his belief that wasps are endowed not only with tools but with the method of using them, the gift being original, perfect from the beginning, not modified by past or future. The action of *Cerceris* does not imply any mysterious science. She runs the end of her abdomen along the under surface of the thorax of the bee and stings at the division of the segments—that is at the points where the sting can enter. The order in which the strokes are given is very variable, and if the neck is protected by gum-arabic, so that it is impervious, the stings between the pro- and mesothorax give just the same result. All that is necessary is that the sting shall reach the line of nervous matter that runs along the ventral face of the thorax. As a matter of fact it does not touch the ganglia, but enters just half way between them. The distance is small and the poison quickly reaches the nervous centers. (Pl. X. fig. 4.)

The order in which the stings are given is variable. We may consider that there are four classes:

In class A. the sting is given:

1st, at the neck.

2nd, at the articulation of the prothorax and the mesothorax.

3rd, at the neck.

In class B. it is given:

1st, at the neck.

2nd, at the articulation of the prothorax and the mesothorax.

In class C. it is given:

1st, at the neck.

2nd, at the articulation of the prothorax and the mesothorax.

3rd, behind, toward the origin of the abdomen.

In class D. it is very probably given in a considerable number of cases, either only in the articulation of the prothorax and the mesothorax, or only in the neck.

Cerceris is far from using the exquisite method of malaxation followed by *Sphex*, as described by Fabre. She is on the contrary, quite brutal. She pricks and squeezes the neck of the

victim and then licks off the juice that exudes. All the bees that have undergone this operation have the neck cut, some on the median line, some on both sides. The supposition that *Cerceris* proceeds differently with the bees which are destined to feed the larvæ, perhaps not malaxing them at all, or only delicately, proves to be incorrect, since half the bees that were taken from nests showed marks of being cut. The other half, upon which no sign of a wound was visible, had probably received lesions which resulted in death after a brief delay. Of five bees taken from nests where the egg had not yet hatched three days), only one responded to stimulation of the electric
three days), only one responded to stimulation of the electric
current by flexing the anterior legs at the moment that it was applied, the others giving no reaction. Moreover of three taken from a nest not yet fully provisioned one gave no response to the electric current.

These facts show that the instinct of the *Sphecidae* may well have been derived from the struggle for existence. If *Cerceris* paralyzes *Halyctus* it is partly in her personal interest, that she may perform the malaxation at her ease. Does not the instinct of all these wasps to paralyze their prey for the benefit of beings which they do not know, since they are still in the egg,—which they can never know, since they will die before the young hatch out; which, by a series of well ordered acts assures the propagation of the race without the insect having the least knowledge of the aim to be reached; does not this instinct appear better than any other so to unite all the conditions that it will serve for an argument of the partisans of the supernatural in Nature? and yet we see that in the actual case the instinct can be brought back to the most natural thing in the world—individual interest and preservation of the individual. It may be that other original causes have presided over the evolution of the instincts of the solitary wasps, but while we wait for new facts, to suppose such causes would be to make a useless hypothesis.

State of the Victims.

When *Cerceris* abandons her victim, after malaxation, it presents disordered movements in all its members; incapable of taking a step, it rolls on its back when one sets it on its legs; the mandibles are immovable and the antennæ nearly so. Spontaneous movement ceases about ten hours after malaxation, but even now a light excitation of the abdomen leads to a moderately lively reaction in the posterior legs.

During all the time that this partial paralysis lasts the tarsi are animated with movements of oscillation which are quite rapid at the beginning and which diminish at the end. These oscillations last, usually, longer in the posterior legs than in the anterior. The nervous center which presides over their movements is, in fact, further from the point pricked by the sting.

Out of eight individuals, seven no longer presented the least movement, either spontaneous or provoked, twenty-four hours (and less than that for some of them), after the operation. The other one presented no movement forty-eight hours after. It is rare that the movements persist so long as this. Even by electricity it often is impossible, in less than twelve hours after the cessation of movement, to bring back the least trace of irritability. Thus the operation performed by *Cerceris* has the effect of plunging the victim, after a brief delay, into a state absolutely comparable with death.

Now what is the rôle of the sting and what the rôle of the malaxation?

To learn this some bees were taken from *Cerceris* as soon as they had been stung, at which point they fall into a state of complete immovability, only the extremity of the abdomen being, from time to time, lightly agitated. This state lasts only a few instants, scarcely a minute; soon the movements of oscillation begin, appearing first in the posterior legs; some seconds later the intermediate tarsi begin to move; then the anterior tarsi; a little later a jerky movement of the anterior legs and of the antennæ announces the reawakening, and in about three minutes the posterior legs move about in a disordered way. The insect then begins to come out of its general numbness and finds itself in just about the same state as a bee which has just been subjected to malaxation. Now since malaxation lasts just three minutes it would seem that this process adds nothing to the sting, but it is only necessary to compare a series of bees which have been subjected to it with one which has not, to be convinced that this is not true.

Half an hour after the operation the bee which has not had malaxation has recovered to the point of vibrating its wings rapidly; its legs move quickly, its antennæ are mobile, and the insect presents its ordinary appearance, even taking some steps but soon rolling on its back. This state of relief from numbness progresses for three hours. In two hours it turns its head right and left, moves its antennæ, even tries to bite with its mandibles. These movements are not automatic but voluntary. It tries to fly but cannot leave the earth.

In the meantime in the bee that was submitted to malaxation the state of torpor persists and only changes to become more complete. The movements show a suppression of all that is voluntary. The only trace of co-ordination is that it frequently strokes its flanks and its legs with the posterior legs as if to rub off pollen. This suppression of the will is the result not of the compression of the neck but of the loss of nourishing juices resulting from the hemorrhage of the great dorsal vessel.

Returning to the bee that has not been malaxed, we find that the movements persist with a certain intensity up to the fourth hour and then diminish and finally disappear. The table shows that movement persists much longer in this class than in the other.

Out of eight bees that were subjected to malaxation after stinging:

7 ceased to move the first day after operation.

1 ceased to move the second day after operation.

Out of eight bees that were subjected to stinging without malaxation:

1 ceased to move the first day.
2 ceased to move the second day.
3 ceased to move the third day.
1 ceased to move the sixth day.
1 ceased to move the twelfth day.

In one case in which there was no malaxation the state of paralysis was truly remarkable, quite comparable to that which M. Fabre has described with the *Curculionidae* of another *Cerceris*. The details are as follows:

The third day after the sting the oscillations of the tarsi persisted in a constant manner; the posterior legs reacted strongly whenever one excited the abdomen; the antennæ were easily excited. The fourth and fifth days gave the same symptoms.

On the sixth day fæces were passed.

On the seventh the oscillations persisted, the antennæ being always half raised when the abdomen was excited; the posterior legs did not react, but the abdominal extremity was recurved. Fæces were passed.

On the eighth, ninth, tenth, and eleventh days the oscillations of the tarsi persisted, rhythmically, with strong accentuation.

On the twelfth day in the morning, the oscillations of the intermediate tarsi were plainly much weaker than in the anterior tarsi, while those of the posterior tarsi persisted with a good deal of vigor. By evening the oscillations of the tarsi had ceased.

On the eighteenth day the tarsi broke off showing that desiccation had begun. *Cerceris*, then, can paralyze its prey and can plunge it into a state of torpor which lasts fifteen days, giving the larva fresh and living food.

An effort was made to get malaxation without stinging, but *Cerceris* would not go on to this part of the treatment until the bee had been rendered motionless by the sting. When the sting was cut off, she used the abdomen as if stinging, trying again and again as this failed to produce the desired result, and finally letting the bee escape. The real object of the sting, then, is to render the bee motionless so that it can be conveniently handled.

Conclusions.

1. The effect of the sting is to produce inhibition; this permits *Cerceris* easily to carry the bee into her hole.

2. Inhibition ceases, but the nervous system has been so injured that the insect does not recover. Still motion may persist for a long time if there has been no malaxation.

2. Malaxation by the effusion of blood which it produces, and also by the lesion of the nervous chain, strikes a fatal blow at voluntary movement, and leads to the suppression of animal life in about twenty-four hours.

State of Preservation of Victims.

Fabre has preserved the beetles of a *Cerceris* for more than a month without their losing their freshness. The crickets of the yellow-winged *Sphex* were preserved for a month and a half, and the victims of another *Sphex* for two or three weeks. Movements, either voluntary or provoked by electricity, betrayed the presence of life. Fabre's conclusions are as follows:

1. Vegetative life is preserved for several weeks after a sting from one of these *Sphecidae*.

2. The preservation of the vegetative life is necessary to the larva.

Are these conclusions applicable to *Cerceris ornata*? The bees which have been stung and malaxed, when put into paper cornets, dried up at once. The muscles were entirely dry, like parchment, in five or six days.

Those which had been only stung did not dry so quickly, and sometimes eight or ten days after movement ceased the muscles were still easily dissociable. These results demonstrate that the result of the complete operation is speedy death.

The bees which were taken from nests never dried up so quickly as those which were operated on artificially, being killed by chloroform, by pricking them between the pro- and meso-thorax, by decapitation or other means.

Resumé of Observations on Fifteen Nests.

