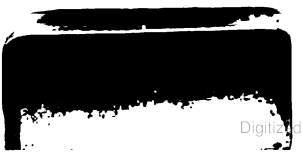

THE NATURAL HISTORY

OF THE

AGRICULTURAL ANT OF TEXAS.

A MONOGRAPH OF THE HABITS, ARCHITECTURE, AND STRUCTURE OF POGONOMYRMEX BARBATUS.

BY

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AUTHOR'S EDITION.
ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.
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TO

MY FRIENDS AND PARISHIONERS

OF THE

TABERNACLE PRESBYTERIAN CHURCH,

OF PHILADELPHIA,

WHOSE KINDNESS TO THEIR PASTOR ALLOWS THE ANNUAL SUMMER VACATIONS
WHICH HAVE MADE POSSIBLE THE PROSECUTION AND PUBLICATION
OF THE FOLLOWING AND OTHER NATURE-STUDIES,

THIS BOOK

IS AFFECTIONATELY INSCRIBED.

PREFACE.

THE best key to the habits of the whole family of ants is a complete life-history of one representative individual. The Agricultural Ant perhaps more thoroughly represents the FORMICARIÆ than any other species. Its admirable social organization; its skill as a mason in excavating its vast and well-ordered system of underground chambers; its extensive surface operations in clearing out circular court-yards to its nests, and roadways to its foraging grounds; the striking variations in its surface architecture from cones to flat disks; its highly-developed stinging powers, which place it among the most formidable of the aculeate species; and (not to mention other characteristics) that special harvesting habit to which it owes its name, and which has attracted to it an especial interest,—all these combine to make the Agricultural Ant of Texas one of the very best representatives of the emmet family in all its most striking instincts.

This fact will, it is hoped, justify the bestowment of so much attention upon one ant. From one the reader may learn all. There are, of course, differences, and wide ones, in special habits, between the agricultural and other ants. But it will certainly be found that the life-history here given will afford a clue by which the habits of most species may be successfully traced and uncovered.

The studies in anatomy, so far as they go, will also serve, in the same way, to point out the chief characteristics in

structure of the tongue, stinging organs, fore-leg, and mandibles.

The above consideration has greater force in view of the marked neglect which myrmecology has received in America. With one or two exceptions, and these quite limited, entomologists have given no attention to the systematic study of ants, and but little to the study of their habits. A wide and well-nigh unexplored field, which holds forth rarest promise of enjoyment and instruction, here opens before naturalists. It is sincerely wished that the following pages may, at least, incite some observer to enter and uncover this vast and wealthy treasure-trove of Nature.

The author has only further to say that, in presenting this book to the public, under his own name as publisher, he has acted under a necessity which naturalists have felt, and must feel, until a constantly-widening circle of readers, who find pleasure and advantage in such works, shall have so far increased its bounds as to give inducement to publishers to undertake such special nature-studies at their own responsibility.

H. C. McC.

PHILADELPHIA, December 27, 1878.

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CHAPTER I.

LITERATURE AND INTRODUCTORY REMARKS.

MR. MOGGRIDGE, in his admirable notes on harvesting ants,[1] calls attention to "the principal questions which still await solution" in the life-history of those remarkable insects. The fifth and last question is this: "Do harvesting ants exist in the Southern States of North America, in Australia, in New Zealand, or at the Cape?" The following notes will give answer concerning the first-named locality. The question had, indeed, been answered before, a fact of which Mr. Moggridge was not ignorant. In the very book from which the above question is taken (see p. 12), he places among the known harvesting ants the subject of this sketch, and cites correctly the authority by whom it became generally known to natural history, Dr. Gideon Lincecum, late of Long Point, Texas.

This gentleman's observations were originally committed to Mr. Charles Darwin, by whom they were communicated to the Journal of the Linnæan Society of London, in a note read April, 1861.[2] Five years afterwards, a paper was published in the Proceedings of the Academy of Natural Sciences of Philadelphia,[3] from the manuscript of Dr. Lincecum,

[1] Harvesting Ants and Trap-door Spiders. Supplement, p. 179.

[2] Vol. vi. p. 29, 1862.

[3] Proc. Acad. Nat. Sci. Phila., xviii., 1866, p. 323. On the Agricultural Ant of Texas, by Gideon Lincecum.

which gave, with some detail, the result of observations upon this ant, extending throughout a long residence in Texas.

Prior to either of the above dates, however, October 23, 1860, a paper was submitted to the Philadelphia Academy of Natural Sciences, entitled "The Stinging or Mound-making Ant, Myrmica (Atta) molifaciens, by S. B. Buckley." This paper was printed in the Proceedings (xii., 1860, p. 445), and is undoubtedly the first publication of the interesting habits of this emmet.

Mr. Buckley's notes are incomplete, in some respects incorrect, but in the main are true to the facts as far as they go. Some of these facts are credited to Dr. Lincecum, and it is probable that to Mr. Buckley's interest in the matter we are indebted for that gentleman's paper.

In view of the above facts, it would seem to be a strange oversight in one who had given so much attention to the habits of harvesting ants as Mr. Moggridge, to raise the question whether such creatures inhabit the Southern States of North America.

Dr. Auguste Forel, in the bibliography accompanying his Swiss Ants,[1] gives expression to the same doubt, in connection with his references to Lincecum's notes. "These observations," he says, "inspire me with little confidence."

The doubt which is thus raised concerning Dr. Lincecum's observations is a fair index of the state of mind which I found to exist among the older members of the Philadelphia Academy, who had more or less knowledge of the author, and the origin of the paper above referred to. While it was believed that there was some basis of fact in the communications made, they were thought to contain much more that was fanciful, and indeed, a shadow of doubt rested upon the whole.

In the course of my inquiries I found that the original manuscripts of this paper, as well as of one upon the Cutting Ant, the "erratic ant," and other Texan Formicariæ, were in

[1] Fourmis de la Suisse, p. 470. "Ces observations, quoique rapportées la par Ch. Darwin, m'inspirent peu de confiance."

the hands of Mr. E. T. Cresson. They had been forwarded to him, several years before, as an officer of the American Entomological Society. Mr. Cresson kindly placed these manuscripts in my hands. They were carefully read, and the reason for the suspicion with which they had been viewed was everywhere quite manifest. The venerable writer had many peculiar notions about society, religion, and the genus homo generally, which he could not refrain from thrusting—in the most untimely manner and objectionable words—into the midst of his notes. These idiosyncrasies, together with some peculiarities of spelling, grammar, and rhetoric more original than regular, had evidently raised in the minds of officers and members of the Academy a question, not as to the integrity of the author, but as to his accuracy as an observer. Several of his papers were, however (after proper corrections and condensations), published, among them the notes upon the agricultural ant. The unpublished papers in my hands have been freely used in the preparation of this work, and have contributed some valuable facts.

In the summer of 1877 I was able to visit Texas for the purpose of settling, if possible, the questions which had been raised as to the accuracy of the reports of Buckley and Lincecum. As will be seen, the observations of Dr. Lincecum were, in many important points, confirmed during that visit, and thus a strong degree of authenticity given to other *facts* recorded by him which I was not so fortunate as to note. In addition to this, a number of new facts were discovered, and many, which were but partially known, completed or enlarged. The point chosen for the field of my studies was Austin, the State capital, not only because of its high and healthful locality, but because it is in the general range of Lincecum's observations, and was known to be a populous habitat of the insects. I arrived in the city on the 4th of July, and on the 6th instant was established under canvas at "Camp Kneass,"[1]

[1] Named from Strickland Kneass, Esq., Assistant President of the Pennsylvania Railroad Company, to whose courtesy I am indebted for transportation to and

three miles southwest from Austin, beyond the Colorado River, on one of the hills that roll upward from Barton Creek, and about half a mile from that stream. The tent was pitched in a young live-oak grove within the "ranch" of two brothers, intelligent young men from the North, who had come to Texas to establish their health. I arranged with these young men to serve as my "housekeepers" and, with occasional outside help, assistants in the heavy excavations and other labors required in the prosecution of my studies. My observations were continuously conducted at this point for two weeks (July 19), and afterwards for several days in the immediate vicinity of Austin. The sole object of my visit was to study the habits of these insects and the Cutting Ant (*Atta fervens*), which is also an inhabitant of that region. My whole time after arriving on the field was, therefore, given for the three weeks of my stay to the work which I had proposed to do.

It was quite impossible, at the distance of two thousand miles, to get satisfactory information as to the best points at which to locate. The country was wholly new to me, and I was compelled to go a good deal at a venture. However, by a favoring Providence I fell at once among friends, who sympathized with my object and forwarded my plans in every way. I owe a large debt of gratitude—which, if these notes have any value, the students of natural history share—to Rev. Edward B. Wright, D.D., pastor of the First Presbyterian Church of Austin, for the assistance which he rendered me. Chiefly through this aid I was settled, with the least possible delay, in a position which was at once pleasant, healthy, and convenient for a camp, and accessible to both the species whose life-history I sought to uncover. I desire here also to acknowledge the aid given me by other citizens of Austin, particularly M. A. Taylor, M.D., and Mr. George Brush.

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from Texas. For convenience the name will be retained in subsequent references to the locality of the principal part of my observations.

After my return to Philadelphia I desired to complete my information concerning some points upon which I needed more light, and referred to Rev. Warner B. Riggs, pastor of the Presbyterian Church at Brenham, Texas. This gentleman kindly made various observations, which are referred to in the following notes, and sent me several colonies of ants for stocking my formicaries. Through Mr. Riggs I was brought into correspondence with Mr. I. D. Affleck, of Glenblythe, in the vicinity of Brenham, whose intelligent assistance, in working out various points which I submitted to him for examination, has been especially valuable. Mr. Affleck adds to a well-educated mind practical skill in agriculture, and, I am glad to say, is increasing the obligations under which he has placed me, by similar contributions to the notes on the Cutting Ant which I have now in preparation.

The studies in the anatomy of the ant will be found quite full concerning the tongue, stinging organs, mandibles, and fore-leg, which particularly excited my interest. For such value as these may have I am largely indebted to Professor J. Gibbons Hunt, M.D., of Philadelphia, who made the preparations from which my studies have been conducted, and continually aided me with his well-known admirable skill as a microscopist. In this department also I have had the benefit, not only of the printed works, but especially of the personal counsel of Dr. Auguste Forel, of Munich. This accomplished myrmecologist has contributed a figure of the stinging organs, which appears in Plate XX.

All the other figures have been traced and drawn in India-ink from my own sketches and camera lucida drawings, by Dr. Edward J. Nolan, Secretary of the Academy of Natural Sciences of Philadelphia. They have thence been reproduced by photo-lithography.

CHAPTER II.

SURFACE ARCHITECTURE AND WORK.

CAMP KNEASS is located upon the highlands of the Colorado River of Texas. The flat table-land stretches away toward the east and south, dropping here and there into depressions which form rich valleys. The soil is unequal in depth, varying from three feet or more to several inches. It is black, unctuous, very sticky in wet weather. The bed-rock is a limestone which crops out frequently, and lies in punctured and striated masses over the surface. The formicaries of the ants are scattered over the soil in vast numbers, within a few paces of one another. My tent-door was not a half-dozen steps from several large communities, and the tent itself was a regular gangway for the busy creatures. These formicaries are, for the most part, flat, circular clearings or disks, as described hereafter, communicating by well-worn roads with the surrounding herbage. They are made in the light soil of the hill-slopes, in the deep, black earth of the highlands and vales, among the rocks, everywhere, indeed. They abound along the roadsides; they are met in all parts of the city of Austin; in the very streets; on the trodden sidewalks; in gardens and yards. Even in the open court of the hotel where I lodged there was a community of ants in full activity. The court is paved solidly with stone, but through the cement which joined the slabs the ants had cut a gateway, and into and out of this they were passing all day long.

Habitat.

On the open prairies vast numbers of ants have their homes, which, however, are modified in form, and present the appearance of a cone very like the hills of *Formica (rufa) exsectoïdes* of the Allegheny Mountains. Hundreds of these are

seen from the window of the railway car on the route from Austin to Hempstead, particularly in Lee and Washington Counties. From Hempstead northward throughout the State the same mounds (apparently) may be seen, and I traced them as far north as Muskogee, Indian Territory. It would be interesting to know the geographical limits within which the insect is distributed, but I can only record that it is certainly found in Texas and Mexico, and probably in Arkansas and the Indian Territory.

There is but one essential condition which appears in the location of a formicary, viz., *the open sunlight.* I do not remember a single exception to this rule, unless, indeed, the two following cases may be considered such. Within a few paces of my tent a nest was made which was partly shaded by a small mesquite-tree that stood just beyond the margin of the clearing. The sapling had probably grown up after the location of the community, and for some reason had been permitted to remain until too old to kill off. The shadow thrown upon the pavement was very slight; nevertheless, fifteen feet distant a new formicary was being established. The path from the ranch to the spring ran between this new hill and the old one, and ants were in communication between the two. An opening had been made in the ground, and the beginnings of a new formicary were quite apparent. This is the only instance observed of what seemed an attempt at colonizing or removing, and I associated it with the presence of the small but growing shadow of the young tree. The other exception came under notice in this wise: While studying the habits of the cutting ant I was tempted to make a night visit to a farm some distance from camp, by the farmer's story of depredations made by these insects upon certain plants and vegetables. A long, dark tramp, a blind and vain search among the fields, compelled us at last to call out the countryman from his bed. He led us directly to one of the cutting ants' nests, which was overshadowed by a young peach-tree. "There they be, sir," cried he, triumphantly. They were agriculturals! So also were the other

Formicaries in sunlight.

nests shown. The reason for this confounding of the two ants on the part of the people hereabouts, and the reason for the "cutting" operations of our harvesters, will be explained farther on. It is only in point here to say that the farmer affirmed that the ants under the peach-tree had stripped off the first tender leaves last spring, so that scarcely one had been left upon the limbs. I am convinced that the reason for this onslaught was the desire to be rid of the obnoxious shade, and open the formicary to the full light of the sun. Thus these two apparent exceptions only go to prove the rule, a rule which on the score of health, at least, the builders of human habitations might profitably consider and apply.

Meridian heat avoided.

In somewhat remarkable contrast to this love of the sunny site for a home is the fact that the agriculturals avoid the meridian heat of the day. The Texas sun throughout July has its greatest fervor within the period from 11 A.M. to 2 P.M. During these hours the ants are retired within their nests. The following observation will exhibit this fact. "Note made of several formicaries at 11.15 A.M. At nest A, two ants are at work on the disk, a few stragglers coming in, none going out. At B, no ants going out, some coming in. At C, D, none outgoing, ants coming in. At E, the disk shaded by the mesquite sapling, ants are at work, going out and coming in. Most of the home-bound ants have come from a distance.

"At A, work stops at 12 M. exactly; at 1.10 P.M. the disk is deserted, workless. At B, work stops at 12.15; at 1.10 deserted. All the formicaries are workless at 1.10. At most of them work had ceased before 12 noon." These observations were repeatedly, indeed constantly made, and always confirmed, with more or less variation according to the character of the weather, but with a uniform result, which permits us to determine the habit of the ants. About 11 A.M. the workers begin to cease their outward-bound excursions into the harvesting grounds, and those then afield are passing homeward along the roads in a stream. At or shortly before 12 M. the last stragglers have passed within the gates, and the

entire community rest within the formicary until 1 P.M., or shortly thereafter. From this time until 2 P.M. there is little movement. Work is then gradually resumed, harvesters push out from the gates along the roads, and by 3 P.M. the out-door industry of the community is in full tide.

The above fact had not escaped Mr. Buckley's notice, who, however, simply records that the ants do "not work during the hot sunshine; but they labor at night and during the cool of the day. On cloudy days their work continues." Mr. Lincecum has the same testimony: "The ant does not work in the heat of the day during hot weather, but makes up the lost time during the night. I have often found them busily engaged at 2 and even 3 o'clock A.M. Before day, however, they call off the workers, and rest till about sunrise." My observations tend to the conclusion that night work is rather exceptional with these insects. I give, for example, this record: "At 8½ P.M. the ants are moving about in a sluggish way, quite in contrast with their day action. Only a few are carrying burdens, these chiefly out of the gate. Others are passing out and in, many are slowly moving around the gate, where they are most numerous, and some are describing the same round farther out from the gate. Are these sentinels?" Again: "At 2 A.M., a few ants are at disks No. 2 and No. 5; some are on the clearing, several are carrying seeds within; the behavior of the others is uncertain. At No. 3, a broken (excavated) disk, the ants are busy." Again: "July 13, 5.20 A.M., heavy dew. Several disks vacant. On some a few are moving sluggishly; on one or two with considerable activity." Dr. Lincecum is probably correct in his statement that in favorable weather, when the ants can operate all day, they do not work late at night. My observations were for the most part made under clear skies, and therefore the industry of the several communities was pursued mainly during the day, and only pushed throughout night hours by the exigencies of an invaded formicary. Buckley's inference that night is their "busy time" does not seem to be warranted by the facts.

Night work.

Before taking up in detail the work just referred to, it will be well to make the reader familiar with the general appearance of the workers. The technical description is appended to this book. The mature inmates of an agricultural ant's nest consist of males (Plate II., Figs. 8, 11), females (Figs. 3, 5, 7), workers-major (Figs. 4, 6, 10), and workers-minor (Fig. 9). The last two forms differ but little from each other, the worker-major being somewhat larger, and with a disproportionately larger head. The out-door work of the formicary, and probably the in-door work, except in the earliest stages of its growth, is wrought wholly by the workers. They compose the bulk of population. The males are drones, and at the pairing season leave the gates to return no more. They are larger than workers, and smaller than the females. They have smaller heads than the other forms, have an additional segment to the abdomen, are without a sting, and, like the unfertile queens, are winged. The female is five-eighths of an inch long, the male four-eighths, the worker-major seven-sixteenths, the worker-minor five-sixteenths of an inch. These and other points of difference may be noted in Plate II. In color, the workers are of a uniform dark claret-brown. The males and virgin females are of a lighter shade, owing perhaps to the fact that they are little exposed to the rays of the sun. They keep closely within-doors, coming out occasionally to enjoy the sunshine. Continually throughout July, I saw both sexes, but many more females than males, thus taking their "constitutional" sun-bath and exercise.

Description of ants.

Effects of sun on color.

While the out-door life of the winged forms is thus limited to these brief excursions, the workers begin very early to labor in the open air. Frequently ants, still quite callow, were noticed on the disk and roads. Individuals were seen of various shades of color, from even a paler brown than that of the sexes to the normal dark-brown of the seasoned workers. Within the formicaries antlings were found too callow to push out-doors, but not far removed from their maturity, who were of a pale-yellow color. The pupæ are quite white.

I have little doubt that exposure to the sun affects young ants precisely as it does the human species; it browns or "tans" them. It is to be considered, however, that the males and females above referred to were young, and that the fertile queens (of whom I took no specimen), in spite of their close confinement to the interior of the formicary, may prove to be as dark as the workers; in which case, the dark-brown color would prove to be the normal result of maturity, and not the effect of exposure.

The work to which these insects devote their lives is divided between the upper world of sunlight and the subterranean regions in which are placed their granaries, nurseries, and abodes. Let us see first how they make and maintain the clear disk, and roads thereto. A number of opportunities were afforded for observing this process. In several cases it was quite apparent that the circumference of the disk was being pushed into the space covered by the surrounding grass. Usually the work was confined to, or in great excess on, one side of the circle. Here were standing a number of what may perhaps be called the "stumps" of grass-stalks (Fig. 17), presenting the appearance of a miniature "clearing" in an American backwoods. The stumps were dry, quite dead and black, and stood slightly above the surface, as the soil had been removed from between the gnarled rootlets. These tiny objects were spread over the inner section of the clearing. The whole so vividly recalled the pioneer scenes in Western forests with which I was familiar in boyhood, that I could not rid myself of the impression that the ants had wrought much on the same principle as the pioneers, who, after having chopped down the trees and cleared away the timber and brush, leave the stumps afield that the roots may loosen by natural decay, so that the stumps may be more easily removed and burned. In the mean time, the surrounding clear soil is sowed, and other clearings pushed into the forest. Whatever of fancy there may be in the analogy as to motive, it certainly holds good as to conduct; for just beyond, and bordering upon, the

Making a clearing.

stump-covered tract, gangs of workers were engaged upon standing tufts of grass. The mode of operating will be quite fully illustrated by reference to the notes on two formicaries. Observations on the first were begun at 5 P.M. Here is an ant at work upon a blade of grass which is already withered and sear. Her head is inverted, and she has grasped the blade with her mandibles close down by the roots, where it unites with the culm. The saw-like edges of the mandibles are applied to the leaf, which finally yields under a process of combined sawing, biting, pulling, and twisting. The leaf falls to the ground, where it is suffered to lie by the worker who hurries away. Another ant is similarly engaged upon the same tuft of grass. Still another works upon a green spire that is sheathed close down to the ground, until it is completely severed; while others, with a wiser and more radical economy, have laid their mandibles at the very roots of the stalk. The mandibles of the ant combine the advantages of teeth, saw, chisel, and pincers. The sawing process is not very noticeable. The biting or chiselling is quite apparent. So also is the tearing or pulling. To accomplish this the ants frequently swing themselves to the under side of the grass, press the abdomen upward against the surface, and so having a fair "purchase," tug violently at the abrasion already made. They also avail themselves of the mechanical advantage of twisting. Firmly grasping the grass with the mandibles as with a pair of pincers, they manage to sway the leaf back and forth and around, thus by the additional strain weakening the strength of the fibres. The insects occupied in this work were for the most part worker-majors. While these severer labors are not exclusively allotted to them, the greater size of the head, with the probable proportionate development of the muscles controlling the mandibles, would seem to give the majors special qualifications for such tasks.

Workers cutting grass.

The second formicary which may be cited for illustration of the above economy, was visited, July 23, at Hempstead, which is about one hundred miles east of Austin in the prairie

country. Here a large proportion of the formicaries assume the shape of mounds more or less conical. A long delay at this place, while waiting for the railway train, gave opportunity to visit several hills which are in an open field within a few rods of the station. A large nest but a few feet from the railway track showed admirably the methods of pioneer work. The whole circumference of the low mound was being enlarged, but on one side the workers were grouped in great force. A few tufts of grass had straggled up the slope within a foot of the gate, which were now being vigorously attacked. At times several ants wrought upon one tuft. Some wrought with head downward, even thrust a little within the soil, and were cutting close to the roots. Others labored with the head upward. The biting and tugging above described were seen here also. One ant had a blade nearly severed, and was applying the twisting process to complete her task. Ants climbed upon the spires, and went away, without any discernible purpose. Some worked a few moments and were off again. Those, however, who had hold at the roots were quite constant in their labor; they had the bearing of serious, determined laborers who intended to finish the task in hand.

Clearing off a mound.

Here I observed what appeared to be a new mode of operation. The workers, in several cases, left the point at which they had begun a cutting, ascended the blade, and passed as far out toward the point as possible. (See Pl. XVIII., Fig. 86.) The blade was thus borne downward, and as the ant swayed up and down it really seemed that she was taking advantage of the leverage thus gained, and was bringing the augmented force to bear upon the fracture. In two or three cases there appeared to be a division of labor; that is to say, while the cutter at the roots kept on with her work, another ant climbed the grass blade and applied the power at the opposite end of the lever. This position may have been quite accidental, but it certainly had the appearance of a voluntary co-operation. I was sorry not to be able to establish this last inference by a series of observations, as the facts were only

observed in this one nest. But an inquiry is suggested which another person may hereafter answer satisfactorily.

The number of ants engaged at any one time in this work of clearing was not very great during July, and the progress made was proportionately small. But enough was seen to show that when the whole energy of a large colony is turned upon that task, the work must advance with great rapidity. Lincecum's statement is therefore quite credible that in the fall of the year, after the grain of the needle-grass which has been permitted to grow on the pavement has been harvested, the straw is cut away and removed, leaving the disk unencumbered until the ensuing autumn. Tough as is the dry stubble, it does not exceed the power of the strong mandibles of the workers. I frequently found in the vicinity of Austin large formicaries, with cleared disks of ten and twelve feet, established in the midst of a thicket of wild-sage, daisy, and other vigorous weeds, with stalks at times as thick as one's thumb and standing two or three feet in height. This rank growth, qnickened by the fat soil and semi-tropical sun of Texas, is as completely under the control of the agricultural ants as are the cleared fields in the midst of American forests under the axe of the pioneer. Not a plant is suffered to intrude upon the formicary bounds, and, although often seen, it always was an interesting sight, after pushing through the weeds, to come upon one of these nests and observe the tall, tough vegetation standing in a wellnigh perfect circle around the circumference of the clearing. (See Pl. I., Fig. 2.) The weeds had crowded up as close as they dared, and in imaginative moments I could almost fancy that the bulky things were looking down with covetous eyes upon the forbidden grounds from which they were held back only by a wholesome fear of the little insects whose energy was continually saying to them, "Hitherto shalt thou go and no further."

Injury to farmers.

It is this habit alone which makes the agricultural ant obnoxious to farmers. In the neighborhood of gardens, nurseries, and ornamented grounds, the cutting or parasol ant (*Atta fervens*, SAY) is a veritable scourge.

But the farmers on the highlands around Camp Kneass had little complaint to urge against these pests, although quite hearty in representing the annoyance caused by the agriculturals. The farmer above referred to, who had really mistaken the agriculturals, in his field, for the cutting ants (a quite common popular error), said that they had cut down quantities of his sweet-potatoes, corn, sorghum, and squashes. Another farmer testified that the ants inflicted quite serious injury upon his crops of corn and sweet-potatoes, cutting down the plants within the circle of their disks again and again. This man also affirmed that "they don't bother the cotton much," a difference which I conjectured might be owing to the fact that there happened to be few formicaries within his cotton-fields. Both these men had supposed that the plants were cut down for food, but undoubtedly the only object of the ants is to establish their disks and open up their roads. To this end all obtrusive crops are removed. If it be considered that some of these formicaries are from seven to twelve feet in diameter, covering a space of from twenty-one to thirty-six square feet, it will be seen that many of them on a farm would withdraw a large surface from cultivation. If, for example, they should be placed as thickly as they are at Camp Kneass, where they are removed but a few paces from one another, and are spread over a wide tract, the loss which they might inflict would be very great. One or two ploughings over the pavements does not dislodge the marauders, who are exceedingly tenacious of their homes. They issue from their underground dwellings, open their gates anew, re-establish their formicary bounds, and by the time the young plants are well started, are prepared to fall upon and remove them.

Roads.

Not only the disks, but the avenues by which the surrounding herbage is penetrated, engage the skill of the emmet pioneers. These roads are in number usually three or four, sometimes as high as seven. They are most frequently two and a half to three inches in width at their entrance upon the disk, but in large nests I have found them five inches wide. Four of the roads of Disk Z (Plate I.,

Fig. 2) were of this width. The length of the forked road was sixty feet; at the mouth its width was six inches, at six inches from the mouth the width was four inches, at one foot, three and a half inches; at two feet, three inches; at three feet, two and three-fourths inches; at four feet, two inches; at ten feet, one inch. The point at which the road forked was two feet from the mouth.

The roads gradually narrow, and at various distances from the formicary almost imperceptibly blend with the open spaces between the tufts of grass, without any marked terminus. I measured no road that could be distinctly traced to a greater length than sixty feet. But Lincecum describes one over three hundred feet long, which traversed sixty feet of thick weeds, underran heavy beds of crop grass one hundred and eighty feet, and then through the weeds growing in the locks of a heavy rail-fence sixty feet more. Throughout its whole extent this road was very smooth and even, and varied from a straight line only so far as to lose some thirty feet of distance in passing from the pavement to the outer terminus. The width was from two to two and a half inches. In some places, on account of insurmountable obstructions, the road separated into two or three trails of an inch in width, which united beyond the obstruction. I have seen these branching paths, one of which is shown at Fig. 2, where the diversion was caused by no obvious obstruction, but apparently by the simple wish to strike out into a new harvesting ground.

These roads, like the pavements, are hard, level, and smooth. Such, at least, was their condition during my visit (July), which was a busy season for seed gathering, if not the height of the harvest. During the winter, when the ants are housed, the ways are overgrown more or less, and the obtruding vegetation has to be sharply attacked in the spring. The reason for keeping the roads clear and smooth is plainly to facilitate the rapid movements of workers from the disk to the harvesting ground, and the carrying of the grain homeward. The increased width of the road at the entrance upon the formicary, is due to a cause precisely analogous to that which widens

the mouth of a river. The incoming ants, converging from all quarters upon the road, and increasing in number as they near the nest, require greater space for free locomotion. So, also, in leaving the formicary, the greatest pressure upon the road is naturally at the entrance. The work of clearing off and keeping clear these vast reaches of public roadways is no inconsiderable one, and is largely augmented by the rankness of vegetable growth in the rich soil and semi-tropical climate of Texas. If a popular comparison may be allowed, and the ant's average length be taken at three-eighths of an inch, and man's at five and a half feet, the work expended upon one such road as above described (three hundred feet long and of average width of one and one-half inch) would be equivalent to the construction and maintenance by man of a good, hard road ten miles long and twenty-two feet wide. If every community of human beings would show an activity proportionate to these insects in the care of all the highways within the above limits, one of the chief causes of annoyance and loss in our vast agricultural regions would be effectually cured, and such a calamity as the "mud embargo" of the winter of '77–'78 would not again befall our great West. In this respect, at least, the agricultural ant shows a wisdom, economy, and enterprise much superior to agricultural man.

CHAPTER III.

HARVESTING HABITS.

We now come naturally to consider the use made of the roads above described, and the economy of the ants associated therewith. I have so far anticipated the main point of inquiry as to state that the roads are built and used as avenues for communicating with harvesting grounds. This fact appeared soon and very clearly. On the first morning after my establishment in camp (and continually thereafter), I was enabled to observe the whole process of gathering and carrying in the crop of seeds. The formicary placed under observation was similar to the one shown at Fig. 15,—a flat, smooth, circular pavement surrounding a low mound with a basin-like top, in the centre of which was an open gallery or gate. There were three roads, upon two of which there was comparatively little activity. On the third the greatest activity prevailed until 11 A.M. This road was in excellent condition,—that is, hard and smooth,—and over it was continually pouring a double column of ants, one outgoing and the other homeward bound, all laden with seeds of various grasses, principally of the buffalo-grass. (Figs. 25, 26, 27.) Several feet from the disk the road became less marked and trodden, but preserved its characteristics for thirty feet or more, running under the grass like a miniature tree-covered avenue. From all points more or less decided trails led into the main road. Closely following the ants one by one along these trails, I was rewarded by the full discovery of their mode of operations.

Gathering grain.

Most of the seeds were ripe, many of them were still hang-

ing upon the stalk, but there was no attempt to pluck them from the plant itself. During my entire stay I never saw a single ant harvesting in this way, although, as will be seen, the Florida harvester does pluck the seeds from the stalk. The seeds which had dropped to the ground, or had been trodden off by the feet of men and animals, were the sole objects of the forager's attention. There was first of all a great deal of beating about around the roots of the grass. With head bent toward the ground, antennæ outstretched and in a continual quiver, with every attitude and motion indicating greatest eagerness, the worker passed from point to point, now to this side, now to that, now around and around, but always pushing farther away into the jungle of grass. It was a severe trial of one's patience to follow her movements. Stooping over on hands and knees, or prone upon the face, crawling slowly along, with eye fixed upon the eager insect, I was sometimes led a tiresome chase of many feet. Throughout all this distance there were frequent pauses, and the application of the mouth to objects upon the ground. Many of these were seeds. Why were they not seized and carried off? I examined some of them, but could note no difference between them and seeds that were afterwards taken. Indeed, at times, I have noticed a discrimination against fresh-looking seeds in favor of those looking blackish and more weather-worn. Are these, maybe, more readily stripped of the husk? Perhaps a skilled botanist might have solved the problem, but it remains a mystery to me. Was it simply fastidiousness? I have often thought that ants were not wholly destitute of that weakness, and are generally quite as apt to show personal peculiarities, and even to be the victim of moods, as larger animals.

Seeds taken from the ground.

At last a satisfactory seed is found. It is simply lifted from the ground, or, as often happens, has to be pulled out of the soil into which it has been slightly pressed by the rain or by passing feet. Now follows a movement, which at first I thought to be a testing of the seed, and which, indeed, may be partially that; but finally I concluded that it was the adjusting

of the burden for safe and convenient carriage. The ant pulls at the seed-husk with its mandibles, turning and pinching or "feeling" it on all sides. If this does not satisfy, and commonly it does not, the body is raised by stiffening out the legs, the abdomen is curved underneath, and the apex applied to the seed. I suppose this to be simply a mechanical action for the better adjusting of the load. Now the worker starts homeward. It has not lost itself in the mazes of the grass-forest. It turns directly toward the road with an unerring judgment. There are many obstacles to overcome. Pebbles, pellets of earth, bits of wood, obtruding rootlets, or bent-down spears of grass block up or hinder the way. These were scarcely noticed when the ant was empty-handed. But they are troublesome barriers now that she is burdened with a seed quite as thick, twice as wide, and half as long as herself. It is most interesting to see the skill, strength, and rapidity with which the little harvester swings her treasure over or around, or pushes it beneath these obstacles. Now the seed has caught against the herbage as the porter dodges under a too narrow opening. She backs out and tries another passage. Now the sharp points of the husk are entangled in the grass. She jerks or pulls the burden loose, and hurries on. The road is reached, and progress is comparatively easy. Holding the grain in her mandibles well above the surface, she breaks into what I may describe with sufficient accuracy as "a trot," and with little further interruption reaches the disk and disappears within the gate. There are variations from this behavior, more or less marked, according to the nature of the grounds, the seeds, and (I suppose) the individuality of the harvesters; but the mode of ingathering the crop is substantially as above. Each ant operated independently. Once only did I see anything like an effort to extend sympathy and aid. A worker-minor seeming to have difficulty in testing or adjusting a large seed of buffalo-grass, was assisted (apparently) by one worker-major, and then by another, after which she went on her way.