When the bees are taken from freshly provisioned nests before the egg has hatched the muscles may remain fresh until the eighth day or even to the ninth or longer, but in some cases, all other things being equal, dryness appears on the fifth day, and is complete on the seventh. Out of thirteen cases four were completely dry on the eighth day. The bees which were caught and killed began to dry at once and dryness was usually complete on the fifth day.

Andrenae, which are sometimes found in the nests, were given to *Cerceris* instead of *Halyctus*, with the result that they always dried more rapidly (in four or five days.)

Finally the contents of each of some freshly provisioned nests have been separated into two parts, one of which was submitted for five minutes to the vapor of chloroform in a tightly corked flask while the other remained intact. Those that had been chloroformed did not dry more quickly than the others. In some cases the chloroformed ones were still fresh when the others were perfectly dry. This experiment goes to show that a good part of the bees are really dead. One may object that they are in a state of numbness analogous to hibernation, and that as they are scarcely breathing they are not affected by chloroform. Possibly this objection is well founded but it is none the less true that this state of numbness is of very short duration, sometimes scarcely perceptible.

The bees, then, are not preserved for a month and a half. They die in ten days or even in a shorter time.

Bees are sometimes found in the cell occupied by the larva of *Cerceris*, which have plainly been dead a long time although they appear intact and show no lesion attributable to the larva. The length of time that it takes the larva to develop is not known. The eggs which have been found fastened to bees have not hatched or have hatched and then died. One of these eggs hatched on the fourth day. At other times rather big larvæ have been kept for three or four days before they spun their cocoons. Thus we have a minimum of eight days for development, and we have seen that the bees sometimes dry up in five days. It is then almost certain that the larvæ of *Cerceris* often have to eat bees which are already dead. It would be interesting to see if, as the instinct of the wasp becomes more perfect, the time necessary for the development of the larva becomes longer, as Darwin would doubtless have thought probable.

As has been seen, we are far from finding such masters in the art of paralyzing as Fabre did. Moreover, there is much variation both in method and in results. Are these signs of perfection of instinct? No. *Cerceris ornata*, from the point of view of instinct, seems to be a transitory type between the butcher wasp and the paralyzing wasp (speaking, now, only of instinct, and not of the line of descent.) The butcher wasp kills and cuts up its victim, eating what it wants and carrying the rest to the larva. The paralyzing wasp is the one that has no individual interest in its prey, as *Sphex* or *Ammophila*. Between these types we may put *Cerceris ornata*, and *Chlorion compressum* which provisions its nest with cockroaches from which the wings and legs have been cut off, certain *Pompilidae*, which, according to Goureau, cut the legs from the spiders which they capture, and *Philanthus apivorus*, which, according to Fabre, squeezes the bee to make it give up its honey (after paralyzing it), and many other cases which show various shades of evolution of instinct.

Errors of Instinct.

While *Cerceris* was away hunting, some dry sand was thrown into the nest and the entrance was then stopped with damp sand. She returned laden with prey, and seeing herself forced to resume the profession of a miner, abandoned her victim, cleared the entrance, penetrated within, came out again, and flew off in search of new prey.* After two successive trips she penetrated a third time into her dwelling and began to reject the dry sand which had been thrown in. In the midst of this sand was a bee. It was evident that in one of the trips that we had seen her make she could not reach directly to the cell which she was provisioning and dropped the victim at the place where she had to stop. Presently the wasp flew away. The hours passed on, and she returned without a bee, entered and threw out the other one which she now considered an encumbering object. Thus of two victims which were procured with great trouble, one was abandoned on the threshold, and the other was dropped half way in—neither served as food for larvae. What of that? *Cerceris* had given the sting—that was enough.

At another time a nest, one of the cells of which was not entirely provisioned, was destroyed at evening. On the next morning *Cerceris* brought a newly stung bee and placed it in the hole. On the following day she came again, charged with prey, and dropped her bee which rolled to the bottom of the excavation. She had not brought the full number for provisioning the nest. Instinct commanded her to bring them, and she obeyed, but not knowing where to put them, let them fall.

These things show the astonishing force with which a habit, once acquired, fixes itself in the brain of an insect, and is transmitted from generation to generation. It is precisely this which constitutes instinct and it is difficult to see how these facts can, as some authors would wish, make us believe that insects are incapable of acquiring habits, which, growing stronger and stronger, are substituted little by little for old ones. In a word, it is difficult to see how any one can find in them any proof of immutability of instinct.

*Our *P. punctatus*, under similar circumstances, dropped the bee while she cleared the entrance but then picked it up and took it in.

CHAPTER XVI.

ON THE SENSE OF DIRECTION IN WASPS.

Pl. IX., fig. 5; Pl. XII., figs. 1—4.

Much of a highly speculative character has been written upon the homing faculty, and, in lieu of a better explanation of certain facts, animals and certain tribes of men have been supposed to possess a sense of direction that was so far independent of experience and instruction as to be instinctive, and, consequently, to a very high degree unerring. Mr. Darwin when considering this matter in relation to bees and wasps, suggested that they kept their course by a process of dead reckoning, every turn that was taken in their excursions being noted and remembered, but Fabre, after testing this suggestion by experiments, concluded that the facts could not be explained in this way. Sir John Lubbock and Romanes have also made interesting observations on this subject which tend to confirm Fabre.

In a former paper, on the social wasps, we narrated a number of experiments which we had made to determine whether wasps could find their way back to the nest when they had been carried to a distance. These experiments served to show that the insects returned to their home unless they had been taken so far away that the over-looked country, as they circled higher and higher, presented no familiar object to their view. With the solitary wasps we have attacked the problem from the other end. In our earlier studies we observed what they did in attempting to return to the nest; in the later ones we have watched them when, after making a nest, they prepared to leave it to go out into the fields or woods in search of food or prey, thinking that the procedure of different species under these circumstances would afford a clue to the faculty upon which they depended to find their way about. If they were furnished with an innate sense of direction they would not need to make a study of the locality of the nest in order to find the way back, but if they were without this sense it would be only common prudence to take a good account of their bearings before going far afield. The minute and careful study of such small matters may not be so pleasant as philosophising about them but it is sometimes more profitable, and we may truthfully say that we have found the investigation of these details of more interest than the corresponding affairs in human life.

The sight of a bee or a wasp returning to its home, without hesitation or uncertainty, from some far distant spot is, indeed, marvellous. When we saw our first *Ammophila* perform this feat we were filled with wonder. How was it possible for her to hunt for hours, in all directions, far and wide, and then return in a direct line to a nest which had been so carefully covered over that every trace of its existence was obliterated? Looked at in this way it is indeed a mysterious process, best accounted for by giving her a sixth or a seventh sense—a sense of direction.

This, however, is not quite fair to her ladyship's intelligence, as a better acquaintance with her would prove. In reading much of the popular natural history of the day one might suppose that the insects seen flying about on a summer's day were a part of some great throng which is ever moving onward, those that are here today being replaced by a new set on the morrow. Except during certain seasons the exact opposite of this is true. The flying things about us abide in the same locality and are the inhabitants of a fairly restricted area. The garden in which we worked was, to a large extent, the home of a limited number of certain species of wasps that had resided there from birth or having found the place accidentally, had settled there permanently. To make this matter clear let us suppose the case of an individual of *A. urnaria*. In June she spent her time in sipping nectar from the onion flowers or from the sorrel that grew on the border of the garden. In July came the days of her courtship and honeymoon, and these too were passed in going from flower to flower, from one part of the garden to another. Many a day we have followed her when she flew from blossom to blossom along a row of bean plants, turning, when she reached the end, and wending her way leisurely back along the next row. Then comes a day when we see her running over the ground and looking carefully under the weeds for a good nesting-place. At last a spot is selected and she begins to dig, but two or three times before the work is completed she goes away for a short flight. When it is done, and covered over, she flies away, but returns again and again within the next few hours, to look at the spot and, perhaps, to make some little alteration in her arrangements. From this time on, until the caterpillars are stored and the egg laid, she visits her nest several times a day, so that she becomes perfectly familiar with the neighborhood, and it is not surprising, after all, that she is able to carry her prey from any point in her territory in a nearly direct line to her hole—we say nearly direct, for there was almost invariably some slight mistake in the direction which made a little looking about necessary before the exact spot was found.

After days passed in flying about the garden—going up Bean Street and down Onion Avenue, time and time again—one would think that any formal study of the precise locality of a nest might be omitted, but it was not so with our wasps. They made repeated and detailed studies of the surroundings of their nests. Moreover, when their prey was laid down for a moment on the way home, they felt the necessity of noting the place carefully before leaving it.

Of the species that catch their prey before making the nest we have good examples in *Pompilus quinquenotatus*, the tornado wasp, and *fuscipennis*, the *Pompilus* with the red girdle.