I made large collections of these seeds gathered by the ants, chiefly from the underground granaries, but partly from the mouths of the workers. Stationing myself near the entrance of a road, I gave a quick, light tap of the finger upon the back of the ant. The seed was immediately dropped, and after a momentary hesitation or confusion the plundered insect ran toward the gate without attempting to resent the robbery or recover the treasure. The behavior was somewhat different when the ant was robbed in the harvest-field. There, after a few confused, gyratory motions, she assumed a ramp-ant posture, and with mandibles wide apart, with tremulous motion and angry mien, stood at bay. The seeds collected from the granaries were found in quantities, both within the shell and naked, as described fully in the notes on architecture. Collections were also made of the refuse which the ants were continually bringing out of the gate and depositing on one side of the disk, toward the circumference. I was not able to verify Lincecum's statement that these were always deposited on the lee side of the clearing. Specimens of this refuse, one box of seeds taken from the ants' mouths, and a number of collections from the granaries, were submitted for determination to the Botanical Section of the Academy of Natural Sciences of Philadelphia, upon which the following report was made:

Kinds of seeds harvested.

ROOM OF THE BOTANICAL SECTION, ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

October 26, 1877.

DR. W. S. W. RUSCHENBERGER, *Director:*

SIR,—The undersigned, appointed to examine the seeds found in the hills of the agricultural ant of Texas, submitted by Rev. H. C. McCook, respectfully report:

1. The material marked as dropped from the mouths of the ants consists of some seeds of a small Euphorbiaceous plant, and the remnants of the glumes of some grass.

2. The seeds through all the other boxes and bottles are of *Buchlœ dactyloides*, which is most abundant; of two species of *Panicum*, one, however, being present in very small quantities,

and the seeds of another grass apparently *Aristida stricta*. With these are seeds of some *Croton*, and occasionally a *Paspalum*, a *Malvaceous* plant, and a *Polygonum*. The seeds taken from the conical mounds near Hempstead, on prairie surface, are nearly all Paspalums and Panicums, with a number of Crotons.

3. A bunch of culms of grasses consists of *Buchlœ dactyloides*, the Buffalo-grass, and *Evagrostis oxylepis*.

4. The specimen of grass taken from the surface-clearings of the formicaries, which grass is supposed to be harvested in crops by the ant, is *Aristida oligantha*.

5. The boxes marked "refuse" which were collected from the surface of the formicaries, and which had been cast out by the ants, we found to contain nothing but glumes and shells, and imperfect seeds of plants named above. There were no perfect seeds among the refuse.

THOMAS MEEHAN,
ISAAC BURK,
J. H. REDFIELD.

Thus the point was established, so far as circumstantial evidence can well go, that Barbatus is a true harvester. The links in the chain of evidence are these:

1. The ant was seen habitually gathering the seeds and carrying them within her nest.

2. The seeds were found entire, as gathered, stored in large quantities within the underground galleries.

3. The grains of the same seeds were found stripped of their shells, stored in large quantities within the galleries.

4. The contents of the refuse-heaps, which the ants were observed carrying out of the gates, proved, under examination by expert botanists, to contain no perfect seeds, and to be the shells and glumes of the seeds stored within the formicary.

5. Mr. Riggs has given me an observation which must add an additional link to this chain of evidence, if it shall be confirmed, by further examination, as a prevailing fact. On the 22d of February, 1878, he opened half a dozen mounds, and

found that the granaries were not nearly as well stocked with seeds as in the fall. "Or else," he adds, with commendable caution, "I had more difficulty in finding the seeds." This discovery points to the actual consumption of the stored grains during the winter months.

Throughout this winter ('77–'78) the ants were active nearly all the season, being housed only a few days. The consumption of grain may, therefore, have been greater than usual. Mr. Riggs observed the ants carrying into the nest bits of grass and morsels of leaves, some of which were forwarded to me. This is not the only instance in which he observed this behavior. On the 10th of December, 1877, he traced an ant-road nearly seventy feet from the formicary, which then forked and was soon lost. This road was covered with ants all going home, and all carrying pieces of grass. There were a few stragglers at the terminus of the road, at which point was a cluster of some fifty pieces of grass cut off, and evidently awaiting carriers.

Among the seeds most prevailing in the granaries are two species of Aristida. One of these appears to be the *Aristida stricta*, or ant-rice, to which Lincecum has given such wide notoriety by the statement that it is actually planted, cultivated, and harvested by the ants, who have received the name "Agricultural Ants" from this fact. (See Plate IV., Figs. 18, 19.) The seed somewhat resembles a grain of oats, and the taste of the kernel is not unlike that of rice. This biennial grass, according to Lincecum, is sown in time for the autumnal rains to bring it up. About the 1st of November, if the fall has favored, a green row of the ant-rice, about four inches wide, is seen springing up on the pavement, in a circle of fourteen to fifteen feet in circumference. In the vicinity of this circular row the ants do not permit a single spire of any other grass or weed to remain a day, but leave the Aristida untouched until it ripens, which occurs in June of the next year. After the maturing and harvesting of the seed, the dry stubble is cut away and removed from the pavement, which is thus left unencumbered until the ensuing

Do ants sow grain?

autumn, when the same species of grass, and in the same circle, appears again, and receives the same agricultural care as did the previous crop. Mr. Lincecum says that he has seen this process go on year after year upon farms where the formicaries are protected from the depredations of cattle. Such is Lincecum's account. "There can be no doubt," is his emphatic assertion, "of the fact that this peculiar species of grass is intentionally planted, and in farmer-like manner carefully divested of all other grasses and weeds during the time of its growth."

My observations are as follows: glancing over the formicaries spread thickly upon the open upland surrounding Camp Kneass, the eye at once noticed this peculiarity,—part of the nests were clear of all herbage; others were partially covered with a tall, yellowish grass, popularly known as the "needle-grass." The name is aptly given, for the three-pronged awns of the plant are sharp and stiff, and penetrate even heavy woollen clothing, inflicting a quite annoying wound. This is probably the "ant-rice" of Lincecum; at all events, it is an Aristida, the plants gathered being identified by the botanists as *A. oligantha*, but some of the seeds as probably *A. stricta*. The manner of growth is peculiar. The cluster of grass is strictly limited by the outer bound or circumference of the formicary clearing, beyond which is the ordinary wild grass which covers the surface of the country. As one looks over the landscape his eye invariably marks the locations of the formicaries by the circular clusters of yellow needle-grass. They stand as distinct in the surrounding herbage as does the farmer's field of wheat, for example, in the midst of fields of oats and Indian-corn. In so far, at least, the needle-grass is entitled to be called a "crop."

An examination of these grass-covered nests showed that the Aristida has exclusive possession of the surface-clearing. This statement rests upon a large number of careful observations, and is made without any qualification whatsoever. So far as the formicaries were covered at all, the needle-grass occupied the ground alone. However, the

Ant-rice on the disks.

entire surface of the clearing was not covered. Generally there was a clear space in the centre, surrounding the gates, which varied in extent according to the area of the formicary. I constructed tables noting the peculiarities of a number of disks, as to soil, size, number of gates and roads, presence or absence of mounds and needle-grass, etc., from which I make the following extract as illustrating the above fact: "Formicary No. 3. Nearly covered with needle-grass. . . . No. 7. 2 feet 6 inches clear space in the centre, a belt of 1 foot 6 inches covered with needle-grass. (See Plate III., Fig. 13.) . . . No. 15. Space 1½ feet diameter, clear, circular belt outside of needle-grass, 2 feet wide. . . . No. 19. Small space at the gate clear; 6 feet diameter (both sides of the circular belt) covered with needle-grass. . . . No. 21. Small nest; about 12 inches diameter clear space, 8 inches grass. . . . No. 23. 4 feet clear, covered with gravel around the one gate; tufts of needle-grass on the outer edge." About one-half of the nests in the above list (thirteen out of twenty-five) were covered more or less with Aristida. But the list embraces a section in which the grass-grown disks were most numerous. Perhaps one-third of the nests at Camp Kneass had crops of this sort. The central clear space on some of the disks was occupied by a low mound, on others by small white pebbles or gravel.

The question arose in my mind, Why should some of the formicaries keep the disks clear, while others preserve a crop upon them? Lincecum has not raised this question, but incidentally drops the remark that, after the grass upon disks outside of fenced fields has been cropped down two or three times by the cows, the ants, finding that there is no chance to carry on their agricultural pursuits, cut away the grass and re-establish the clean pavement. This is probably a mere conjecture, at least no facts are given to establish the statement. I am utterly at a loss to account for the difference at Camp Kneass. The formicaries were all in open common, which had never been enclosed, and the cattle had free range for many square miles around. They frequently annoyed the

camp, and marks of their presence around the nests were abundant. Yet, within a few feet of one another were disks perfectly clear, and disks covered with needle-grass. It is hardly probable that the cattle, for reason or at hap-hazard, denuded some of the disks and spared others. Indeed, during the period of my visit, when the Aristida was quite ripe, and the tops bristling with prickly awns, there would seem to be the best reason why animals of all kinds should rather avoid than seek the disks bearing needle-grass. When the Aristida is young and green it is of course more inviting. However, it seems to me quite unlikely that cows and horses could seriously attack a crop which the ants were intent upon preserving without receiving such annoyance from the formidable stings of the workers as would repel them before inflicting much damage. But this, too, is conjecture. If location, soil, exposure to winds, or other causes operate to produce this division into clear and grass-grown disks, I was not able to discover them. It may be added that the Texas cattle did not often crop the ant-rice until their increased numbers forced them to feed upon all kinds of grass. Camp Kneass was situated in the midst of a wide range of open country which allowed free, choice pasturage. Washington County, where Lincecum's observations were made, is quite thickly settled, and the cattle there would probably be driven to closer cropping of their feeding grounds.

Some observations communicated by Mr. Affleck may be introduced here. He writes that the roads are scarcely distinguishable in winter, being entirely overgrown when the grass has a winter growth. There is a difference in this respect between the roads leading to flat disks and those radiating from cone disks, the former being less overgrown than the latter. This fact seems to indicate the greater degree of energy on the part of the flat-disk ants. Indeed, their movements are not hindered except by rain or severe cold. During moderate weather, such as prevails in Texas for at least half the winter, or after a frosty morning, they are almost as numerous and energetic outside

Winter. Grass-grown roads.

the nest as during the summer. Their activity, however, seems to be directed exclusively to enlarging or repairing the nest, and they are rarely seen very far from home. They also seem as combative and venomous at this time as at any other.

The ants of a cone disk, on the contrary, remain within the nest during almost the entire winter. Such as venture outside move very sluggishly about the cone, and, if interrupted, retreat slowly to the interior. About the first of March ordinarily their hibernation ceases, and they come out in full force. This period is earlier or later according to the nature of the season. Rev. Dr. Wright informed me that he had come to regard this annual appearance of the ants as an evidence that spring had fully come. His recollection is that the ants retire to winter-quarters about the first of December. Some time before this their labor has ceased, or their activity is greatly lessened. The temperature of February and March in Texas is about the same, and during the sunny days previous to the spring exode, the ants come out, bunch themselves into balls the size of one's hand, and remain in that position a couple of hours. This "snugging" of ants is not an infrequent occurrence among other species. For example, I have seen it on a crisp autumn day, after a sharp frost, in a large colony of our familiar *Crematogaster lineolata*, found under a stone in Fairmount Park. In this case the larvæ and pupæ were in the centre of the mass.

Hibernation.

Snugging on sunny spring days.

When issuing in spring, the agricultural ants first bend their energies to repairing the damages sustained by the nest during their hibernation, if we may apply that word to the partial suspension of activities above described. They clear away all vegetation, and many bunches of the grass, *Aristida oligantha*, were found by Mr. Affleck cut down to the roots. Later in the season both flat and cone disks were found free from grass of every description, in the estimated proportion of twenty to one. The cone disks, in particular, had been completely covered during the winter. On the 23d

Spring clearings.

of May a letter received from him showed that this condition of the exterior formicaries had changed in the case of the flat disks, which had then become entirely overgrown with bunches of *Aristida oligantha*. The grass was found only on the circle and within the disk. This peculiarity was so marked that he was able to distinguish the locality of the nest at the distance of fifty yards. This exactly confirms my own observation. On the contrary, the cone disks at the same date were entirely free from the grass, a fact which it was thought might be accounted for by the more thorough work made at first by the inhabitants of these nests; the elevation of the grass upon a loose soil, quite accessible from beneath, allowing the insects to lay their mandibles at the very root of the Aristida. Mr. Affleck, it may be said, is decidedly of the opinion that the ants do not by their own volition control this growth, and thinks that they are overtaken by it as the season advances, in spite of their exertions. So far from agreeing with Lincecum's theory that the grass is sown and cultivated, he considers that it may be obnoxious, and that it is only yielded to after vigorous effort to suppress it. It seems hardly credible, however, that the energy and skill which enabled these creatures to wholly clear away a winter growth which had overrun the disks, should be foiled in the effort to keep them clear. Moreover, the exclusive occupation of the disks by the grass is a fact which must be counted in favor of the voluntary action of the ants, unless, indeed, there is some peculiarity in the behavior of the Aristida, which may explain in a natural way its localization upon the open disks. It would materially aid to the solution of the whole question were some botanist to show whether the seed of *A. oligantha* prefers such clear spaces as the nests show, and being carried to the same are kept within the original open, both by their natural preference and the opposing barrier of the surrounding grasses. The reader can draw from the above facts an inference quite as likely to be correct as my own; but I do not hesitate to say that as at present advised, I do not believe that the ants deliberately sow a crop, as Lin-

Crops reappearing on the disks.

cecum asserts, but that they have, for some reason, found it to their advantage to permit the Aristida to grow upon their disks, while they clear off all other herbage; that the crop is seeded yearly in a natural way by droppings from the plant, or by seeds cast out by the ants or dropped by them; that the probable reason for protecting the Aristida is the greater convenience of harvesting the seed; but, finally, that there is nothing unreasonable, nor beyond the probable capacity of the emmet intellect, in the supposition that the crop is actually sown. Simply, it is the Scotch verdict,—"Not proven." Crops are preserved.

A harvesting ant of Florida has been referred to as gathering a crop of seeds by cutting the same from the stalks. As this insect will be alluded to in other parts of this work, a more extended notice of it may be made in this connection. It was an event of no ordinary interest, giving no small degree of satisfaction, in the midst of my studies of the single known American species of harvesting ants, to fall upon the trail of a second species, and not only to have an account of its habits from an approved naturalist, but to be able to study thoroughly its habits under artificial environment. During the winter of 1877–78, Mrs. Mary Treat, a well-known writer upon popular natural history, and a good and careful observer, sent me specimens of an ant from Florida for determination, which proved to be a species of Pogonomyrmex, described by Smith, from a specimen from Georgia, as *Atta crudelis*, without any record of its habits. From its resemblance, in many features, to the Texas agricultural ant, and its Southern habitat, I wrote to Mrs. Treat, predicting that it would probably prove to be a harvester, and requested that this point be examined. An early answer came that it was indeed so. Mrs. Treat made many interesting and valuable observations upon this Florida harvester, and sent me several colonies, upon which I also made many observations in artificial formicaries. This ant is probably widely distributed throughout Florida. Mrs. Treat also observed the same or a similar ant in great numbers in Georgia, with nests The Florida harvester.

even in the streets of Savannah. Some of these Georgia nests, however, she saw to be flat disks instead of cones, as she had always seen them in Florida, a coincidence with the architecture of the Texas Barbatus (see Chapter V.), which, if confirmed by a series of observations by some one in the two States named, would be a most interesting fact. This ant is figured on Plate XI. Fig. 49 is the worker-major; Figs. 48 and 50 show the profile view and head of the worker-minor; Fig. 46 is the large-headed soldier, and Fig. 47 a side view of an unwinged queen. The natural length is indicated in each form except the queen, which is somewhat greater than the soldier's.

These ants make small, regular mounds in the low pine barrens of Florida. Within these nests Mrs. Treat found storerooms piled with seeds of Euphorbia and Croton and several species of leguminous seeds. The kitchen-middens contained chaff of *Aristida speciformis*, an abundant grass in the neighborhood. The seeds were freely eaten, particularly when sprouted or swollen. The yellow pollen-dust of the pine was also eaten. In order to test the disposition of Crudelis to garner the seeds from the stem, bunches of millet were obtained from the North, and stalks eighteen inches high, crowned by the boll of close-set seeds, were stuck in the mound of an active formicary. The ants mounted the stems and set to work vigorously to secure the seeds, clusters of twenty or more being engaged at once upon one head. The seeds were carried off and stored within the nest. This experiment proved pretty conclusively that in the seeding season Crudelis does not wait for the seeds to drop, but harvests them from the plant.

Harvesting seeds from the stalk.

Mrs. Treat was not able to obtain like results from her artificial nests, the ants persistently refusing to cut off seeds, although they stored away the seeds loosely scattered to them. My imprisoned Crudeles did a little better. The seeds on some of the bunches of millet placed in their nests were harvested in a quite natural way, so that I was able to get the mode and make the Figures 70 and 71, Plate XV. The ant described

when first seen was engaged upon a small bunch of seeds, the stem of one of which she grasped by her mandibles and was attempting to cut it off. The head was bent down, the body curved upward, and frequently the abdomen was thrown forward and under until it rested upon the little ball of seeds, as shown at Fig. 71. In this position she had the advantage of a strong "purchase" or leverage for tugging at the stem. Presently the position was changed to that of Fig. 70; the bunch of seeds was quite lifted up, turned over, and the stem wrought upon by the toothed mandibles, while the ant "sat" upon her two hind pair of legs and the turned-under abdomen, as more fully described and shown at Fig. 68. The ant was engaged twelve minutes in cutting off one seed, which she immediately carried below. I watched for an hour thereafter, but she did not return to renew her labor.

CHAPTER IV.

THE ANCIENT BELIEF IN HARVESTING ANTS—HOW IT WAS DISCREDITED AND HOW RESTORED.

THE chapter which follows does not properly belong to the natural history of the ant. It is rather a history of the changing opinions of men about that natural history. However, my mind has been interested in pursuing it, and some readers will be pleased to follow. It has thus been separated from the rest of the work that those who are only interested in proper nature-studies may pass it by without inconvenience. Nevertheless, one may be permitted to suggest that the chapter has this value to naturalists, if nothing more, that it may illustrate the danger of a generalization as to the habits of animals from even the best authenticated facts, when those facts lie within a limited area.

Two of the earliest references in literature to the ant are in the Bible, and make mention of the harvesting habit. These are in the book of Proverbs, and are as follows: Prov. vi. 6, 7, 8, "Go to the ant, thou sluggard; consider her ways, and be wise: which having no guide, overseer, or ruler, provideth her meat in the summer, and gathereth her food in the harvest." Prov. xxx. 24, 25, "There be four things which are little upon the earth, but they are exceeding wise: the ants are a people not strong, yet they prepare their meat in the summer." These words certainly carry upon their face more than an implication, even a plain assertion of the habit of garnering food in the time of "harvest,"—that is to say, grains or seeds in the season when they are ready for garnering.

The Bible.

The Hebrew verb in the phrase *provideth her meat*, תָּכִין, *takin*, is well translated "provideth," having the meaning "to prepare," "to dispose in order." The verb in the parallel phrase, אָגְרָה, *âgĕrâh*, signifies "to collect, to gather together," and is certainly aptly taken to express the garnering work of a harvesting ant. The same word is used in Deuteronomy xxviii. 39, for gathering in the vintage, and for gathering in summer in Proverbs x. 5. While, therefore, it is possible that the expressions might be limited to the idea of a general provision of needed food in season, the ordinary interpretation lies clearly upon the face, and is supported by the Scripture use of kindred terms.

The Hebrew name for the ant is in confirmation of the common understanding of these texts. It is נְמָלָה, *nemalah*, from the verb נָמַל, *namal*, to cut off, evidently from the known fact that the ants cut off the seeds from the stalk, or, as Bochart supposes,[1] from their cutting off the head or germ of the grain to prevent it from growing. The word is used, Job xxiv. 24, for cutting off ears of corn. The Arabic word is similar to the Hebrew, viz., *nimala*.

The fact that the inspired writing intended to convey the idea of a true harvesting is supported by the unbroken series of expressions in ancient writers, based upon such a habit existing in ants in the same geographical province. The Hierozoicon, Bochart's great work upon the animals of Sacred Scripture, so remarkable for the vast and learned research which it displays, has an array of such authorities gleaned from various languages. These are arranged under the twentieth, twenty-first, and twenty-second

The learned Bochart.

[1] "*Nemala*, An quia granorum capita abscindit, ne regerminent?" HIEROZOICON, ed. David Clodii, Frankofurti ad Mœnum, Anno 1575, Pars secunda, Lib. iv., Cap. vigesimum. Libr. Acad. Nat. Sci. Phila. On the contrary, the opinion is advanced by Parkhurst and Rev. Wm. Houghton (Art. ANT, Sm. Bib. Dict.) that the Hebrew *Nemalah* is the exact equivalent of our *insect*, and is derived like it from the extreme tenuity at the junction of the thorax and abdomen, as though the body had been *cut into*, or cut away. This implies a nomenclature far more in accordance with modern than ancient ideas and observations.

chapters of the Fourth Book of the Second Part.[1] They contain quotations in the Greek, Latin, Hebrew, Syriac, and Chaldaic languages from Pliny, Lucian, Ælian, Zoroaster, Aristotle, Origen, Basil, Epiphanius, Eustathius, Pisidias, Rabbi Levi, Alkazuinius, Alkamar, Plutarch, Chrysostom, Ambrosius, Virgil, Horace, Hesiod, Ovid, and others whom the curious reader may find for himself.

One who will take the pains to follow the author through these chapters will be agreeably surprised to find how much accurate knowledge the ancients had of the life history of the ant in other particulars than their harvesting habit, mixed as it was with much that was mythical, and (in our retrospect) absurd in the highest degree. It would be impossible to burden these pages by quoting from many of the authors above named. Selections from a few will suffice here to indicate the general tenor of this ancient testimony. Virgil, in his Æneid,[2] compares the departure of the Trojans to swarms of harvesting ants invading the fields of yellow grain. Dryden thus renders the simile,—

"The beach is covered o'er
With Trojan bands that blacken all the shore:
On every side are seen descending down
Thick swarms of soldiers, loaden from the town.
Thus in battalia march embodied ants,
Fearful of winter and of future wants,
T' invade the corn, and to their cells convey
The plundered forage of their yellow prey.
The sable troops, along the narrow tracks,
Scarce bear the weighty burden on their backs;
Some set their shoulders to the ponderous grain;
Some guard the spoil; some lash the lagging train;
All ply their several tasks, and equal toil sustain."

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[1] *Loc. cit.*, CAPUT *vigesimum.* Formicæ nomen Latinum, Græcum, Hebræum, et Chaldaicum. CAP. *viges. primum.* Explicatur *Solomonis* locus de formica Prov. vi. 6: *Vade ad formicam, O piger*, etc. CAP. *viges. secundum.* Explicatur *Solomonis* locus alter de Formica *Prov.* xxx. 29: *Quatuor ista sunt minima terræ*, etc.

[2] Æneid, Bk. iv., l. 402, seq.

The same author,[1] in the Georgics, places the ant among the pests which plagued the farmer of the Mediterranean shores at his threshing-floor,—the mouse, mole, toad, and various vermin produced by Mother Earth. Virgil.

"——— populatque ingentem farris acervum,
Curculio, atque inopi metuens formica senectæ."

The curculio lays waste vast hoard of grain,
And the ant, too, fearful of a destitute old age.

Horace[2] embalms in verse the same foresight and industry. He is impaling the miser upon the point of his satire, and turns against him his favorite model, the economical ant, in this wise:

"Parvula (nam exemplo est) magni formica laboris,
Ore trahit quodcunque potest, atque addit acervo
Quem struit, haud ignara ac non incauta futuri
Quæ, simul inversum contristat Aquarius annum,
Non usquam prorepit, et illis utitur ante
Quæsitis sapiens."

Which I thus translate:

"The little ant, of great industry,—that favorite model with the miser,—bears away in her mandibles whatever she can, and adds it to the store which she is accumulating, not unmindful nor improvident of the future. But then, she, as soon as Aquarius saddens the ended year, ceases to creep forth from her nest, and wisely uses those stores which she has gathered beforehand." Horace.

Ælian, the "honey-tongued" sophist, who wrote in the early part of the second century, gives in his "De Animalium Naturæ"[3] a graphic account of the gleaning operations of ants around the threshing-floor. "When the crops are gathered," he says, "the ants assemble to the threshing, bustling up and down upon the threshing-floors, singly, in pairs, or triplets.

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[1] Georgics, i., l. 185–6. [2] Bk. i., Satire i., l. 33, seq.

[3] Claudii Æliana, De Animalium Naturæ. Petro Gillio Gallo et Conrado Gesnero Helvetio interpretibus. Lugduni. Apud Antonium Candidum, 1616, Lib. ii. cap. xxv. Libr. Acad. Nat. Sci. Phila., Greek and Latin.

Ælian. Leaving their own home and accustomed roof, they seize the wheat and barley, and return with them upon a common path. Some choose out the grains, others fall to bearing burdens, and with high honor and courtesy they yield the path to each other, particularly the unburdened to those who are carrying loads. When they have returned to their caves they pile up the grain in separate heaps,[1] and gnaw through (exterebrant) each grain in the middle. The gnawings (quod excidit) they convert into food. The rest of the seed, because thus gnawed, is sterile. In this manner the ants, most noble and watchful housekeepers, contrive within their caves, lest, being wet by the inflowing rains, the perfect seed should sprout and shoot above the ground; a result which would leave them to scarcity of food and hunger, and the loss of all their toil and carefulness. In this respect, therefore, as in many others, Nature has been bountiful to the ant."

Jewish Talmud. Mischna. A strong corroboration of the accuracy of Solomon's observation is found in the Talmud, a work embracing the body of the laws and traditions of the Hebrews, with the comments of learned Rabbins thereon. It is divided into two parts, the first of which, the Gemara, contains the written law; the second, the Mischna, is a collection of traditions and the views and decisions of doctors of the law who are held as high authority. It is in the latter that the testimony is found. The second Treatise of the Mischna, PEAH, *De Angulo*, contains laws relating to the corner of the field to be left to the poor to glean them (whence the Latin name), and generally such laws as relate to the rights of the poor on the soil of the Holy Land, based particularly upon Lev. xix. 9; xxiii. 22; and Deut. xxiv. 19. Under this head there is a law, with various decisions thereon, relating to the property rights to stores of seeds found in the

[1] "Granorum acervos sibi construunt," I understand to mean the wheat by itself, the barley by itself; although the idea may be that the general mass is divided among the granaries into separate heaps.

formicaries of ants in the field. I give a translation of the entire passage.[1]

11. The little caves of ants, when in the midst of a standing crop, are adjudged to the owner of the field; of those behind the reapers, the upper part is the property of the poor, the lower of the proprietor. R. Meir decides that all belongs to the poor, because whatever is in doubt in gleaning goes to the gleaner.

On this are the following comments and opinions: R. Moses ben Maimon (Maimonides). The little caves of ants (*foramina formicarium*) are holes which ants dig in the earth, into which they carry seeds; but if, in the midst of a standing crop, seeds of the same sort are found, they fall to the owner of the field, forasmuch as the poor in no degree partake of the standing crop, but only of that which falls behind the reaper; because it is there that the right of the poor (jus pauperis) obtains, the Mischna declares the topmost seeds, which are the whiter, to belong to the poor. But the lowermost seeds fall to the owner of the field, since they are darker in color, and for that reason we declare them to be older and the seeds of the past year. But R. Meyer decides that it might possibly occur that even a new seed might grow of a black color, because it could hardly happen that among good seed there should not be found a bad one; and since thus the case may be in doubt, we decide that the gleaner has the benefit of

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[1] MISCHNA. Cum clarissimum Rabbinorum Maimonidas et Bartenoræ. Commentariis Integris. Latinitate donavit ac notis illustravit Guilielmus Surenhusius. Amstelædami. Pars Prima. פאה, Tractatus de Angulo, p. 53 seq.

Section "11. Formicarium cavernulæ," etc. I have consulted the edition in the Loganian Library, Ridgway Branch Philadelphia Library. The English collections of Barclay, and De Sola & Raphael, both refer to Treatise II., but neither has extracts. Theologians and Bible students had knowledge of these passages, as see Delitzsch, commentary on Proverbs, under the above cited texts, and passages in the Talmud and Midrash, in the Hamburg Real-Encyclopädie für Bibel und Talmud, 1868, p. 83. But naturalists have been introduced to these interesting allusions by Mr. Moggridge, whose attention was called to it by Dr. F. A. Pratt, and who introduced the text into the supplement of his book. I give not only the text of the law, but all the decisions and comments upon it, as of special value and interest here.

the doubt (spicilegium dubium habeatur spicilegium), as the Mischna declares. The decision of R. Meyer is pronounced right.

R. Ob. de Bartenora thus comments upon the text: *Holes or little caves of ants.*—In these the ants are accustomed to collect stores. *In the midst of a standing crop.*—Understand by this the seeds which are found in these holes before they begin to reap. *To the owner.*—They belong to him because no part of the standing crop belongs to the poor. *Behind the reapers.*—If after they begin to reap the grains of wheat are found, it is to be supposed that the ants carried them thither; wherefore the grains which are uppermost in these foramina, or the upper ears of corn, fall to the poor, because there the law of gleaning obtains; but the lower grains fall to the owner, because over them the law of the standing crop holds good. Besides, the upper grains are whiter, while the lower ones are of a deeper yellow (viridiora), approaching even to blackness, by which we know them to be older. R. Meyer decides that the whole store falls to the poor, because it is not possible to collect a heap of grain upon the threshing-floor without finding among them some of a mature color (viridia), and it is possible that some of these may have been added to the new store, which had just been reaped; in which the poor has a portion, because the gleaning has the benefit of a doubt, as Scripture saith, *Pauperi et perigrino relinques ea,*—*i.e.*, leave to the poor that which is thine, even the doubtful gleaning. The decision of R. Meyer is right.

The editor Surenhusius adds this note: When R. Meyer declares, *quod spicilegium dubium est spicilegium*, this much is conceded to him by the sages. But they disagree only in this, that the sages say that, inasmuch as the lowermost grains have, without doubt, been brought by the ants into the underground nests, they fall to the owner of the field; while R. Meyer says that it is a doubtful question whether they may have been carried in by the ants, and so fall to the poor.

It may be remarked that the above law of the Mischna itself (11. Formicarium, etc.) probably dates no later than the

close of the second or beginning of the third century. Its original authors must have been personally familiar with Palestine, and had at least ordinary knowledge of its more common fauna. It is therefore corroborative testimony as to the early existence of harvesting ants in Palestine, even if we suppose the commentators, including the learned Maimonides, to have had no better knowledge of the facts in the case, from personal observation, than modern Jewish and Christian commentators upon sacred books seem to possess. Allowance may, of course, be made for the well-known scrupulousness of the Jews of the period concerning small matters of ceremonial duty and legal behavior, such as our Lord Jesus Christ referred to when He charged the doctors and lawyers of his time with tithing mint, anise, and cummin, while they neglected weightier matters of the law.[1] We may not, therefore, be justified in arguing that the stores of grain in the formicaries of the Palestine ants were very large. The law of the Mischna would have been formulated quite as readily, no doubt, in view of small stores as large. Still the fact remains, and its force must be acknowledged, that such a law does give proof of a widely-distributed presence of harvesting ants in Palestine, and a knowledge of their habit among all classes of people.

Such, without multiplying quotations, is the unvarying tenor of the allusions in ancient literature to the ant, so far as I have been able to trace them. If we may so much anticipate as to add that the authors of these passages were for the most part residents in the countries surrounding the Mediterranean, in which modern research has uncovered two species of ant most addicted to harvesting seeds, we would certainly be over-credulous to suppose that they spoke without any personal knowledge of the facts of which they wrote.

Yet we cannot, on the other hand, forget that the English classics abound in similar allusions, which it is hardly to be doubted are based upon a traditional faith in the facts them-

[1] St. Matt. xxiii. 23.

selves on the part of the authors. They could not have observed any such habit in English ants, as it does not appear to exist. They accepted the testimony of Scripture, the Greek and Latin classics, and the church fathers, and embalmed the borrowed sentiment in their own writings. Only one of these authors shall be quoted here. Milton has this reference to the ant,[1] in his matchless account of the creation of living things, which he has placed in the mouth of Raphael. The angel is reciting to Adam the origin of Insect life, and with zoological accuracy places the Hymenoptera at the very head.