The tornado wasp may make her nest anywhere from one to ten feet from the spot on which she has deposited her spider, while *fuscipennis* never goes more than fourteen inches away. During the process of excavation both of these wasps pay several visits to the spider and frequently they have difficulty in finding it. As an example of this kind of trouble we give a diagram (Pl. XII., fig. 5), of the course followed by an individual of *fuscipennis*, after she had finished her nest, in trying to find her spider and in bringing it home. This and the other similar diagrams that are given, are reductions of large tracings that were made on the spot. Although not absolutely correct they are exact enough for all practical purposes. Whenever there is an error it is necessarily in the direction of making the path pursued by the wasp appear shorter and less complex than it really was. The individual in question had placed her spider on a cucumber vine not far from the ground. It was not hidden by leaves but was fully exposed to view. The nest was only eight inches away but when it was finished and the wasp went to bring the spider, she found it only after a search of three minutes, and then when she went back to the nest she at first passed to one side and went some inches beyond and had to retrace her steps.

We watched ten different individuals of this species and every one of them had trouble in remembering the path between the nest and the spider. Once we caught one that had just hung up her spider, and released her, almost immediately, on the same spot. She hunted about in the wildest way for fifteen minutes, going further and further away, and would never have found her treasure if we had not helped her. Such an amount of running and flying, here, there, and everywhere, would be incomprehensible in an animal endowed with an innate sense of direction, and we fear that the wasps must surrender to the bees or the cats all claim to such distinction. Certainly we have discovered no trace of it in the forty-five species that we have studied.

The best evidence that wasps depend upon a knowledge of the place in returning to their nests, is given by the pains that they take to acquire that knowledge. When *Sphex ichneumonea* was ready to dig her nest she had great difficulty in finding a place that suited her. Many a spot was merely looked at and passed by, while others, that seemed more attractive, were left after they had been excavated for a little way. At last, the nest dug, she was ready to go out and seek for her store of provision and now came a most thorough and systematic study of the surroundings. The nests that had been partly made and then deserted had been left without any circling. Evidently she was conscious of the difference and meant, now, to take all necessary precautions against losing her way. She flew in and out among the plants first in narrow circles near the surface of the ground, and now in wider and wider ones as she rose higher in the air, until at last she took a straight line and disappeared in the distance. The diagram (Pl. XII., fig. 1) gives a tracing of her first study preparatory to departure. Very often after one thorough study of the topography of her home has been made, a wasp goes away a second time with much less circling or with none at all. The second diagram (Pl. XII., fig. 2) gives a fair illustration of one of these more hasty departures. To some philosopher sitting in his study and reading learned works upon instinct and reason, this may seem all foolishness, and certainly if he prefers to believe that the wasp is endowed with a sense of direction, and that all this flying here, and circling there, has nothing to do with her method of finding her way, he is at liberty to do so, even if this does leave a rather large unexplained residuum.

If the examination of the objects about the nest makes no impression upon the wasp, or if it is not remembered, she ought not to be inconvenienced nor thrown off her track when weeds and stones are removed and the surface of the ground is smoothed over; but this is just what happens. *Aporus fasciatus* entirely lost her way when we broke off the leaf that covered her nest, but found it, without trouble, when the missing object was replaced. All of the species of *Cerceris* were extremely annoyed if we placed any new object near their nesting-places. Our *Ammophila* refused to make use of her burrow after we had drawn some deep lines in the dust before it. The same annoyance is exhibited when there is any change made near the spot upon which the prey of the wasp, whatever it may be, is deposited temporarily. We learned from experience how important it was not to disarrange the grass or plants on such occasions. The wasps are in many cases so prudent as to conceal their booty among the leaves and this made it very inconvenient to keep our eyes upon the captured prey, as was quite necessary if we wished to follow it on its travels. To avoid the discomfort of lying on the ground or of twisting the neck at some impossible angle for half an hour at a time, we sometimes gently moved the intercepting objects to one side, but even such a slight change cost us dear in time and patience as it threw the wasp out of her bearings and made it difficult for her to recover her treasure. We recall one exceedingly warm day in September when we were delayed in this way for forty minutes, when she would have seized the spider and gone on her way without a pause had we not interfered.

Very often the wind would shake the plant so that the spider or caterpillar would fall to the ground. Under these circumstances the wasp was not at all disconcerted but, on not finding her prey where she had left it, dropped at once to where it was lying. This is probably only an extension of their ordinary habits. A wasp that takes spiders learns to follow them as they drop from the web on being disturbed. In this they are evidently guided by sight, but perhaps they are also aided by the sense of smell under other conditions, to the extent, at least, of recognizing the place upon which their prey has lain. With so much to build upon it is easy to see how natural selection may have perfected the habit. We are delaying a long time over details but we feel that to invoke an unknown sense is only permissible after a careful study of the daily life of the animals in question has left the problem unsolved.

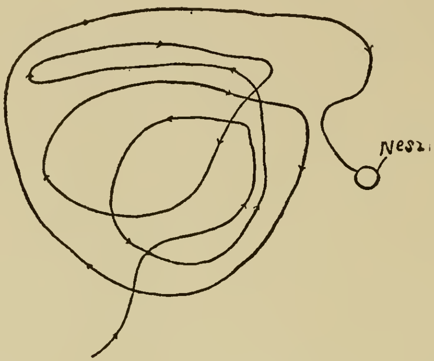
Among the wasps that first make the nest and then provision the larder, *Astata bicolor* is one of the most interesting. She makes a permanent abiding-place and probably uses it until all of her eggs are laid. It is evident that since she comes and goes many times during the several weeks of her occupation she does not need to make a prolonged study of the environment at every departure. Her first survey, just after the nest is completed, is most thorough, and, as a usual thing, when she first comes out on each succeeding morning, she reviews the situation more or less carefully. Individuals differ in this respect, however, some studying their local habitat much more than others. In this as well as in all other matters our observations are in complete accord with those of Sir John Lubbock who says: "Indeed, many of my experiences seem to show not only a difference of character in the different species of ants, but that even within the limits of the same species there are individual differences between ants, just as between men."*

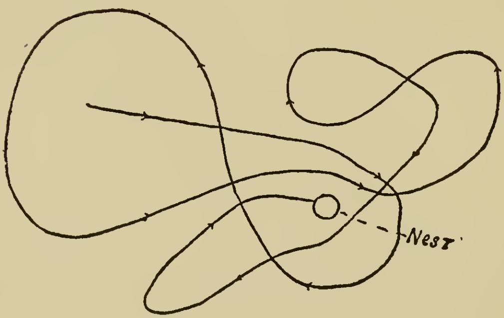
Astata bicolor made her study in a different way from *Sphex ichneumonea*. She first flew from the nest to a spot near by and settled there, returning, after a moment, to the nest, or else flying to another resting place. After pausing in a number of places (in the case of the one followed in the diagram, thirteen), she finishes by a rapid zig-zag flight. (Pl. XII., fig. 3.) Another wasp of this species, *unicolor*, differed from *bicolor* in not returning to the nest from the different resting places, and in walking from one to another of them instead of flying, although the last part of the study was made on the wing. (Pl. IX., fig. 5, and Pl. XII., fig. 4.) After we had excavated a *unicolor* nest, the owner dug a second hole five inches away. At eleven o'clock of the day on which this nest was completed she went away and was gone until fifteen minutes after one. Upon her return she was much perplexed as to the situation of her home, there evidently being some confusion in her mind between the old nest and the new one. At first she alighted upon the first site and scratched away a little earth, and then explored several other places, working about for twelve minutes, when she at last found the right spot.

Cerceris deserta was one of the wasps that objected strongly to our presence, and she also made a great deal of fuss about leaving her nest. Nearly all the species circle before leaving a spot to which they intend to return, but *deserta* begins her flight with a series of short zig-zags in the form of a half circle

*Ants, Bees, and Wasps, p. 95.

on one side of the nest. (Pl. IX., fig. 1.) *C. nigrescens*, too, began with semi-circles, while *C. clypeata* flew entirely around and around the opening. The contrast between the deliberate movements of *Astata* and the rapid flight of *Cerceris* is quite remarkable.





The last wasp that we studied in the summer of 1897 was *Tachytes sp.*? This species stores her nest with young grasshoppers and after catching them she usually has the greatest difficulty in getting back to her nest. The above diagrams show just the number of turns made by one individual in bringing home her two grasshoppers.

We have now given a sufficient number of instances, from widely separated genera, to show the care that is taken by wasps to acquaint themselves with the surroundings of their nests. It has also been shown that in spite of all this care they frequently have trouble in finding their way about. All these facts have led us to conclude that wasps are guided in their movements by their memory of localities. They go from place to place quite readily because they are familiar with the details of the landscape in the district they inhabit. Fair eyesight and a moderately good memory on their part, are all that need be assumed in this simple explanation of the problem.

When working with the social wasps some years ago we were struck by the rapid way in which they entered and left the nest. This, however, is only an apparent exception to the rule. We have seen the young workers of *Polistes fusca* make repeated locality studies when they first began to venture away from home, but as they occupy the same nest all summer they of course grow more and more familiar with their surroundings, until they become so thoroughly acquainted with them that they can find their way without the least difficulty. We have no doubt that with them, as with the solitary wasps, the faculty is not instinctive, but is the direct outcome of individual experience.

CHAPTER XVII.

THE STINGING HABIT IN WASPS.