English Classics.

"First crept
The parsimonious Emmet, provident
Of future, in small room large heart enclosed;
Pattern of just equality perhaps
Hereafter, joined in her popular tribes
Of commonalty; swarming next appeared
The female bee, that feeds her husband-drone
Deliciously, and builds her waxen cells,
With honey stored. The rest are numberless,
And thou their natures know'st, and gav'st them names."

Let us now trace the steps by which the ancient opinion and writings upon this point were first carried into discredit, and then finally, within the last few years, were restored to confidence.

Gould,[2] a clergyman of the Church of England, was among the first, in his "Account of English Ants," to question the harvesting habit of ants. One who may not have access to the original book will find a quite complete abstract of his work given in the *Philosophical Transactions*[3] (London, 1747), by Rev. Henry Miles, D.D., F.R.S. Our author, says Dr. Miles in this abstract, with great deference to the writers who have held the affirmative, and with

Ancient opinion discredited.

[1] Paradise Lost. Bk. vii., l. 484, seq.

[2] An Account of English Ants, by the Rev. Wm. Gould, A.M., of Exeter College, Oxon. London. Printed for A. Millar, opposite Katherine-Street, in the Strand, 1747, in large 12mo. p. 78, seq. Phila. Libr. Co., Ridgway Branch.

[3] Philosophical Transactions, London, vol. xliv. Part II. For the year 1747, p. 360, seq. Libr. Acad. Nat. Sci. Phila.

extreme decency, differs from them, offering a handsome apology for himself. He suggests that in warmer regions they may not undergo the chill they do with us; and therefore, may not pass the winter in a state of numbness. That if this be the case, a store of food must be necessary to them, which is not to our Northern ants, which live, as it were, entranced. He adds, that upon the most impartial examination of authors, the opinion seems rather to be supported by its antiquity, than reduced to a clear demonstration. He tells us, that upon the most exact and frequent examination of numerous settlements, in the winter, he could never trace out any reservoirs of corn or other aliment. He then resorted to experiment. A number of complete colonies of various species of ants were placed in the early spring, in flower-pots and other vessels, so that while the formicary was thus located conveniently for observation, the free and natural behavior of the ants was not restricted. These were kept under close observation during the entire year; they came and went, bringing and seeking food, and reared their young exactly as other nests of like species, but never stored any grain, and never were seen importing seeds of any sort to their homes. They eagerly attacked a pot of honey or a jar of sweetmeats, but never were tempted by wheat, corn, or any other vegetable seed. These experiments were conclusive as to English species, and they were ingeniously, patiently, and skilfully conducted.

Rev. Wm. Gould originates the doubt.

Mr. Gould was of course compelled to meet the uniform record of ancient literature, particularly that of the Book of Proverbs. It speaks well for his clear judgment that he at once gave the true solution, as already indicated, viz., the probability of different species with different habits modified by different climatic environment. Not to be limited to one reason, however, admirable as it was, he adds: "Or perhaps it might have been a received opinion, as was the Sun's Motion; from whence this great Prince (Solomon) might recommend it as a worthy Example of Industry and Wisdom."

Dr. Miles assents to Mr. Gould's view, and justifies himself by declaring, after an examination of the original, that the expressions in the Proverbs necessarily mean no more than that ants collect their food in its proper season. That they do this in winter can only be determined by examining into the fact, which he declares Mr. Gould has done, at least with respect to English ants, and determined that they do not eat in winter and have no stores of food laid up. He concludes thus: "The Opinion therefore of their laying in Magazines against winter seems to me to have been grafted on these Scriptures rather than found in them, and this from a Conclusion, naturally enough made, from observing their wonderful Labor and Industry in gathering their food in the Summer, supposing that this must be to provide against Winter. And, after all, great Part of their Labor, which may have been bestowed in other services, might easily be mistaken, by less accurate Observers, for carrying in Food."

Rev. Dr. Miles.

Thus the counter-current of thought set in, and from this time forth, for more than a hundred years, it ran steadily away from the ancient opinion with scarcely an opposing record among naturalists. Latreille,[1] among the greatest of entomologists, and very foremost of myrmecologists at the opening of the present century, thus wrote: "Many years ago the Wise man sent us a journey to the school of the ant, that we might there learn his lessons. I cannot be so weak as here to perpetuate the popular error upon which is based this advice which the Wise man has given us, and which has never since ceased to be reproduced. We cannot attribute to the ant a useless foresight. Since she is torpid during winter, why should she establish granaries for this season? But in studying the behavior of this little animal, we need not the less be profited; her laborious life shall be to us equally a true model, and we shall still have cause enough

Latreille.

[1] Histoire Naturelle des Fourmis, Paris, 1802, p. 23. Libr. Acad. Nat. Sci. Phila.

to exclaim, filled with admiration, *Vade ad formicam, O piger!* Go to the ant, thou sluggard!"

Huber,[1] whom Kirby has well called "the great historiographer of ants," incidentally records his accordance with the prevailing dissent, as follows: "I am naturally led to speak in this place of the manner in which ants subsist in winter, since we have relinquished the opinion that they amass wheat and other grain, and that they gnaw the corn to hinder it from germinating." Huber.

Kirby,[2] like Gould, a clergyman of the Anglican Communion, and a man whose name occupies a highest place among entomologists, throws the great weight of his decision against the ancient opinion, but more cautiously than Latreille and Huber. He admits the force of the negative testimony of his contemporaries, and records with apparent approval the surmise that the ancients observing the ants to carry about their pupæ, which in shape, size, and color not a little resemble a grain of corn, and the ends of which they sometimes pull open to let out the enclosed insect, mistook the one for the other, and this action for depriving the grain of the corculum. He subscribes to the opinion advanced by Gould that a harvesting habit might indeed possibly be found in tropical species, but emphatically endorses the opinion of Dr. Miles, above quoted, that the popular interpretation of Solomon's words has been fathered upon them rather than fairly deduced from them, and that the Proverbs simply mean that the ant with commendable prudence and foresight makes use of the proper seasons to collect a supply of provision sufficient for her purposes. Rev. Wm. Kirby.

I will close this series of quotations by an illustration of the manner in which Christian apologists of the present time have

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[1] Recherches sur les Mœurs des Fourmis Indigènes, par P. Huber, Paris-Geneva, 1810, chap. vi., § 5, p. 202. Libr. Acad. Nat. Sci. Phila. Natural History of Ants, Johnson's Translation, London, 1820, p. 237, Libr. *id.*

[2] An Introduction to Entomology. By William Kirby, M.A., F.R. and L.S., Rector of Barham, and William Spence, Esq., F.L.S. Second edition, vol. ii. London, 1818, p. 46, seq. Libr. Acad. Nat. Sci. Phila.

escaped from the difficulty raised by the discrepancy between the record of Solomon and the experience of modern myrmecologists. It is drawn from that noble work of sacred scholarship, Smith's Biblical Dictionary, article "Ant." I quote from the American Edition, which is in many respects superior to the English. The paper is written by an Anglican clergyman, the Rev. William Houghton. "The fact is, that ants seem to delight in running away with almost anything they find,—small portions of sticks, leaves, little stones,—as any one can testify, who has cared to watch the habits of this insect. This will explain the erroneous opinion which the ancients held with respect to that part of the economy of the ant now under consideration; nor is it, we think, necessary to conclude that the error originated in observers mistaking the cocoons for grains of corn, to which they bear much resemblance." The author very properly argues that it is not credible that Aristotle, Virgil, Horace, and other ancient writers could have been such poor observers as to mistake ant-cocoons for wheat kernels, close as the resemblance may be between the two objects, and then adds: "Ants do carry off grains of corn [cereals] just as they carry off other things, not, however, as was stated, for food, but for their nests." The fact which forms the basis of this statement is confirmed by an observation of the distinguished American missionary, Dr. Thomson, quoted from his excellent work "The Land and the Book."

Modern Christian scholarship admits the doubt.

Thus is laid a supposed sufficient groundwork for the popular opinion existing in Solomon's day, upon which his proverbs were erected.

It may be remarked, by the way, that the essential point in this part of the learned rector's argument is by no means so surely established as he appears to believe. After a somewhat extended observation of many species of ants, I regard it as the exception rather than the rule that they waste their energies in the portage of useless, miscellaneous material; and as to the carriage of grain and seeds I cannot think that it is ever habitually done in order to construct nests therewith, if

this is what is meant by the somewhat indefinite expression "for their nests." I have never found grain in the structure of a formicary of any species, and it is the sort of material that would hardly be safe so used, unless indeed its power to germinate should be destroyed before being mingled with the earthen components of the ordinary elevated mounds or underground nests.

Having satisfactorily accounted for the popular (supposed) error, the writer thus accounts for the use which an inspired writer felt justified in making of the same: "If such was the general opinion, is it a matter of surprise that the wise man should select the ant as an instance whereon he might ground a lesson of prudence and forethought? The teaching of the Bible is accommodated to the knowledge and opinions of those to whom its language is addressed, and the observations of naturalists, which, as far as they go, do certainly tend to disprove the assertion that ants store up food for future use, are no more an argument against the truth of the Word of God, than are the ascertained laws of astronomical science, or the facts in the mysteries of life which the anatomist or physiologist has revealed."

One must admit the ingenuity of this apology, and especially the force of the closing remark, since a Book that has been written for spiritual purposes alone, and for all ages, peoples, intellects, and conditions of culture, cannot be held in its current speech to the strict laws of criticism, by which avowedly scientific literature is properly tried. Nevertheless, it will not be without great satisfaction that the above quoted writer and all devout believers in Holy Scripture may learn that the best explanation of the supposed discrepancy is, that there is no discrepancy! that, after all, Solomon was a correct observer, and his two questioned proverbs are based upon facts; that later naturalists have been compelled to reverse the decisions and re-interpret the experience of earlier naturalists, as they have done so often before, and will continue in the future to do.

A Christian apology.

We may now briefly glance at the history of the observa-

tions by which the current of opinion is being carried back into the old channel. The earliest record that I have been able to find of a grain-gathering ant made during the present century, was made in India, by Lieutenant-Colonel W. H. Sykes, of the British Indian army. The observation was first made at Poona, India, June 19, 1829, but the account was not made public until 1834, when it was read before the London Entomological Society.[1] Colonel Sykes observed in several places on uncultivated land near the regimental parade-ground, more than a score of little heaps of grass seed (Panicum) each containing about a handful. These were raised by a species of ant, afterward named by him *Atta providens*, hundreds of which were employed in bringing up the seeds to the surface from a store below. The grain had probably got wet at the setting in of the monsoon, and the ants had taken advantage of the first sunny day to bring it up to dry. The store was very reasonably conjectured to have been laid up from the time of the ripening of the grass seeds in January and February, five months preceding the observation. Colonel Sykes was aware that his discovery militated against the observations of entomologists in Europe, and was therefore careful not to deceive himself by confounding the seeds of a Panicum with the pupæ of the insect. This observation was confirmed in October of the same year, after the closing thunder-storms of the monsoon, by finding the same species similarly employed. One of the heaps then being carried contained a double handful of grass seeds.

The old opinion restored.

Colonel Sykes, 1829.

Mr. Buckley's account of our agricultural ant, referred to in the introductory chapter, was given A.D. 1860, and appears to have been the first notice of the presence of harvesting ants in North America. A brief note[2] by the same author appeared in the early part (January) of 1861.

Buckley, 1860.

[1] Trans. Ento. Soc. London, vol. i., 1836, Art. XXII., Descriptions of New Species of Indian Ants, by Lieut.-Col. W. H. Sykes, F.R.S., etc., pp. 99–107 and Plate XIII. Libr. Am. Ento. Soc., Phila.

[2] Note on Ants in Texas, Proceed. Acad. Nat. Sci. Phila., 1861, p. 10.

Then followed Mr. Darwin's abstract of Lincecum's letter in the Proceedings of the Linnæan Society of London, which gave such wide publicity to this same ant; and five years thereafter (1866) appeared Dr. Lincecum's paper in the Proceedings of the Philadelphia Academy. Lincecum, 1861–66.

It was reserved for an English naturalist, the late Mr. J. Traherne Moggridge, to show conclusively that the old faith in the harvesting habit of ants was true of some species, and that several of these species exist in Southern Europe. Mr. Moggridge spent the leisure of an invalid life, which unhappily closed too soon, in thoroughly studying the habits of *Aphenogaster* (*Atta*) *structor*, and *Aph. barbara*, the harvesting ants of Italy and Southern France. His work, "Harvesting Ants and Trap-Door Spiders," is the most valuable contribution to the literature of this subject, and one which the general reader, as well as the more scientific, may read with pleasure. Mr. Moggridge not only observed these species gathering and transporting the seeds of various plants, but opened many nests at various periods of the year, and uncovered the numerous granaries filled with the same. He observed, moreover, the care which the ants exercise over the seeds in cutting off the radicle of sprouted grains, and bringing them up to the surface to dry after rains. Finally, he proved by continued observation that the stored seeds are actually used for food. It will be seen in these pages, that what has thus been accomplished in pursuing the history of *A. structor* and *A. barbara* has now been done, with much more of detail, in many respects, in behalf of our best known American species of grain-gathering ants. Moggridge.

It will be understood that, in the above sketch of the changes of opinion and the progress of observation upon this interesting emmet industry, I have not attempted to embrace every author who has written upon the subject. The aim has been to present a bird's-eye-view of the history, touching only upon the more important and most typical records, and those of greatest local value. The chapter would, however, be incomplete without this added fact. In the same volume, in part

upon the same page, and the next succeeding article to that in which Darwin gave Lincecum's name and observation to publicity, is a paper by Frederick Smith, the eminent English entomologist, describing certain species of ants from the Holy Land.[1] The last two given in this list are *Atta barbara* and *Atta structor*, the harvesters so accurately observed by Moggridge. Indeed, from a collation of the different localities at which these species have been found, it is hardly to be doubted that they inhabit the entire circuit of the Mediterranean shores. Here lived and wrote the men of antiquity, whose names and experiences have been recorded above, and who, therefore, must have had full opportunity to note that industry which they have commemorated. How accurately they saw and how truly recorded has already been seen.

Harvesting ants in Palestine.

Side by side with these descriptions of Mr. Smith we may place a record by a careful and trustworthy observer, Dr. Thomson,[2] who for a generation has been an American missionary in Palestine. He thus describes the habits of the harvesting ants of that country, and, although he does not give, and apparently did not know, their scientific names, it is probable that the above species are the ones referred to. All summer long, says Dr. Thomson of these ants, and especially in harvest, every denizen of their populous habitation is busy. As we walk or ride over the grassy plains, we notice paths leading in all directions from their subterranean granaries,—at first broad, clean, and smooth, like roads near a city, but constantly branching off into smaller and less distinct, until they disappear in the herbage of the plain. Along these converging paths hurry thousands of ants, thickening inward, until there is an unbroken column of busy beings going in search of, or returning with, their food. There is no loitering or jostling; every

[1] Descriptions of New Species of Ants from the Holy Land, with a Synonymic List of others previously described. By Frederick Smith, Esq., Journal Proceed. Linn. Soc. Zoology, vol. vi., 1862.

[2] The Land and the Book. By Wm. M. Thomson, D.D., vol. i. pp. 520, 521; vol. ii. pp. 262, 263. Harper's Edition.

one knows his business, and does not intermeddle with others. They are great robbers, and plunder by night as well as by day, and the farmer must keep a sharp eye to his floor in harvest or they will abstract a large quantity of grain in a single night. Leave a bushel of wheat in the vicinity of one of their subterranean cities, and in a surprisingly short time the whole commonwealth will be summoned to plunder. A broad, black column stretches from the wheat to their hole, and you are startled by the result. As if by magic, every grain seems to be accommodated with legs, and walks off in a hurry along the moving column. The farmers remorselessly set fire to every ant city they find in the neighborhood of their threshing-floors. The testimony of this most competent witness shows that the habits of the ants are to-day precisely as in the days of the authors of the Mischna, and indeed one might say as in the time of Solomon. Had they been as numerous then, and as well known, as now, in that country, or any portion of it, or as the agriculturals are in Texas, it would not be strange, but the most natural result, that their habit of storing grain should have been popularly taken as typical of the family; or, at least, that "the ant," without reference to any particular species, should be spoken of as a harvester. It is greatly to be wondered at, to say the least, that among all the hundreds of clergymen, and other Christian tourists, who, during the last century, have travelled in Palestine, no one (so far as I have been able to discover) has taken the pains to gather the material for removing the doubt which naturalists had cast upon so interesting a statement of the inspired writer. Verily, "the seeing eye" is a rare gift!