Among writers on psychology and biology there are few subjects that have given rise to more speculation than the origin and purpose of the stinging habits of hymenoptera. Each school of philosophy claims the solitary wasp as evidence of its favorite opinions. That admirable observer, Fabre, remarks that Darwin dreaded much the problem of instinct and that had he known the results of his—Fabre's—latest observations on the stinging habits of solitary wasps his anxiety would have resulted in a frank avowal of impotence to make instinct enter the mould of his formula; while we, on the other hand, find among these very habits good examples of the workings of natural selection.

Writers on this subject have uniformily acsumed—upon what evidence we have thus far been unable to discover—that the wasp, instinctively or intelligently, uses its sting for the single purpose of paralyzing without killing its prey, that it may thus provide its offspring with a fresh supply of food. To show to what extremes this idea has been carried let us quote a remarkable passage from Eimer. He says: "When the nest is ready, the wasp brings into it larvæ of beetles and other insects, which she has paralyzed by stinging them in the ganglia which govern muscular action. This is one of the most marvellous instincts that exist; since the wasp operates on various larvæ with nervous systems of various forms, she must effect the paralysis in various ways, and even apart from this, she makes a physiological experiment which is far in advance of the knowledge of man. The wasp thus carries one motionless but living larva after another into her tube until it is full, and she rolls up the larvæ and packs them so skilfully that they take up as little room as possible. Finally, she lays her egg in the store of living food, and closes the opening with clay. Then she begins a new tube, and so lays one egg after another.

"What a wonderful contrivance! What calculation on the part of the animal must have been necessary to discover it! The larvæ of the wasp require animal food. Dead food enclosed in the cell would soon putrefy, living active animals would disturb the egg, and accordingly the wasp paralyses grubs and packs them like sacks of meal one after another in the cell. How did she arrive at this habit? At the beginning she probably killed larvæ by stinging them anywhere, and then placed them in the cell. The bad results of this showed themselves; the larvæ putrefied before they could serve as food for the larval wasps. In the meantime the mother-wasp discovered that those larvæ which she had stung in particular parts of the body were motionless but still alive, and then she concluded that larvæ stung in this particular way could be kept for a longer time unchanged as living motionless food. It may be suggested that the wasp only paralyzed the larvæ in order to carry them more easily; but even if this were the case, she must, since she now invariably acts in this way, have drawn a conclusion by deductive reasoning.

"In this case it is absolutely impossible that the animal has arrived at its habit otherwise than by reflection upon the facts of experience."

Here we have as pretty an account of the habits of wasps as could have been given in a fairy book. One can hardly be expected to take such statements seriously, since it is certain that the writer has no knowledge of the life histories of these insects.

In "Mental Evolution in Animals" Mr. Romanes says: "Several species of the Hymenoptera display what I think may be justly deemed the most remarkable instincts in the world. These consist in stinging spiders, insects, and caterpillars *in their chief nerve centers,* in consequence of which the victims *are not killed outright*, but rendered motionless; they are then conveyed to a burrow previously formed by the *Sphex*, and, continuing to live in their paralyzed condition *for several weeks are at last available* as food for the larvæ when there are hatched. Of course the extraordinary fact which stands to be explained is that of the *precise anatomical*, not to say also *physiological knowledge* which appears to be displayed by the insect in *stinging only the nerve centers of its prey*."*

Before beginning any discussion of this remarkable instinct it is most important that we have before us the facts that are to be explained. Romanes depended upon Fabre for his knowledge of the subject, and while Fabre is unquestionably the most accurate of observers it does not necessarily follow that all of his inferences must be accepted. We have used the quotation from Romanes because it represents the current opinion of naturalists on the subject, and also because it presents the instinct as dependent upon several matters of fact. The first assertion, that the prey is stung in the chief nerve-centers is not a matter of ascertained fact at all but an inference drawn from the observation that some of the victims are not killed but only paralyzed. The next step in the argument is a more or less unconscious one, namely, that the wasp does not desire to kill but *means* to paralyze. Then comes the assertion that the prey remains motionless for several weeks. So far as we know the facts relating to this point, they are as follows: Out of our forty-five species of solitary wasps about one-third kill their prey outright. Of those that remain there is not a single species in which the sting is given with invariable accuracy. To judge from the results, they scarcely sting twice alike, since the victims of the same wasp may be killed at once or may live from one day to six weeks, or perhaps ultimately recover. Even the caterpillars of *Ammophila*, the most distinguished surgeon among the aculeate hymenoptera, live anywhere from two to forty days.

To take a rapid review of some of the genera, among the

*The italics are ours.

Crabronidae the two species with which we are familiar almost invariably store up flies that are killed before they are brought into the nest; our common *Diodontus*, as well as our *Stigmus*, stores up dead aphides; *Rhopalum* stores dead gnats; *Oxybelus* and *Bembex* kill their flies; nearly all of the beetles taken by our *Cerceris* were dead, there being in all these cases an occasional exception, one out of twenty-five or thirty being left alive. *Astata bicolor* kills at least half of her bugs before storing them. Turning to the spider hunters the French *Pelopaei* are always obliged, according to Fabre, to content themselves with cadavers, while ours killed most of their spiders in stinging them and packing them away, and so many more died shortly after the nest was sealed that by the time the egg hatched not more than a third were still alive. It has been supposed that with these *Pelopaei*, the wasp mother protected her nurslings from the evils of unwholesome diet by laying up large numbers of small spiders instead of a few large ones, the process of decomposition being hastened after a break has been made in the skin. *Agenia bombycina* deliberately breaks the skin of the one large spider which she places in her cell, by cutting off all the legs to make it fit better. Her young are certainly fed upon dead matter since even if the spider survived her sting it would die under this severe operation. Our little friend, the tornado wasp, gives her offspring but one spider, and this at the moment of its entombment is quite as often dead as alive. *Pompilus marginatus* uses the same method, killing as frequently as not, and with both of the spiders that we saw taken by *Salius* the sting proved fatal. As has been said *Ammophila*, the most skillful operator of all, stings her caterpillars in so uncertain and variable a manner that many of them die before they are attacked by the larva. It must be acknowledged that if the wasps are really aiming to produce a state of paralysis, and especially if they are trying for even results, they are one and all of them in the novitiate state, and are not as yet entitled to rank as masters in the art. However this inference as to what they are striving for is purely gratuitous since there is nothing in such a refined operation that has the slightest utility for them. Should the wasps themselves be permitted to ask a question at this point they would probably inquire why we should imagine that they need to preserve the prey for "several weeks," when their larvæ hatch and begin to devour it in from one to three days?

The assumption that the larvæ must be nourished upon fresh food is the central point from which all these wonderful inferences are drawn. Strangely enough, in all these speculations a very important fact has been overlooked—the fact, now fully established, that the larvæ are able to subsist on prey that has been killed outright, and that where they are nourished upon a single insect or spider, the food, although it must begin to decompose within a few days, still serves its purpose through the whole period of alimentation. Clearly then, the purpose of the stinging is not to paralyze and preserve the prey alive, since the wasp has no reason for attempting any such difficult procedure, the larva thriving quite as well upon dead as upon living food.

Much of the mystery that surrounds the stinging operation depends upon the supposition that the wasps are enabled by some power that serves them in lieu of anatomical knowledge, to sting the center of some particular ganglion without the variation of a hair's breadth to the right or left.

"All," says Fabre, "from first to last shows us as clear as a drop of water that the external structure of the victim goes for nothing in the method used. It is the internal anatomy that determines it. The points touched are not the most penetrable; they fulfill a major condition beside which penetrability is unimportant. This condition is nothing less than the immediate neighborhood of the nervous center the influence of which must be abolished. Body to body with its prey, soft or hard, the depredator comports itself as if it knew the locality of the apparatus of innervation better than any one of us." Writing of another wasp (*Scolia*) he says that she "wishes her prey inert but alive; she does not want a cadaver which would soon be poison to her young. * * * A millimeter upward kills, a millimeter downward paralyzes—on this slight inclination depends the race of *Scolia*."

As a striking example of the wonderful precision and discrimination practiced by wasps in stinging their prey Fabre cites *Philanthus apivorus* which, by a single stroke in the cervical ganglion, inflicts death so suddenly that every muscle is relaxed. If this manœuvre were not performed with accuracy the wasp would be unable to suck the honey from the dead bee; and if the honey were left in the bee it would harm the larva for which the victim is destined. The utility of the whole performance rests upon the pernicious action of honey as food for young wasps, and Fabre has done what he can to test this point by feeding the larvæ upon bees from which the honey was not removed, as well as upon honey alone, with the result that when thus treated they invariably died. But larvæ under artificial conditions die from all sorts of causes and we cannot but feel that he has been too ready to draw his conclusions when we find that the young of *Cerceris ornata*, observed by Marchal, thrive upon bees from which the honey has not been removed.