Thus "the wheel has come full circle round." The latest nature-studies here at least touch the earliest, and greet them as honest and exact. Of course the error into which Gould, Huber, Latreille, Kirby, and other observers as justly eminent, permitted themselves to fall, was caused by a too hasty generalization. Certainly, few of the ants observed by them had, or have to-day (so far as we know), the harvesting habit.

Simply, their experience had not covered a sufficiently wide field. Their premises were in a measure correct, their conclusion wholly false. The error is, perhaps, more worthy of notice in the case of Latreille, as *A. structor* is one of his own species,[1] whose habits appear to have fallen under his personal notice. It must be allowed, indeed, that the harvesting habit is limited to a few species, so far at least as present observations inform us, although there is reason to believe that a wider and closer study of the economy of ants will uncover many more.

[1] See Ess. sur l'hist. des fourmis de la France, p. 46, and Hist. Nat. des Fourmis, p. 236; and p. 286 for *A. barbara*, which was also known to him.

CHAPTER V.

THE ARCHITECTURE OF FORMICARIES.

ALLUSION has already been made to the characteristic forms of the external portion or disk of the formicaries. A more detailed description will now be given. There are six prevailing forms more or less dissimilar, which for convenience we may distinguish as the Flat disk, the Mound disk, the Gravel disk, the Cone disk, the Mound nest and Cone nest. The first three are found at Camp Kneass and generally upon the hills around Austin, the flat disk being the prevailing form. The opportunity to study the hills in the prairie country being extremely limited, I referred a number of questions to the Rev. Warner B. Riggs, who kindly undertook to furnish the desired information. In the immediate vicinity of Brenham, where the soil is sandy, the mound nests and cone nests prevail. Several miles beyond the town where the black soil appears, the flat disks reappear, not more than half of the formicaries having elevated cones. Very few of these have bare zones around their bases, only three out of about fifty hills. It thus appears that in the lowlands the characteristics of the formicaries are not different from those of the upland nests, except that the cone nest and the cone disk there appear. Perhaps a wider examination of nests in the hill country would show the presence of these also. At the present stage of our information it seems that the flat disk is the most typical form, as it is most widely distributed, and that independent of locality. There is evidently, however, some relation between the flat disks and the black soil. The tendency to this form in that soil, noted by Mr.

Formicary disks. Their forms.

Riggs on the prairie, was observed by me upon the hills. I have no explanation to suggest.

The Flat disk.

Fig. 2, Plate I., represents one of these disks, which, for convenience of reference, I have marked Disk Z, as it was one of the nests opened in order to study the interior. It was one of the largest, the longest diameter being 10 feet 6 inches. A point was taken by the eye, as near to the centre of the disk as might be, and several diameters measured through this point as follows: 8 feet 3 inches (east and west); 8 feet 4 inches (north and south); 9 feet 5 inches; 10 feet; 10 feet 1 inch; 10 feet 1 inch; 10 feet 4 inches; 10 feet 6 inches. It will thus be seen that the circumference of the disk very nearly approached a circle. Some of the disks at Camp Kneass are nearly 12 feet in diameter. Among the smallest in my lists are one 1 foot 8 inches in diameter, one 1 foot, and the smallest seen was 6 inches in diameter. The prevailing size is 4 to 5 feet diameter. The surface of Disk Z was quite smooth, and for the most part free from grass. At the point represented by the upper margin of the figure there was a "clearing," that is, a spot covered with roots and stubble, and upon the bank beyond there was a space over which evidently the grass had been trimmed down almost to the ground. This section presented the appearance of being under manipulation by the workers for enlargement of the disk. On the opposite side were a few tufts of grass.

Mound disk.

Fig. 15, Pl. III., represents the Mound disk. The one figured is located in the black soil. The mound is 2½ feet in diameter, with a depression in the centre, in which are two connected gates. There were seven very wide and plainly-marked roads. Tall tufts of mesquite grass grew on the margin near the mouths of some of the roads. The width of the belt, or flat, bare space between the mound and the margin, was about that of the mound. The number of disks of this form at Camp Kneass was very small. In one list of 25 nests, only two such occur; in another of 30 nests, only four.

I have used the term Gravel disk to designate those nests which have a mass of gravel around the gate, and an open belt beyond. Quite a number of these were found, always in stony or gravelly soil. Some of the nests were made in the midst of the nuggets of limestone which covered certain portions of the common. The ground around these stones was smoothed in the usual way, the circular margin was maintained, and the work of the formicary seemed to go on with ordinary vigor. Some of these rocky disks were without any accumulations of gravel; others had flat, low gravel-heaps entirely or sometimes partially surrounding the gates. Most of the gravel disks were placed in a light pebbly soil, and the gravel, which had evidently been brought out from within, was arranged in form similar to the mounds just described. In opening out galleries and granaries in such soil, it became necessary for the ants to remove the pebbles, which, through a natural economy of time and strength, were deposited at the nearest convenient point to the surface-opening. A mound thus gradually grew around the gate. These gravel mounds are from one to two inches high, depressed in the centre, and are free from intermixed soil. Some specimens of gravel collected had an average weight of one and three-sixteenths grain, which is a quite formidable load for a small insect. Lincecum speaks of gravel mounds 18 inches, and 2 feet high, with a diameter at the base of 4 feet. He records one of these stone pyramids nearly 3 feet high, and nearly 6 feet in diameter at the base, in which there were many little fragments of stone, some of them carried to the very top, any one of which would weigh more than twenty-five ants. Six ants (alcoholic specimens), accurately weighed by me, gave successively 13.5, 13.25, 12.5, 9, 8, 7.5 millimetres. As a millimetre is approximately one-sixty-fifth of a grain, the weights carried by these ants (one and three-sixteenths grain) were thus from five to nine times their own bulk. In one case, I saw an ant carry a long distance a pebble which must have weighed twice or three times as much as any of those weighed by me, so that Lin-

Gravel disk.

cecum's supposition is credible. Such a calculation certainly gives a striking view of the muscular power of ants. Think of a man weighing 160 pounds carrying twenty-five times his own weight, or 4000 pounds, say from the bottom of an English coal-pit to the top of a shaft as high as the pyramid of Cheops!

First mention of Barbatus. Nuttall.

The earliest reference to the agricultural ant, of which I have knowledge, was made in connection with this form of nest. It is found in Nuttall's[1] "Travels into Arkansas Territory," published A.D. 1819. The observation was made upon "Cedar Prairie," in the neighborhood of Fort Smith, then a simple and solitary military post, now a flourishing city. "Among other objects of nature," says the writer, "my attention was momentarily arrested by the curious appearance of certain hillocks, about three feet high, generally situated in denudated places, and covered over with minute pebbles. These, on closer examination, proved to be the habitations of swarms of large red ants, who entered or came out by one or two common apertures." It is not difficult to recognize our Texas emmets under this description, and it is much to be regretted that the enterprising traveller did not suffer his attention to be more than "momentarily arrested" by their habits. In several particulars, however, it will be seen that these habits have remained unchanged during the sixty years that have intervened since this first record. I do not know whether the species now exists in the neighborhood of Fort Smith.

Mound nests and Cone nests.

I have used the terms Mound nest and Cone nest to designate formicaries whose surfaces are simple mounds or cones, with no distinct belt or bare zone between them and the surrounding grass. They correspond, the latter especially, in general appearance to the "hills" of *Formica exsectoïdes*, so familiar in our Northern mountain regions. The nests which I examined at Hempstead, and at a station in Lee County, were of these forms, as were those seen

[1] Travels into Arkansas Territory. Thomas Nuttall, pp. 145–6. A.D. 1819.

in great numbers from the railway car along the entire route through Texas, from Austin to the Red River, and northward as far as Muskogee, Indian Territory. The material of these mounds and cones is a light, sandy soil, easily pulverized, with no gravel intermixed. The grass of the surrounding prairie comes close up to the base of the cone. The mounds and cones examined by me had crater-like depressions at the summit, in the midst of which at least one gate, usually the principal one, was placed. The second gate was generally toward the margin of the crater, or even beyond it. Mr. Riggs sent me the following measurements, all in inches, of six mound and cone nests located in the near neighborhood of Brenham:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Circumference at base.....	270	32	160	52	276	216
Distance over mound.....	85, 95	12	54	18	104	60
Height.....	5	3	5	1	6½	7

These hills, says Mr. Riggs, are generally conical for some distance from the base. The tops of the majority are crater-shaped, although the top of some of the large hills (No. 6) is a flat surface, without a crater. The position of the gates is as above indicated. The large hills were all covered at the date of observation, the early part of December, with the same grass as the ground in the vicinity; the small hills, which were supposed to be new, were bare. On the black soil beyond Brenham, only about half of the nests have elevated surfaces, and of these more than three-fourths are bare, a marked and unaccountable reversal of habit. Plate III., Fig. 14, represents a cone nest observed at one of the railway stoppings east of Austin.

The Cone disk.

Out of fifty nests in one list noted upon the black soil, Mr. Riggs found three having the external form which I name the Cone disk, that is, a cone rising in the centre of a disk. Fig. 14 placed in the centre of Fig. 15 will give the form. In each of these three nests, the width of the free belt is three feet; the height and base of the cones not given. Two of the belts were entirely bare, but on the third a new growth of grass was coming up.

The appearance of these cone disks in Texas at the surface of the agricultural ant nests, has additional interest from the fact that similar cone disks are found in the Rocky Mountains, upon the plains of Western Kansas, Colorado, Wyoming, and Utah. They are constructed by a different species, *Pogonomyrmex occidentalis*, Cresson. Prof. Joseph Leidy collected a number of these ants in the summer of 1876, which were kindly placed at my disposal, together with valuable information concerning their formicaries. The disks vary in diameter from three to eighteen feet, the base of the cone occupying about one-third of this space at the centre of the disk. The cone rises to the height of from ten to eighteen inches, and on the exterior, at the locality of the observation, is composed of small, loose gravel stones. The interior is of friable soil, intermingled with fibres of roots, and excavated into galleries. The circular belt, like the flat disks of the agricultural ant, is entirely bare of vegetation, level, clear of loose soil, or, if gravelly, the pebbles are firmly impacted, not unlike a stone-laid street. Occasionally, however, bunches of grasses, as Eriocoma and Triticum, are retained near the outer border. The sage-bushes, grease-wood, and other vegetation of those plains, densely skirt the circumference of the disk.[1]

Variation of nest-forms.

The relative position of the flat and cone disks became a question of some interest to me, after Mr. Affleck had communicated some of the facts related above concerning apparent differences in habit between the inhabitants of the two forms of nest. I can detect no difference in the structure of specimens drawn from the different nests, and am at a loss to account for variations in the behavior and what appears to be a fixed characteristic in architectures. I therefore requested Mr. Affleck to make some extended observations upon all the formicaries in his neighborhood, in order to determine if there were anything like a fixed grouping among the individual exteriors of the several nest-forms, or if, on the contrary, cone nests, mound disks and flat disks were interblended

[1] See a brief notice in Proceed. Acad. Nat. Sci. Phila., 1877.

promiscuously. Should the distribution prove to be in separate groups, it occurred to me that the fact would be one step *forward* in determining a tendency on the part of each group to perpetuate its own form. Mr. Affleck kindly undertook the inquiry, and illustrated it by the accompanying diagram, showing the location of the formicaries on his own plantation. The figure (Fig. 16, Plate III.) represents a section three hundred yards wide and a mile and a half long, extending northeast from the dwelling-house, D. There are five groups of formicaries on this strip, located and distributed as follows:

Relative grouping of flat and cone disks.

Beginning at the running brook, represented by the open curved lines, on the extreme west of the section, we find two groups, viz., No. 1 of two cone disks (there is an error in the figure), represented by the open circle, and four flat disks, No. 2, shown by the crossed circle. They are in stiff, black soil, mostly a deposit, and occupy about the same elevation in a depressed situation. The groups appear to be separated by a small dry branch, represented by the black curved lines. The lower of Group 1 is a very large nest, situated immediately upon the bank of the stream, one side of the nest extending down the bank. This formicary has occupied the site for a long time; the other is of recent origin. Group No. 3 includes a number of flat disks on a rocky hill, elevated about 50 feet. There is a good deal of soil on the hill. The number of disks is not stated, but they are all of one form. No. 4 is a group of cone disks situated at the head of a dry branch, on an elevation of 75 feet. No. 5, also composed of cone disks, is located on an elevation of 100 feet, nearly three-fourths of a mile from No. 4. These last two groups are in a rich alluvial soil. Mr. Affleck's conclusion of the inquiry is, that all the nests "are either cone or flat disks, and they are invariably found in colonies, and never in the immediate vicinity of each other." In a subsequent letter Mr. Affleck answered some questions intended to evoke wider and yet more careful examination of this point by the following con-

clusive statement: "The grouping of the nests is certainly as I represent. I might cite a hundred cases to establish the fact. I could give you diagrams in any direction from my house or elsewhere showing the fact." The facts as exhibited in the above chart certainly point to such an inference. But more extended comparison must be made before a fixed conclusion can be reached. The investigation is one in which any intelligent person in the field can aid.

At Camp Kneass there were no cones, the only approach being the low mounds already described. My attention was not called to this relative grouping at the time of my visit, but I did observe that the mound disks were for the most part grouped near one another, and that they were chiefly upon the light and gravelly soil, while the flat disks were placed in the deep black soil. The genesis of the mound thus seemed to rise naturally from the economy of the ants in the carriage of pebbles brought up from the excavations and deposited in growing masses near the gate. The facts as to distribution were not noted carefully enough to aid in any generalization.

There is one point that Mr. Affleck's chart, in connection with the notes of Mr. Riggs, appears to throw light upon. It has been stated that the flat disk seems to be the normal form of the agricultural ant nest, and that the cone is popularly supposed to be an elevated modification thereof, caused by the liability to inundations in low or flat situations. It seemed an admirable proof of the superior intelligence of this insect that she should thus be able to adapt herself to changed environment, and develop a habit which should overcome successfully serious natural obstacles to her distribution. This is the view which I was inclined to hold, as quite in accord with all that I had observed. But, turning to Mr. Affleck's plat, we are struck first by the fact that one of the groups of flat disks and one of cones are located on the lowest point of land, at the same elevation, and, moreover, that the two groups are both and about equally exposed to inundation by reason of their nearness to a stream. The common theory is only so far favored that the two nests on the

Genesis of the cone disk.

very bank of the water are cones. The location of group No. 3, on a rocky hill, looks toward the same theory, but on the other hand the two remaining groups are cone nests and are on the highest elevations, No. 4 at 75 feet, and No. 5 at 100 feet. There may be some local peculiarities which, if known, might greatly modify this reasoning; but, as the facts stand, they seem to place the particular shape of the exterior formicary quite outside of any relations to the overflowing waters.

Not caused by struggle to escape inundations.

The statements of Mr. Riggs fall into the same channel. In the vicinity of Brenham the soil is sandy and the nests are all crowned with mounds or cones; farther out upon the prairie the two forms appear in juxtaposition. I have no notes from Mr. Riggs on the grouping of the forms, nor directly as to the relation of form to inundation, but the fact is plainly stated that cone disks and flat disks are each distributed in the prairie and in about equal proportions. The inference, particularly with some knowledge of the surface-level in that vicinity, is clearly the same as that taken from Mr. Affleck's plat.

I observed no ants engaged upon either mounds or disks in work of construction or repair, with one exception. Near the edge of one disk, and close by a grass clearing on which a party of ants were busy, one worker was occupied upon a heap of pulverized soil, apparently in removing it. The mouth was placed down to the earth, there was a rapid movement of the fore-feet, as though the dust were being thrown into the mandibles or mouth, or between the two. Then the abdomen was bent under, thrust forward, and applied to the mouth. Whether in this motion there was simple pressure of this organ against the dust, or the deposit of some secretion in order to moisten the particles of dust and cause them to adhere, I could not at that time determine. The ant then turned and deposited the pellet upon another part of the disk, not far distant. This work went on for some time with the utmost regularity, the same movement of the abdomen being invariably repeated. I was

Construction and repair of disks.

obliged to abandon the observation before the work ceased, and before I was satisfied as to the real purpose of the insect. Had the heap of coarse dust been formed through voluntary action of the ant by scraping the surface, and was this a part of the usual mode of reducing the inequalities of the disk? I could query, but could not answer. Close by the spot where this dust-gatherer was engaged, several other workers were loading themselves with pellets of earth, which they carried to other points, with no purpose that I could divine. I regretted the necessity which compelled me to leave this interesting observation, even though after a considerable period of time it had yielded such unsatisfactory results. I afterward frequently watched the same formicary, but neither there nor elsewhere did I see any similar labors. The energy of the entire colony seemed to be directed chiefly toward the work of harvesting, and in some degree toward the clearing away of intruding vegetation. Lincecum refers to such labors, saying that the ants bring to and pile upon their mounds the pellets of earth thrown to the surface by earthworms; and, again, that the "pavement is formed by selecting and laying such grits and particles of sand as will fit closely over the entire surface." The trustworthiness of this observation or opinion (it is uncertain which) is much strengthened by Professor Leidy's description of the pebble-paved zones which surround the conical formicaries of the Rocky Mountain ants. In the black prairie soil, continues Lincecum, where there is no sand, the ants construct the pavement by levelling and smoothing the surface and suffering it to bake in the sunshine, when it becomes very hard and firm. Whether all this is the result of personal observation or one of those "guesses" which abound in the venerable doctor's paper, it is also impossible to say. That the ants are amply endowed for such labors I am satisfied by my own observations, and Lincecum's statement is not improbable.