The sting in both bees and wasps, was originally an ovipositor and even today, in the egg bearers, its most important use is to direct and place the newly laid ovum. There can be little doubt that its character as a weapon of offense and defense has been added later to its primary use. In the social wasps as well as in the social and solitary bees, its use is confined to defensive operations, even such genera as *Polistes* and *Vespa*, that feed their young on animal food, not bringing it into play to aid them in the capture of prey, since they have sufficient weapons in their strong mandibles. Moreover, it is probable that there are many solitary wasps that never sting their victims. If, in the nest of *Bembex*, flies are found that have survived the squeezing of the thorax, no one suggests that there is anything mysterious or remarkable in the matter, but let another wasp subdue its victim by means of the sting instead of the mandibles and we overlook the explanation, so near at hand, that all that it does, in most instances, is to overcome the resistance of its prey. We believe that the primary purpose of the stinging is to overcome resistance and to prevent the escape of the victims, and that incidentally some of them are killed and others are paralyzed.

Monteiro saw a combat in which a wasp stabbed a spider right in the abdomen "when it instantly curled up its legs and dropped like dead to the ground." We, ourselves, have often witnessed such fights and the effect of the poison of the wasp is as instantaneous as an electric shock. The habit of stinging in the ganglion (where that habit is found) has doubtless been developed through natural selection, the power of quickly and effectively reducing a vigorous foe to absolute helplessness being clearly an advantage. With those families that live on creatures that are themselves armed with poisonous falces, as in the case of spiders, we see an additional reason why the practice of stinging to disarm them would be beneficial in the struggle for existence; and it may be that we have here a partial clue to the infrequent use of the sting in flycatchers.

Pompilus scelestus takes a spider much larger than herself, reducing it in a moment to a condition of absolute helplessness. For three or four hours after it is stung it is as limp as a drop of jelly so that it can be dragged to the nest and packed tightly down into its close fitting tomb. Within the next twenty-four hours it recovers, showing that the nerve-center has not been wounded by the lance of the wasp, but only benumbed by the transfusion of the poison. The rapid return to health has no menace for *scelestus* and no advantage for the spider, since the earth will hold it motionless until its life is ended by the growing larva.

But what of *Sphex* and *Ammophila*? For the first the cicada or grasshopper is strong and active and it is obviously desirable to put it into an inert condition as speedily as possible, not only to prevent its escape, but for facility in transporting it. *Ammophila* has often far to carry her caterpillar, and this, too, through grass and over many a rough road. With a perfectly limp and unresisting burden it frequently takes an hour or two, and with a struggling captive the day would not be long enough. To bring so soft a creature into a manageable state by using the mandibles would reduce it to a pulpy mass and deprive it of half its value, and the process of malaxation, which often supplements the stinging, can only be practiced after the caterpillar is quiet. As to the numerous stings that are given by *Ammophila* it is plain, from the variations that have been found, that the number of wounds and the order in which they are given are not important factors in her life history. From what we have seen, one sting, or at most three, one in the middle and another at each extremity, would be quite sufficient for all her purposes. Perhaps the others are supernumerary, like the several nests made by many species of birds, all but one of which are afterward destroyed or deserted, the purpose of the stinging, nevertheless, being to overcome, just as the purpose of nest building is nidification. In any case the extra stings cannot be held to invalidate the hypothesis which we have offered to explain the general purpose of the act.

CHAPTER XVIII.

CONCLUSION.

Our study of the activities of wasps has satisfied us that it is impracticable to classify them in any simple way. The old notion that the acts of bees, wasps, and ants were all varying forms of instinct is no longer tenable and must give way to a more philosophical view. It would appear to be quite certain that there are not only instinctive acts but acts of intelligence as well, and a third variety also—acts that are probably due to imitation, although whether much or little intelligence accompanies this imitation, is admittedly difficult to determine. Again, acts that are instinctive in one species may be intelligent in another, and we may even assert that there is a considerable variation in the amount of intelligence displayed by different individuals of the same species. We have met with such difficulty in our attempts to arrange the activities of wasps in different groups that we are forced to the conclusion that any scheme of classification is merely a convenience, useful for purposes of study or generalization, but not to be taken for an absolutely true expression of all the facts. This kind of perplexity is well understood and allowed for in all morphological work but it has never been fully realized in the study of habits. The explanation is not far to seek. The habits of but few animals have been studied in sufficient detail to bring out the evidence that there is as much variation on the psychological as on the morphological side.

Another difficulty which has been clearly stated by both Morgan and Wundt, namely, the tendency to interpret the actions of animals in terms of our own consciousness, must always be with us. Wundt himself after indirectly criticising Romanes for this confusion, falls into it himself. He tells how, when a boy, he made some observations upon a garden spider.

He says: "I had made myself, as a boy, a fly-trap, like a pigeon-cote. The flies were attracted by scattered sugar, and caught as soon as they entered the cage. Behind the trap was a second box, separated from it by a sliding door, which could be opened or shut at pleasure. In this I had put a large garden spider. Cage and box were provided with glass windows on the top, so that I could quite well observe anything that was going on inside. At first nothing particular happened. When some flies had been caught and the slide was drawn out the spider, of course, rushed upon her prey and devoured them, leaving only the legs, head, and wings. That went on for some time. The spider was sometimes let into the cage, sometimes confined to her own box. But one day I made a notable discovery. During an absence the slide had been accidently left open for some little while. When I came to shut it, I found that there was an unusual resistance. As I looked more closely, I saw that the spider had drawn a large number of thick threads directly under the lifted door, and that these were preventing my closing it, as though they had been so many cords tied across it.

"What was going on in the spider's mind before she took this step towards self-preservation—a step, mark you, which but for the *vis major* of the boy-master would have been perfectly adequate to effect the desired result? The animal psychologist will possibly say: 'The spider must first of all have come to understand the mechanism of the sliding-door, and must have said to herself that a force operating in a definite direction could be compensated by another in the opposite direction. Then she set to work, relying upon the perfectly correct inference that if she could only make movement of the door impossible, she would always have access to the victims of her murderous desires. There you have a consideration of general issues, an accurate prevision, and a cautious balancing of cause and effect, end and means.' Well, I am rather inclined to explain the matter otherwise. I imagine that as the days went by there had been formed in the mind of the spider a determinate association on the one hand between free entry into the cage and the pleasurable feeling attending satisfaction of the nutritive instinct, and on the other between the closed slide and the unpleasant feeling of hunger and inhibited impulse. Now in her free life the spider had always employed her web in the service of the nutritive impulse. Association had therefore grown up between definite positions of her web and definite peculiarities of the objects to which it was attached, as well as changes which it produced in the positions of certain of these objects,—leaves, small twigs, etc. The impression of the falling slide, that is, called up by association the idea of other objects similarly moved which had been held in their place by threads properly spun; and finally there were connected with this association the other two of pleasure and raising, unpleasantness and closing, of the door. That was surely enough to rouse the prisoner to action. Any other intellectual or inventive activity is entirely unnecessary. If she had not had these associations at her disposal, she would certainly never have hit upon the plan she did."

Had Wundt been familiar with the habits of spiders he would have known that whenever they are confined they walk around and around the cage leaving behind them lines of web. Of course many lines passed under his little sliding door and when he came to close it there was a slight resistance. These are the facts. His inference that there was even the remotest intention on the part of his prisoner, to hinder the movement of the door is entirely gratuitous. Even the simpler mental states that are supposed to have passed through the mind of the spider were the product of Wundt's own imagination.* He does not, how-

*This quotation from Wundt furnishes a good example of the futility of any attempt to understand the meaning of the actions of animals until one has become well acquainted with their life habits. When Froude, in his "Cat's Pilgrimage," makes the bee urge upon all animals that it is their plain duty to make honey, while the cow expresses a pained surprise that many insects neglect to furnish milk, we see how a wider knowledge on their part would have prevented much misunderstanding.

ever, fall into the unfortunate habit of many workers in the field of comparative psychology—that of withholding such a statement of the facts as will enable one to mark them off from the inferences of the observer.

We arrange the activities of the wasps that we have studied into two groups, Instincts, and Acts of Intelligence, it being understood that these classes pass by insensible stages into each other, and that acts that are purely instinctive when performed for the first time, are probably in some degree modified by individual experience. In this classification the question of origin is not considered. The facts are grouped under the two heads, the inferences that they warrant being left for later consideration. Under the term Instinct we place all complex acts that are performed previous to experience and in a similar manner by all members of the same sex and race, leaving out as non-essential, at this time, the question of whether they are or are not accompanied by consciousness. Under Intelligence we place those conscious actions which are more or less modifiable by experience. It is this power that enables an insect to seek, accept, refuse, choose,—to decline to make use of this or to turn to account some other thing. Many writers prefer the term Adaptation for these activities and it possesses certain advantages. With these definitions in mind, let us group the activities of wasps under the two heads.

Instinct.

With the *Pelopaeus* wasps we were present on several occasions when the young emerged from the pupa case and gnawed their way out of the mud cell. They were limp and their wings had not perfectly hardened, and yet when we touched them they tried to attack us, thrusting out the sting and moving the abdomen about in various directions. These movements were well directed, and, so far as we could observe, quite as perfect as in the adult wasp. Stinging, then, is an instinctive act.

The particular method of attack and capture practiced by each species in securing its prey is instinctive. *Ammophila* pricks a number of ganglia along the ventral face of the caterpillar; *Pelopaeus*, we believe, stabs the spider in the cephalothorax, and probably the several species of *Pompilus* do the same. *Astata bicolor* adopts the same tactics in capturing her bugs, while it is said of the fly-catchers that they commonly overcome their victims without using the sting. It is by instinct, too, that these wasps take their proper food supply, one worms, another spiders, a third flies or beetles. So strong and deeply seated is the preference that no fly robber ever takes spiders, nor will the ravisher of the spiders change to beetles or bugs.

The mode of carrying their booty is a true instinct. *Pompilus* takes hold of her spider anywhere, but always drags it over the ground, walking backward; *Oxybelus* clasps her fly with the hind legs, while *Bembex* uses the second pair to hold hers tightly against the under side of her thorax. Each works after her own fashion and in a way that is uniform for each species.

The capturing of the victim before the hole is made, as in the case of *P. quinquenotatus*, or the reverse method pursued by *Astata*, *Ammophila*, *Bembex*, and others of preparing the nest before the food supply is secured is certainly instinctive; as is also the way in which some of these wasps act after bringing the prey to the nest. For example *S. ichneumonea* places her grasshopper just at the entrance to the excavation and then enters to see that all is right before dragging it in. In experimenting with a French *Sphex* which has the same habit, Fabre moved the creature a little way off; the wasp came out, brought it to the opening as before, and went within a second time. This was repeated again and again until the patience of the naturalist was exhausted, and the persistent wasp took her booty in after her appropriate fashion. She must place the grasshopper just so close to the doorway, she must then descend and examine the nest, and after that must come out and drag it down. Nothing less than the performance of these acts in a certain order satisfies her impulse. There must be no disturbance of the regular method or she refuses to proceed. Again, we see *Oxybelus* scratching open her nest while on the wing and entering at once with the fly held tightly in her legs. Each way is characteristic of the species and would be an important part of any definition of the animal based upon its habits.

The general style of the nest depends upon instinct. *Trypoxylon* uses hollow passages in trees, posts, straws, or brick walls; *Diodontus americanus*, a member of the same family, always burrows in the ground, as do *Bembex*, *Ammophila*, and *Sphex*. In the case of *Trypoxylon* the passage may be ready for use or may require more or less preparation; the instinctive part is the impulse that impels the insect to use a certain kind of habitation. Any one familiar with *T. rubrocinctum* would never look for their nests in standing stems or under stones; to use Mr. Morgan's test, he would be willing to bet on the general style of the dwelling place. All of these acts are similarly performed by individuals of the same sex and race, not in circumstantial detail but quite in the same way in a broad sense. Variation is always present but the tendency to depart from a certain type is not excessive. In the drawing of the nest of *Cerceris nigrescens* the burrow is seen to be tortuous, this style of work being common to many species in the genus and very characteristic. No *Sphex* nor *Ammophila* constructs any such tunnel. The adherence of all the members of a species to a certain style of architecture, is, then, due to instinct.

The spinning of the cocoon, in those species in which the larva is protected in this manner, and its shape, are instinctive. We find that closely allied species in the same genus make very different cocoons as is seen in *T. rubrocinctum* and *T. bidentatum*. Some wasps never cover themselves with a cocoon, as in the Australian species *Alastor eriurgus* and *Abispa splendida*.* It is a well known fact that silk worms sometimes omit the spinning of a cocoon; but this does not affect the argument since

*Nests and Habits of Australian Vespidae and Larridae, by Walter W. Froggatt, Proceedings Linnean Society of N. S. W., Vol. IX., Series 2nd.

the descendants of these individuals make the characteristic covering. Such cases are probably due to individual variation or perhaps to atavism, this throwing back being not uncommon among forms that are well known.

Not all of the instinctive facts here enumerated are displayed by each species studied, although as a general proposition they are common to most of them. We have doubtless overlooked some activities that should come under this head as we have not made a thorough study of any sufficient number of species to make a final settlement of the matter. For convenience we give the eight primary instincts that we have enumerated in tabular form.

Instincts.

1. Stinging.
2. Taking a particular kind of food.
3. Method of attacking and capturing prey.
4. Method of carrying prey.
5. Preparing nest and then capturing prey, or the reverse.
6. The mode of taking prey into the nest.
7. The general style or locality of nest.
8. The spinning or not spinning of a cocoon, and its specific form when one is made.

Intelligence.

It is obviously more difficult to distinguish actions of this class than of the other. One must be familiar with the normal conditions of the insects in question before he is able to note those slight changes in the environment that offer some opportunity for an adaptation of means to ends, or before he is competent to devise experiments which will test their powers in this direction.

We find two classes of intelligent actions among the hymenoptera which are sufficiently distinct to be considered separately, although, like all natural groups, they grade into each other. The first of these includes those actions that are performed by large numbers in a similar fashion under like conditions, while in the second class each act is an individual affair, as where a single wasp, uninfluenced in any way by the example of those about it, displays unusual intelligence in grappling with the affairs of life. Examples of the first class are found in such modifications of instinct as are shown by *Pelopaeus* and other wasps in the character of their habitations. *Pelopaeus*, instead of building in hollow trees or under shelving rocks, as was the ancient custom of the race, now nests in chimneys, or under the eaves of buildings. We have found *T. rubrocinctum* taking advantage of the face of a straw stack that had been cut off smoothly as the cattle were fed through the winter. The same power of adaptation is shown by Fabre's experiment with *Osmia*, in which he took two dozen nests in shells from a quarry, where the bees had been nesting for centuries, and placed them in his study along with some empty shells and some hollow stems. When the bees come out, in the spring, nearly all of them selected the stalks to build in as being better suited to their use than the shells. All of these changes are intelligent adaptations to new modes of life, serving to keep the species in harmony with its surroundings. The same thing may be seen when a number of social wasps work together to replace the roof of their nest when it has been torn off.

An instance of the second class is seen in one of our examples of *Pompilus marginatus*. This species, while searching for a nesting-place, leaves its spider lying on the ground or hides it under a lump of earth, in either of which positions the booty is subject to the attacks of ants; the wasp in question improved upon the custom of her tribe by carrying the spider up into a plant and hanging it there. We have now and then seen a queen of *Polistes fusca* occupy a comb of the previous year instead of building a new one for herself, showing a better mental equipment than her sisters who were not strong minded enough to change their ways and so built new nests alongside of unoccupied old ones which were in good condition. In *Bembex* society it is good form to close the door on leaving home, but sometimes a wasp will save time by leaving the entrance open. This, however, is a doubtful case as the advantage would, perhaps, be more than balanced by the exposure of the nest to parasites. The most conspicuous example that we have seen of intelligence among wasps, was in that individual of *Ammophila* that rose above her fellows by using a stone to pound down the earth over her nest.

The general impression that remains with us as a result of our study of these activities is that their complexity and perfection have been greatly overestimated. We have found them in all stages of development and are convinced that they have passed through many degrees, from the simple to the complex, by the action of natural selection. Indeed, we find in them beautiful examples of the survival of the fittest.

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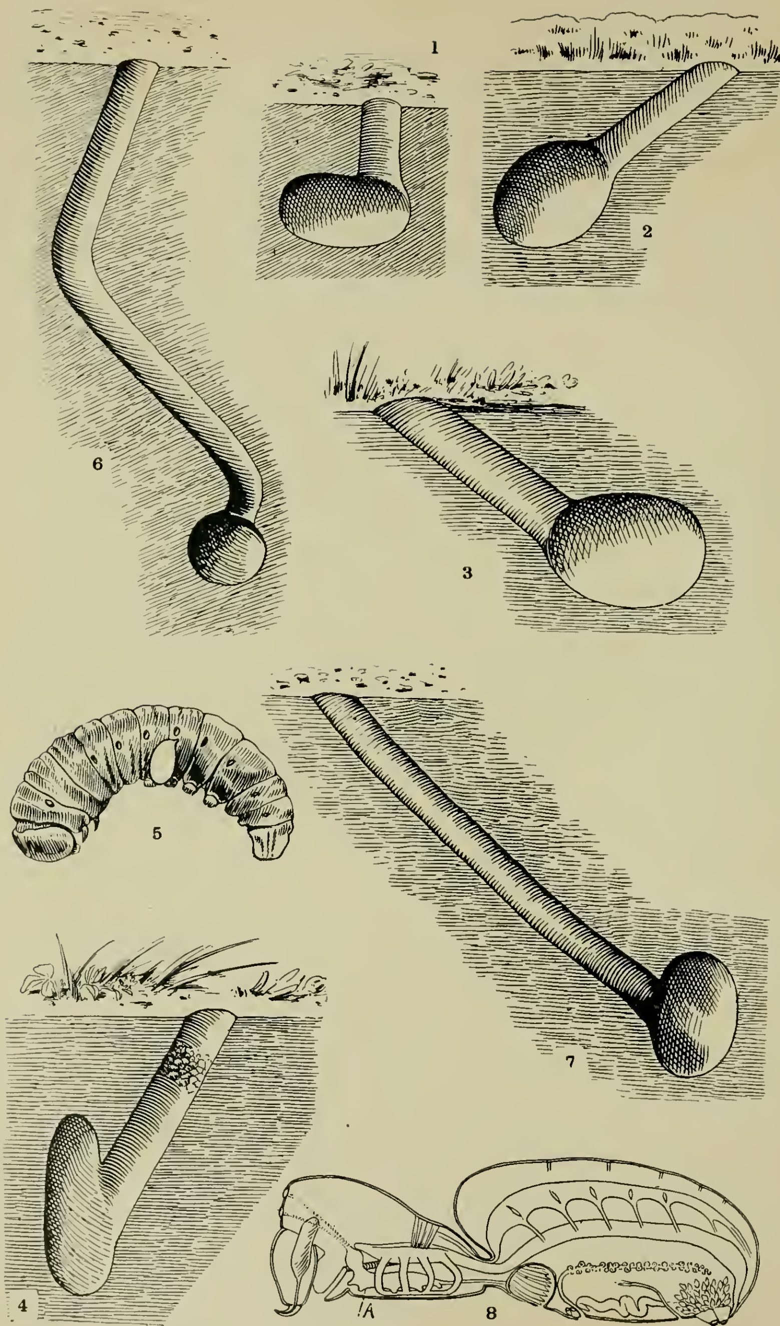
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PLATE VIII.