I tried to test the opinion that the ants deliberately level and smooth the disks by another mode than actual view of

the process. Beyond the camp was a rivulet with sloping banks, upon which were a number of disks. Do these follow the slope of the hill, or are they level? The first disk examined was a very large one laid out upon a grassy slope. The disk was an almost level floor, its plane being nearly at right angles to the perpendicular. After a careful examination and consideration of every possible circumstance that could have modified the position of the disk, I could come to no other conclusion than that the ants had, in some way, controlled the matter. The upper section of the circumference, toward the top of the slope, had evidently been cut down and the surface of the disk graded to the level plane which it presented to the eye. I turned to other formicaries, confidently expecting confirmation of what seemed a new and interesting exercise of the emmet intellect. I was disappointed. Here and there a tendency toward establishing a level grade was manifest, but the dozen or more additional disks examined followed the slope of the hill. They were denuded of grass, and sunken a little below the surrounding surface soil, but otherwise showed no decided variation. The conclusion drawn from the study of the first disk was therefore abandoned, and had not the impression made thereby been so strong as to leave the thought that the point may be worthy of further examination by some one on the field, the record should not have been entered here.

Are disks always level?

The entrance to the interior of the formicaries is by one, two, or more gates. As a rule, there is but one gate, occasionally two, rarely three, and Mr. Riggs reports one disk with four gates, one of them being near the base of a low mound. Of twenty-one nests at Camp Kneass, seventeen had one gate, two had two gates, two had two connected gates. There seems to be a tendency to an increased number of gates in the nests with cones and mounds. In a group of five reported by Mr. Riggs, one had one gate, three had three, one had four. In such nests the gates are situated in the crater, and at or near the centre. This is

Gates.

the invariable rule, and appears strangely in contrast with the nests of *Pogonomyrmex occidentalis* among the Rockies, which, according to Professor Leidy, have the gates invariably at the base. The hills of our Pennsylvania *Formica exsectoïdes* among the Alleghenies combine both of these features, the great majority of entrances being at the base, but various gates being also scattered over the surface of the cone.

In the flat disks the gates are located near the centre, only one exception having been noted. For example, at Disk Z (Fig. 2) two diameters were drawn cutting each other at right angles, the main gate being the point of intersection. The four radii measured as follows: first diameter, 5 feet 1 inch and 5 feet 4 inches; second diameter, 5 feet 6 inches and 4 feet 7 inches. When disks have two gates there are sometimes one quite large and another small one near it. Again, they are of nearly equal size, and from three to five inches apart. In other cases the gates are connected by a smooth, regular sunken way, as represented at Plate V., Figs. 20, 22. In one case the gates were connected by a sunken, shelving triangular approach, as at Fig. 21. The gates are all simply circular openings at the surface, from one-half to three-fourths of an inch in diameter.

Within the gate is a vestibule (Fig. 23, v.) shelving downward at an angle of about or less than 45°. In one nest with two gates the galleries into which the gates opened united upon the vestibule at the distance of one inch and a half from the surface. The vestibule is from one to two inches wide, quite smooth, and one-half to three-fourths of an inch high. It resembles closely in form and dimensions one of the smaller granaries described below. At a distance from the gate varying, in the formicaries opened, from one-half inch to two and a half inches, the vestibule diverges into one or more tubular galleries connecting with granaries and nurseries. The upper galleries are nearly or quite horizontal.

Vestibule.

In order to make detailed studies of the interior of the

formicary, a number of nests were opened up, several of them being completely dug away to a depth of three feet. The amount of manual labor required for the prosecution of this work was very great, and it was necessary to have the aid of two men. While Tindall and Pearson used the spade and pick, I carefully manipulated the granaries and nurseries with a trowel and large knife, and was thus able to uncover in the various nests enough of these chambers with their connecting galleries to give a satisfactory, I might almost say complete view of the interior architecture. Some of the nests were cut (one-half being removed), so as to expose vertical sections. Others again were gradually scraped down, very thin layers of soil being removed by the spade, until the exposure of granaries, when the knife and trowel were used. In this way horizontal views were obtained, the most perfect of which was that represented at Fig. 28, Plate VI. This drawing was made from a mound disk, which is distinguished as disk W. The mound had but slight elevation, and was two feet three inches in diameter. The granaries figured were found an inch and a half below the surface. The group well represents the general structure of these store-rooms, and may be described as a series of circular, oval, and crescent or horseshoe-shaped rooms, quite uniformly one-fourth of an inch in height, but ranging to three-eighths and one-half inch. The formicary had two gates, the vestibule of the main and more central of which inclined toward the granaries. The circular gallery *a*, *a* measured in diameters three and one-half by four inches; *b*, three and three-fourths by three and three-fourths inches; *c*, six inches long by three wide. The granaries were all nearly but not quite upon the same plane; several were one-fourth of an inch below the others. Some of the rooms, as *d* and *h*, were connected by a gallery; others showed galleries, as at *d*, *i*, opening downward perpendicularly from a central spot, or at an incline from the side, as at *e*. The arms at *a* and *b* did not seem to have any gallery connection, as in *h*, but to be simple irregularities, perhaps, like the bays in a long bridge, or basins in a canal, to

Granaries.

relieve any unusual pressure upon the space of the chamber. The floors, walls, and, as determined by the fragments removed,[1] the roofs also were hard and smooth.

This effect may be due, in part, to the gradual abrasion wrought by numbers of insects in their continuous rapid movements; but it is probably also caused by some rude practice of the mason's craft on the part of the ants. This conclusion is formed from the condition of some of the chambers in disk Z, whose interior will be fully described hereafter. The top stratum of the nest was the black soil; below this were a light yellowish soil and the "adobe," as it is called, a hard, white, chalk-like clay. In the granaries made in this light soil and in the adobe, the floors, walls, and roofs were plastered with a thin, even coat of the black, unctuous soil, which had been brought for that purpose, in the case of at least one large chamber, ten inches from the surface. In the light soil I could easily find a reason for this in the probable increased consistency which the stiff clay might give to the granary walls. The black soil, in fact, served as a kind of cement. I could not so readily suggest a reason for the fact in the rooms cut in the adobe.

Seeds.

Within the granaries of nest W (Fig. 28) were masses of seeds, such as have been already described. In the upper ones the larger part of the seeds were still within the shell, the most of those in the lower rooms being husked, and some of them quite green. Green and dry seeds were found together in granaries fifteen inches from the top.

[1] It may be well to remark, by the way, that the black sticky soil in which were located some of the excavated nests very much favored the study of this subterraneous architecture, although greatly increasing the labor. In one nest opened shortly after a shower, the friability of the soil was so greatly overcome by the moisture that an admirable section view was had. Some fragments which showed portions of granaries were laid aside, and dried so hard that I was enabled to bring them home entire, and they are admirable natural specimens. Had my time allowed after the discovery was made (near the close of my stay), I could doubtless, by previously pouring a few bucketfuls of water upon a disk in the black soil, and working with care, have procured entire a much more complete set of specimens. I record the hint for the advantage of future students.

The seeds were piled up one upon another, apparently nearly to the roof. Narrow gangways were left at the outer margin between the grain-heaps and the wall. In another formicary opened, the naked seeds in most of the store-rooms were covered with a glutinous material, which gave them a glossy appearance, and caused them to adhere to the floor as though stuck by mucilage. A portion of one of these floors was preserved, and still has the seeds adhering to it. From these store-rooms fully a pint of seeds, chiefly of the buffalo-grass, was taken, the greater amount being in the galleries nearest the surface. The greatest depth at which seeds were found was two and a half feet.

Depth of formicaries.

The distance to which formicaries are carried downward probably varies according to the soil and the number of the community. The great work involved in digging out the number of nests required for study of the granaries, prevented me from going farther than four feet below the surface, at which point galleries still were found leading downward. Pearson, an intelligent young man assisting in the excavations, said that while engaged in sinking a well upon an adjoining farm, he saw these ants at fifteen feet below the surface coming out of the ground from holes similar to those which we were then uncovering. After closely questioning him and testing his ability to judge accurately of such a fact, I was satisfied that he had not been deceived. The well had been sunk near the nest in the idea that the ants go down to water, which would surely be found at a convenient distance below the surface disk. However, after carrying the well down ninety-six feet, no water was found.

Nurseries.

The large nest Z, whose disk has already been described, was opened in the manner represented at Fig. 24, Plate V. A cutting was made along the disk at *ba*, and then a cavity of about five feet in diameter made from the central portion. The nursery, which is shown at Fig. 30, Plate VII., was found at the point marked *c* (Fig. 24), ten inches below the surface. The floor of this chamber was uncovered entire, and most of the side walls also, by tedious

and careful manipulations with knife and trowel, my assistants in the mean while constantly brushing off and pulling from my person the hordes of irate insects who attacked me as I bent over at work in the excavation. After a drawing had been made, a plaster cast was taken of the room, by which its contour was perfectly preserved, and thus the original drawing corrected, and the figure here given (Fig. 30) made accurate. In this nursery nothing was placed but white larvæ and pupæ in great number, and a few callow antlings, of a livid yellow color. The floor was horizontal, level, horseshoe-shaped, the opening or horns directed inward, one of them pointing toward a line drawn perpendicularly through the main gate, to which there was evidently ready access by galleries. A section of a gallery, *g*, was preserved in the cast, which slanted toward the gate. The distance from the nearest point of this horn of the crescent to the gate, in a direct line, was fifteen inches. The floor was hard, quite smooth, and (as also were the walls) covered with the sticky, black top-soil, which showed in marked contrast with the reddish, sandy earth in which the nursery was excavated. In the midst of one of the horns was what appeared to be a column, *h*, passing from floor to roof. At *b* there was the appearance of a gallery opening downward at a slight inclination. The measurements of this room are as follows: from *b* to *c*, three inches; *c* to *d*, four inches; *d* to *a*, one and one-half inches; from *a* to the angle below, one inch. A total width of nine and one-half inches. The depth of the horseshoe from *b* to *e* was five inches. The greatest depth was six inches.

This crescent, or horseshoe-shape, is evidently a common form of the underground chambers, as it was frequently found in the excavations. One of these was taken out nearly entire from a nest in the black soil, and is preserved in a matrix of plaster. Fig. 29 represents this chamber, nearly natural size. FF is the floor, smooth, hard as though baked, and level, except at the inner edge of the arm, IF, where the surface is slightly elevated and convex. In the centre of the communicating passage a tubular gallery opened, which extended

upward at *g*, expanding into what may have been a dome-like interior, or possibly a gallery opening upward. The wall of the communicating hall was rounded as at C, and arched, this form continuing along the side wall to E. The height at C is one-fourth of an inch. The dimensions are as follows: AB, two and one-half inches; IF, one and three-eighths inches; GH, three-fourths of an inch; *mm*, across the mouth of the dome, one-half inch; the diameter of the gallery itself one-fourth inch. At various points throughout this formicary galleries were met quite uniformly of the same width, hard and smooth like the store-rooms with which they communicated, and for the most part running obliquely downward.

Section views of nest interiors.

In order more perfectly to develop the subterranean architecture, several nests were opened in a manner to give section views of the arrangement of chambers and galleries. Plate VIII., Fig. 37, will show the grouping of chambers in a section of nest X. The drawing is made to scale from actual measurements, and the proportions are correct. The cutting was made through the centre to the depth of eighteen inches. The rooms were grouped chiefly upon one side of the gate. They were not arranged directly over one another, but in a series, inclining toward the centre of the formicary. The distance between the rooms varied greatly, as shown by these measurements: from *a* to *b*, one-fourth inch; *b* to *c*, two and one-half inches; *c* to *d*, one inch; *d* to *e*, one inch; *e* to *f*, one and one-half inches; *f* to top, three and one-half inches; *g* to top, four inches. The length of the openings, as exposed in the section, varied from two to five and three-eighths inches; the prevailing length was from three to four inches. At three and one-half inches, more or less, from the surface there was a series of chambers running horizontally across the section from *h* to *i*, nearly upon a line. The last of this series, *m*, was a large, irregularly-shaped store-room, worthy of especial notice. The exposed section is represented at Fig. 36. How much had been cut away on the other side of the section could not be positively determined, but, judging from the conformation of the chamber, as compared with other

rooms, and its location in the cutting, I concluded that the depth of the room was about three and one-half inches, and that I had therefore uncovered about one-half of this grand store-room. The dimensions of the remaining portion were as follows: height, one and three-fourths inches; greatest depth, one and three-fourths inches; greatest width, two inches. Thus the entire chamber may be described as an irregular cavern with a dome-shaped roof, the summit of the dome being one and three-fourths inches from the floor; the floor smooth and hard, of an irregularly oval form, the greatest length three and one-half inches, the greatest width two inches. The floor was smooth and hard as in all the other chambers; the roof was also smooth, but less so than the floor. In the room were found seeds and ants. Three-fourths of an inch below this great vaulted store-room was a chamber, *i*, three-eighths of an inch high, and five and three-fourths inches long. I believe that there was communication between this chamber and the vault above, but did not see the opening. At various points throughout the excavation were met tubular galleries, quite uniformly of the same size, viz., one-quarter of an inch in diameter. The interior of one of the ordinary chambers in this formicary, nest X, is represented at Fig. 33. The drawing is made from a fragment preserved from the wreck, and which is now in my collection. The length from *c* to *d* is one and one-half inch; the width, *a* to *b*, two inches; the height of the room three-eighths of an inch. The average length of the rooms was estimated to be about two and one-half inches. They were similar in form, and finished as the vault above described.

One other section view will suffice to give a correct knowledge of the interior architecture of a formicary. This is taken from Nest Z, Plate IX., Fig. 39. The section exposed and described in the following figure was situated at the angle marked *a*, in the sketch of the cutting shown in Fig. 24. The section was located under the main gate, and the portions of the disk immediately surrounding. The surface represented in the drawing is in length from C to D, fourteen

Galleries in stories.

inches, in depth from the top to the floor of GH, eight inches. The rooms and galleries on this surface were carefully opened and cleansed from soil and dust, were measured and drawn, and finally the main features preserved by plaster casts. The accuracy of the outline was thus assured. A glance at Fig. 39 will show a general tendency to an arrangement in stories, four of which are indicated in the sketch. The roof of granary B was reached at two and one-fourth inches from the top. It was a large room, and apparently communicated directly with the gate. The gallery connection with the chamber A at the opposite side was not uncovered, but there was probably one which had been cut away or lay farther in. The second story or tier of rooms began at C, two and one-eighth inches from the top. The word "began" is of course used relatively, for it is apparent that the series extended farther toward the left, where a gallery, *g*, was seen leading off eastward and sharply inclined downward. Room A was one and one-fourth inches long, one-fourth of an inch high, and had an exposed depth of one inch. The gallery connection of this series was traced continuously from C to D. From C it extended with an inclination of over 45° downward for two inches, and then led off to the right in a general horizontal direction. Along this line of gallery, g^1, at various distances from one another, were store-rooms, placed successively at two and one-eighth, three, three and one-fourth, and four and one-half (D) inches from the top.

The third series, EF, was situated below the second, at an average distance of about one and one-half inches, approaching within one inch at the large room, F, which was two inches long and two inches deep. Near the middle of the series was a gallery, g^3, leading directly downward, distinctly traced for a short distance, and evidently communicating with the double room GH. This room, in the fourth series, was seven and seven-eighths inches from the top. The large chamber, G, was three inches long, and was connected with a smaller one, H, which again had evidently been united by a gallery, g^4, with other rooms which had extended toward the

right. All the above rooms and galleries were similar in construction to those before described.