Figs. 1–2. Nests of *Ammophila urnaria*, ¾ natural size.

Figs. 3–4. Nests of *Ammophila urnaria*, natural size.

Fig. 5. Caterpillar with egg of *Ammophila urnaria.*

Fig. 6. Nest of *Cerceris nigrescens*, tunnel 3½ inches long.

Fig. 7. Nest of *Oxgbelus quadrinotatus*, natural size.

Fig. 8. Side view of spider: A, nervous system. (After Emerton.)

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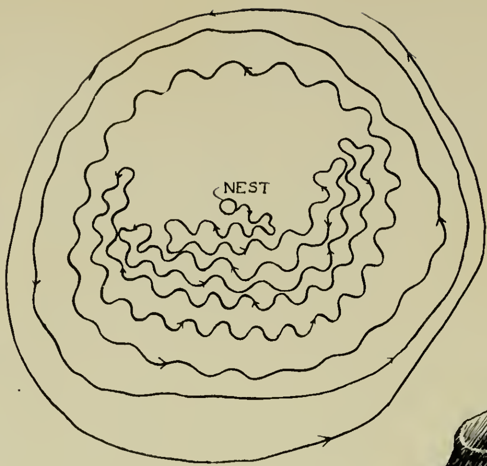

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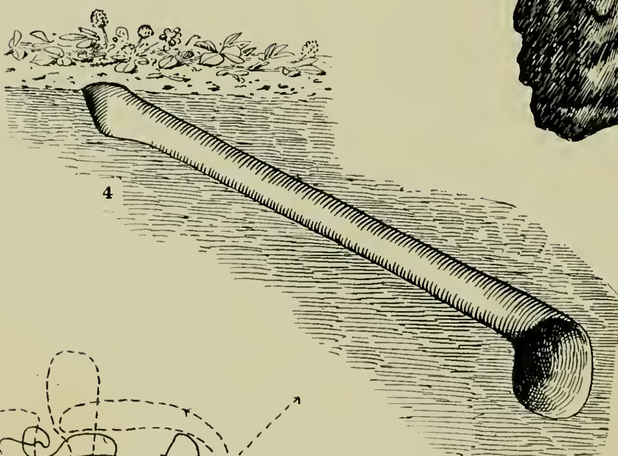

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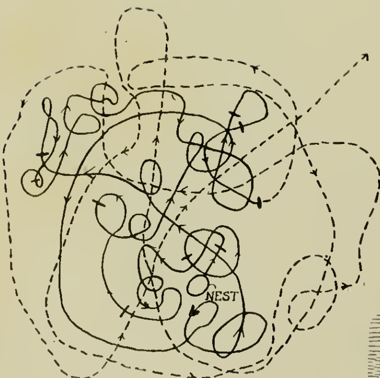

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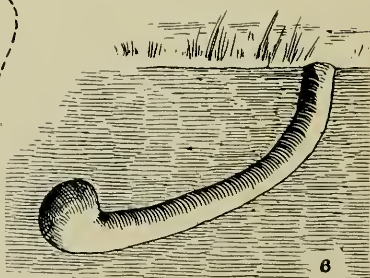

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PLATE IX.

FIG. 1. Locality study of *Cerceris deserta.*

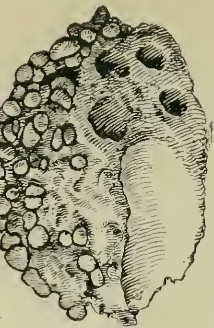
FIG. 2. *Lycosa Kochii*, found in nest of *Agenia bombycina*, $\times$ 2.

FIG. 3. Nest of *Agenia bombycina*, $\times$ 2.

FIG. 4. Nest of *Bembex spinolae;* tunnel 3½ inches long; pocket 2 inches below surface.

FIG. 5. Locality study of *Astata unicolor.* The continuous line shows the course walked over by the wasp; the short marks at a right angle indicate resting-places; the broken line indicates flight.

FIG. 6. Nest of *Astata bicolor;* tunnel 2¼ inches long; pocket 1½ inches below surface.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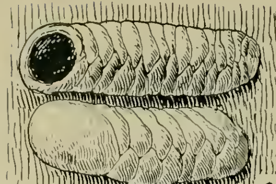
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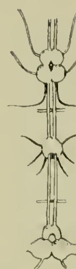
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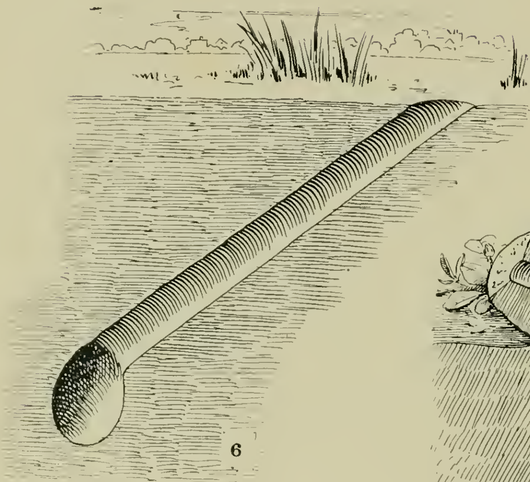
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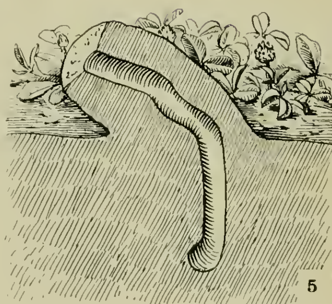
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7


8

PLATE X.

FIG. 1. Variety of nest of *Pelopaeus coeruleus*, showing lumps of mud plastered on outside.

FIG. 2. Vertical cell of nest of *Pelopaeus coeruleus*.

FIG. 3. Horizontal cells of nest of *Pelopaeus coeruleus*.

FIG. 4. Nervous system of *Halyctus*. (After Marchal.)

FIG. 5. Nest of *Diodontus americanus*, natural size.

FIG. 6. Nest of *Pompilus quinquenotatus*, nearly natural size.

FIGS. 7–8. Examples of *Epeira strix* that have been paralyzed and hung up on bean and sorrel plants by *Pompilus quinquenotatus*, that they may be out of the way of ants while she digs her nest.

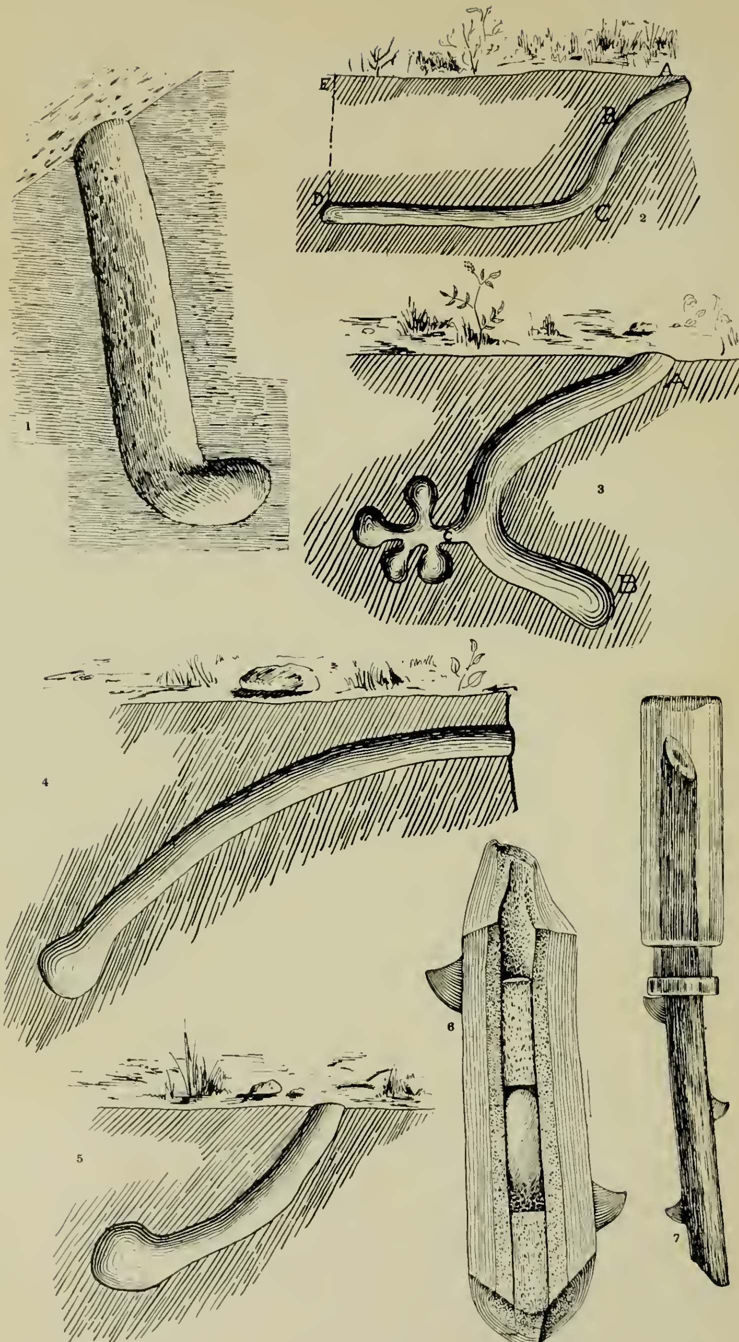

1
E
B
A
D
C
2
A
3
B
4
6
5
7

PLATE XI.

FIG. 1. Nest of *Sphex ichneumonea;* tunnel 7½ inches long; pocket ½ inch by ¾ inch.

FIG. 2. Nest of *Philanthus punctatus;* A—B, 3½ inches; B—C, 5 inches; C—D, 14 inches; D—E, 8 inches.

FIG. 3. Nest of *Astata unicolor;* A—B, 2 inches; B—C, 1½ inches; A—C, 2 inches; C, four cells where the bugs were stored. B—C gallery occupied by wasp while in nest.

FIG. 4. Nest of *Chlorion coeruleum;* nearly ¼ natural size.

FIG. 5. Nest of *Tachytes sp?.;* tunnel 2 inches long; pocket 1½ inches below surface.

FIG. 6. Nest of *Crabro stirpicola* in blackberry stem; × 2.

FIG. 7. Bottle fastened to stem to measure work of *Crabro stirpicola.*


1
NEST
2
NEST
3
NEST
4
NEST
5
NEST

PLATE XII.

FIG. 1. A thorough locality study by *Sphex ichneumonea.*

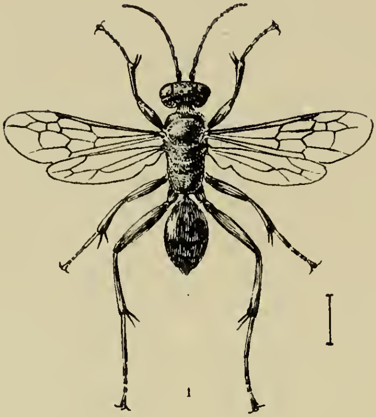
FIG. 2. A hasty locality study by *Sphex ichneumonea.*

FIG. 3. Locality study of *Astata bicolor*. The wasp flew from nest to 1, paused a moment, then flew back; then to 2, paused and flew back; then to 3, paused, then to 4, paused and flew back to nest; flew to 4, 5, 6, 7, 8 and 9, pausing at each spot, and flew back to nest along 10; flew, successively, along 11, 12 and 13, resting at the spots designated; from 13 she circled around nest in direction of arrow points and departed.

FIG. 4. A second locality study of *Astata unicolor*. The continuous line shows the course walked over by the wasp, the short marks at right angles representing resting places; the broken line indicates flight. Line 1 shows the first study, leading back to the nest, and line 2 the second, ending in flight and departure.

FIG. 5. Course followed by *Pompilus fuscipennis* in finding her spider and in retracing her steps to the nest. The nest being completed the wasp went skimming over the ground as indicated by the line, until the spider, which had previously been stung and placed upon a leaf, was found. She then dragged it some distance beyond the nest to the point 2, from which place she took it to the nest.

The locality studies are all very much reduced.



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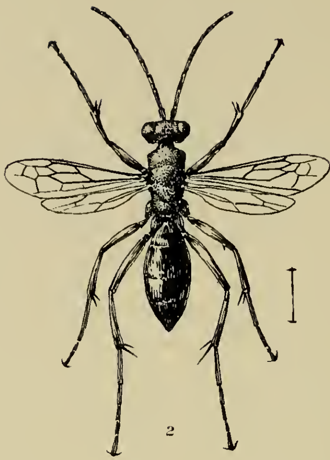

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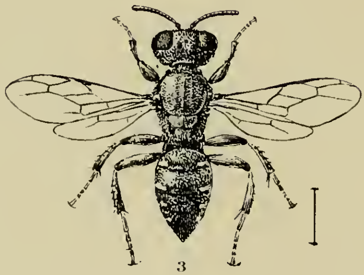

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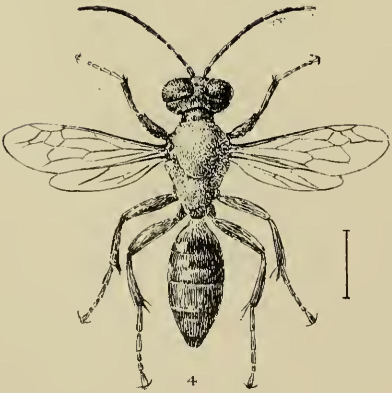

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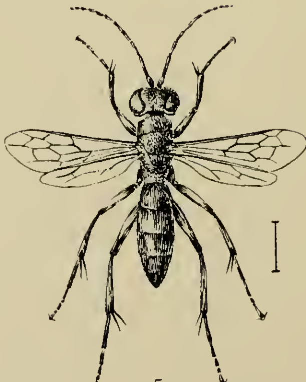

5

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PLATE XIII.

FIG. 1. *Agenia architecta* ♀, × 4.

FIG. 2. *Salius conicus* ♀, × 4.

FIG. 3. *Oxybelus quadrinotatus* ♀, × 4.

FIG. 4. *Tachytes sp?* ♀, × 4.

FIG. 5. *Aporus fasciatus* ♀, × 4.

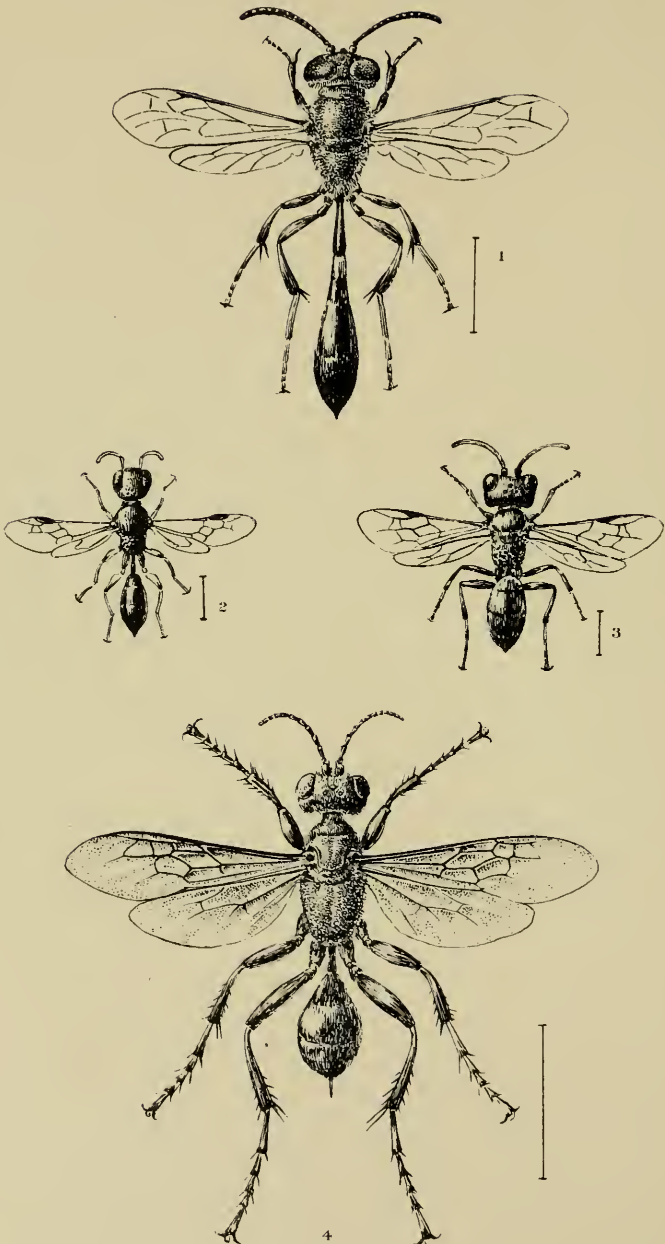

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PLATE XIV.

FIG. 1. *Trypoxylon rubrocinctum* ♀, $\times$ 4.

FIG. 2. *Stigmus americanus* ♀, $\times$ 4.

FIG. 3. *Diodontus americanus* ♀, $\times$ 4.

FIG. 4. *Priononyx atrata* ♀, $\times$ 2.