My opportunity for visiting the formicaries in the prairies east of Austin was limited, but I had time to explore several cones with sufficient thoroughness to insure a tolerably clear knowledge of the interior construction. This has been confirmed and enlarged by the note of Mr. Riggs, and by specimens of nests well preserved sent me by Mr. Affleck. As one passes over the railway from Austin to Hempstead he sees spread over the open prairies large numbers of these nests. They are, for the most part, low, conical mounds, of various sizes, some of them apparently from eight to ten inches in height. Many of these have the crater-like depression at the top, and are surrounded with needle-grass. At one of the stations in Lee County I visited and cut into two of these mounds. The material of which they were constructed is a black, sandy soil, easily pulverized, containing no gravel. At less than half an inch from the surface, and again at one inch below, store-rooms were found, resembling those above described and figured. They were united by cylindrical galleries of great regularity. Indeed, these rooms and galleries appeared to have even a higher architectural finish than those of the disks explored at Camp Kneass. Seeds were found in all the rooms, chiefly a small, yellowish, flat, heart-shaped seed. A large, hard, black, smooth-shelled Croton was found upon the *outside* of the mound. I took to the cars a section of one of these nests, showing portions of two rooms, with a gallery communication between them two and a half inches long, which, in spite of the friable nature of the soil, I carried safely as far as St. Louis.

Nests on the prairies.

Mr. Riggs sent me a rough outline of a section of a mound nest, cut through the middle, which is represented at Fig. 31, Plate VIII. This was a very low nest, the perpendicular distance from the main gate, *mg*, in the crater, *cc*, to the ground surface, *ss*, being one inch. The distance across the top from *s* to *s* was eighteen inches. The circumference at the base, fifty-two inches. There was a second entrance, *g*, quite near

the base. The position of the rooms above and for a short distance below the surface is shown by the oval outlines *sr*, *sr*. Mr. Riggs states, particularly of the large mounds examined, that he found no granaries in them "except in a line running straight down in the centre of the hill." I had given him directions for obtaining a view of the rooms from above, by making a horizontal section, as at Fig. 28, but he failed in this. So loose was the texture of the soil of which the formicary was composed, that it was impossible to prevent the whole structure from breaking up under the manipulation. Nothing could be discerned in the ruins but irregular lines of commotion, where the ants were struggling to get out. Perhaps, if I had thought to suggest that the nests should first have been thoroughly moistened, a different result might have been had. However, there is little doubt that the interior of these mound and cone nests is substantially the same as that of the subterranean formicaries already described.

Specimens and section views sent by Mr. Affleck confirmed this opinion. One store-room was sent in nearly perfect condition, the toughness of the soil from which it was taken preventing it from crumbling. Its general shape, as will be seen at Fig. 50, Plate XII., is that of the granaries of flat disks, already described. The main room is a V-shaped excavation five-eighths of an inch in height, two inches deep, and two inches wide at the mouth, *mm*. A lip, *l*, extended from one side of the mouth, and on the other side curled around in a small circular chamber, *rr*, with domed roof. The opening to this circular room was seven-eighths of an inch wide; its depth was one and one-fourth inches, and its height five-eighths of an inch. The ground or floor plan alone is given here, but in the specimen the sections of the roof are entire, and, being replaced in site, show the two cavities with circular openings.

Granaries in cone nests.

It thus appears from the above observations, that the elevations upon the disks are true nests, permanently used for habitation, store-rooms, and nurseries, and not simple accu-

mulations of earth excavated from underground galleries. In this respect they resemble the mound nests of the Allegheny Mountains and of the New Jersey barrens. There is, however, a marked difference between the two; the cones of the mound-building Formicidæ being literally honeycombed with galleries, while those of the agricultural ant have comparatively few.

Three vertical section views were made by Mr. Affleck. The disk shown at Fig. 32 had an elevation of about three inches, and a diameter at the base of ten feet. It required great care to trace the rooms, which varied in size from one to three inches in diameter, and from one-half to three inches in height. The larger openings appeared to be chambers from which three or four passages branched off. The average size of the passages was about one and a half inches wide, and three-quarters of an inch in height. Every part was smooth and hard. This excavation penetrated to the depth of fourteen inches, at which point trace of the ants was lost. The galleries, according to Mr. Affleck, are ordinarily about three inches below the surface, sometimes more, sometimes less, and they penetrate to a depth not reached by his observations. He expresses the opinion that the formicary, although it approaches the limit of the belt on every side, does not extend underground beyond it. Fig. 35 is a section of a large mound nest, fourteen feet in diameter, domiciled by an unusually large colony. There were two gates, *a* and *b*, placed on the edge of the crater, six feet apart, and connected by a gallery, *g*. A store-room, *sr*, was uncovered under one gate, filled with larvæ one-eighth of an inch long and about one-sixteenth of an inch wide. One cone nest, Fig. 34, was cut and a section view made. The cone was five feet in diameter at the base, and had an elevation of fourteen inches. There were two gates, but about half-way down to the level of the surface of the ground the galleries united. This gallery did not again branch until it had passed beneath the surface-level. The exterior of the cone was covered by a crop of growing mes-

quite, common prairie-grass, etc., which, although sparsely distributed, had a vigorous growth.

These illustrations of interior architecture may properly close with a comparison of the same with that of the Florida harvester, *Pogonomyrmex crudelis*. The materials for such a comparative view are not abundant, but enable us to infer that there is a quite close resemblance in the work of the two congeners. Mrs. Treat describes the nests of Crudelis as small mounds, from four to six inches high, regular in outline, with a crater-like depression on the summit, in the centre of which is the gateway or entrance. Chambers or store-rooms, filled with various kinds of seeds, were scattered irregularly throughout the nest to the depth of twenty-two inches below the surface. These nests are therefore similar in structure to the cone nests of Barbatus. From the artificial formicaries which I established with the colonies sent me from Florida, I endeavored to obtain further material for comparison. The figures at Plate X. were drawn from a nest kept in a large glass jar, the soil within which had been sufficiently hardened to manipulate it freely. Fig. 40 shows the appearance presented when the top soil was carefully removed. Columns *c*, *c*, *c* remained, placed at irregular intervals, which had been the supports of various rooms or open spaces and their connecting galleries. These broken columns did not, of course, present the smooth top-surface drawn in the figure. The bridges of earth at *b*, *b*, which remained unbroken, show the manner in which the columns were joined. The floor of this horizontal section was irregular, and was pierced by galleries opening downward. Fig. 41 is a vertical section of the same, which indicates the tendency to arrange the open spaces in stories 1, 2, 3, 4, and 5. At 2, and just above it, 3, were what seemed to be rooms, shaped very much like those described in the architecture of Barbatus. There were galleries penetrating both laterally and downward, and one connecting gallery, *g*, showed quite plainly. The floors were smooth, and the series of open spaces, as at 4, and 3–3, presented suites of rooms not unlike the horseshoe chambers (Plate VII.) of the

Architecture of Florida harvester.

agriculturals. So far as the data from natural environment permits, and making proper allowance for the influence of artificial environment, the inference of a close resemblance in the architecture of the two ants is authorized. In respect of exterior structure, as has already been stated, the resemblance also holds in the nests of the other known North American congener, *P. occidentalis*.

CHAPTER VI.

MODES OF MINING.

THUS far my observations went under natural environment. I was enabled to complete these, in part, by means of artificial nests. One of my colonies was placed in a box eighteen inches long by twelve wide and eight high. This was furnished with glass top and sides, through which the movements of the insects were readily seen. A "terrace" of earth four inches high occupied about two-thirds the length of the box; on the remainder, or "flat," as I shall call it, soil was thinly spread. In the centre of the terrace a clump of grass in sod was planted. This clump gradually disappeared under the operations of the ants, until nothing was left but a few stubble ends protruding above the surface. The severed spires were carried into the flat. It was not a difficult matter to manage these pieces, although when quite long their bulk made them somewhat inconvenient. In such cases the carrier would sometimes place herself above the piece, so that three of her legs were on either side, grasp it with the mandibles, and walk away astride of it, two-thirds or more extending under the body, and reaching beyond it backward, the rest stretching forward. (See Plate XVIII., Fig. 88.) I had sowed on one part of the terrace some of the seed which I brought from Texas; a few of these, as they sprang up, were permitted to remain, the others were cut down.

Artificial nests.

I was also permitted to gain a hint of the manner in which (possibly) the surface of the disk is brought to the comparatively smooth condition in which it is found, which, as far as

it goes, tends to confirm Lincecum's statements. At the time when the box was filled, the only soil which I could obtain was from a rough, damp sod, which balled in digging out, and presently hardened. Thus the surface of the terrace and flat was left covered with lumps of dry earth three-fourths of an inch and less in diameter. The first colony introduced made very little effort to excavate galleries. A large addition was afterward made to its numbers, and then the ants became somewhat more active. A gallery was begun against one edge of the box, and in the course of a few days the surface of the terrace adjacent to the gallery gate was quite smooth. The change had been effected in great part by the workers depositing the small pellets of earth which they were continually bringing up from below between the lumps of hard soil above referred to. The inequalities of the surface were thus rapidly reduced in a most natural way, simply by filling in between them. I am quite satisfied that this observation explains the smoothness of the disks. The particles of soil brought up in large quantities from the excavation of galleries and chambers are dropped into the surface cavities and between the elevations, just as in my artificial nest, and with the same result. The action of the rains and the constant motion of multitudes of insects do the rest. There are also, doubtless, some premeditated efforts (other than cutting down straggling vegetation) to maintain the surface condition thus obtained. Such efforts, however, are probably neither very extensive nor systematic, although Lincecum's note gives a different impression. He declares that everything which happens to fall upon the disk is cut to pieces and carried away. The droppings of cows are quickly removed. A large corn-stalk, purposely placed by him upon a disk, in the course of two or three days was hollowed out to a mere shell, and that too, he predicts, "would be cut to pieces and carried off in a short time." He also says that when the ball in which the scarabæus (the popular "tumble-bug") deposits her egg is rolled upon the disk, it is cut into fragments and carried beyond the formicary bounds. The

Smoothness of disks explained.

mother-beetle, who has ventured to roll her spherical treasure upon the forbidden grounds, is fiercely attacked, and unless she immediately retreats, is quickly despatched. I was not able to verify these statements. On the contrary, I frequently saw the beetle's egg-balls lying upon the disks unmolested. I counted eight of these upon one disk, where they remained during my stay untouched by the ants. They were equally indifferent to various objects, clods of earth, etc., which I placed upon their nests. The fact that the energy of the formicaries was so largely directed at that season toward the harvesting of seeds may possibly account for the totally different results of my observations. At other seasons, when the superfluous energy of the active creatures is released from the duty of garnering the seed-crop, it may be directed toward the improvement of the public grounds. In that case, as may be confidently inferred from such notes as I have recorded, they have the ability to accomplish all that Lincecum has claimed for them.

Construction of galleries.

The construction of galleries, which it is impossible to observe in nature, was observed easily and with entire satisfaction in the artificial nests. Large glass globes and jars, as well as the glass box, were used, and as the ants invariably began their work against the surface of the glass, and continued the cuttings close up against the same, every motion could be watched under a magnifier. I distributed my colony, which numbered about two hundred in all, into various-sized smaller glass jars, and thus had repeated and prolonged opportunity to see the ants at work. The small jars could be readily held in my hand and the workers followed in all their movements without any disturbance. My note-book has numerous notes and sketches of the various modes of work, but it is not necessary to give many of the details, which are, indeed, somewhat monotonous. The general methods of work were the same, although I scarcely ever watched a gallery without seeing some variation of method according to varying circumstances of the digging, and (I suppose) idiosyncrasies of individuals. The transfer of my notes on two of the

smaller nests, No. 2 and No. 3, will give a full knowledge of the mode of excavating. The jars were filled to the height of about two inches with good garden soil, which was packed in until quite hard. Sixteen ants were placed in No. 2. They had just arrived from Texas in a close tin box, riding safely and soundly in the mail-bag all the long journey upon the loose tissue-paper, which, by my instructions, had been placed in the canister. They first expressed their satisfaction at the "jail delivery" by the usual ablutions, and then heartily partook of the broken Croton-seeds which had been furnished them. Then followed another general purification, combing, brushing, licking of head, abdomen, and legs.

Now they begin work. Several ants have dropped out of the groups engaged in cleansing, and made scant forays upon the top-soil, in various parts of the surface. At length one has begun, evidently with serious purpose, at the edge of the disk close up to the glass. Her first motion is precisely like that of a dog digging in a rabbit burrow. The head is down close to the soil. The fore-legs, by rapid alternate scratching movements, dig out and throw back particles of soil lying loose upon the top. The head is pushed in as the hole deepens, the antennæ being kept in a continual flutter, the flagellum pushed forward when possible beyond the plane in which the mandibles move. These organs seem to feel the way inward, even appear to be used at times to clasp lightly loosened pellets of soil. A few moments suffice to so deepen the opening that the dirt cannot be thrown out by the paws. The soil is also somewhat finer. Now the mandibles are brought into use, although the fore-feet still do good service in excavating. Moreover, they are pressed up against the little masses of loose pellets grasped by the mandibles, and thus compact them for more convenient carriage.

Beginning work.

Another ant now comes to the help of the first; a third soon follows, and before the gallery is sunken very far a fourth and fifth join in the digging. There has been no communication, that I can observe, to secure this assistance,—

nothing like a call to her comrades by the original worker, nor by any of her successors. Her movement, if I may so speak, is contagious. Her excitement has been communicated by some imperceptible bond of sympathy to others of the colony who have joined her in the work, as if urged by some uncontrollable instinct. The excitement, however, has not captured all the little community. The most part of them continue at various avocations, seemingly indifferent alike to the work and the workers. Some leisurely feed upon the seeds, some clean themselves or their neighbors, some wander about aimlessly, climb up the sides of the jar, or hang thereon listlessly. Frequently the animated diggers run against or stalk over these idlers, even at times partly upsetting them. But the infection of toil is not communicated by such contact. The miners stride on, drop their loads, and hurry back, fairly aquiver at times with eagerness, while the other parties good-naturedly get up and resume their avocations.

Gaining recruits.

It may be best stated here that it is rare for the ants to continue a great length of time at work upon the galleries. They stop, cleanse themselves, eat, and rest. I did not succeed in fairly testing the fact by experiment or observation, but I believe that the digging is conducted by relays. The excitement which carries individuals into the trenches seizes all in turn, is intermitted and repeated as long as there is any necessity or opportunity for exertion.

Duration of work.

There is probably a difference in individuals, perhaps also in formicaries. Mr. Affleck thinks the ants dwelling in mounds are of a more sluggish habit than those in disks. Circumstances control the disposition to work. Ants who had little disposition to work in the large box, when placed in a jar soon displayed great activity. Society has its influence: three ants in a small jar remained for a number of days upon the surface of the soil without the slightest attempt at digging. They fed freely, lapped moisture, were evidently healthy, but would not dig. They were reinforced by four individuals from the same nest, but more recent arrivals from

Texas. The new-comers breathed fresh vitality into the inactive three, and in a little while the gallery-making was going merrily on.

Mode of digging.

After the little miner has penetrated the ground so far that it becomes difficult to throw out the dirt backward by the fore-feet, the mandibles become the chief implements of both excavation and carriage. The pellets of earth are bitten off or cut and twisted off, and, being seized firmly by the mandibles, are removed. The ant at first "backs" out of the gallery and turns at the opening. As the tube deepens she backs a short distance, then turns and goes out with her head foremost. There are widened basins (Plate IX., Fig. 38, c) in the gallery in which the worker may turn around without inconvenience, and the gallery itself generally becomes wide enough to allow this, though not without some effort. The presence of in-coming workers often makes the process of turning one of considerable difficulty. But the greatest patience and forbearance are constantly shown in this and in all other mining operations. I have had many occasions to admire the good nature with which the crowding, jostling, trampling, and over-walking is endured in the galleries and elsewhere. An ant rushing underground to engage in digging, or hurrying out with a load, or carrying to and fro a dead body of a comrade, goes straight forward with intense energy, and commonly strides directly over her fellows in the path, instead of turning to one side. I do not recall, and have not recorded a single case of ill-temper or opposition in such cases. The "crowding" is evidently regarded as a necessary part of the communal duty, and is borne in a manner becoming good citizens. The same general fact is true in food-taking. The selfishness of our domestic vertebrates while at their meals is well known, and stock-breeders are compelled habitually to guard against it. But the ants are more nobly organized in this respect. I have never but once—and my observations have not been few—seen among them any such show of selfishness and bullying. The single exception was a big-headed

Kindliness at work and meals.

Floridian *crudelis*, who compelled a small worker to retire from a bit of juicy Croton-seed in order to enjoy it herself. It is to be noted that this exception occurred with one of the soldier caste, not with a worker proper.

In sinking the galleries the difficulty of carrying is not great in a moist or tough soil, which permits the ant to obtain goodly-sized pellets for portage. But when the soil is light and dry, so that it crumbles into dust as it is bitten off, the difficulty is greatly increased. It would be a very tedious task indeed to take out the diggings grain by grain. This difficulty the worker overcomes by balling the small particles against the surface of the gallery, the under side of the head, or within and against the mandibles. The fore-feet are used for this purpose, being pressed against the side face, turned under, and pushed upward with a motion similar to that of a man putting his hand upon his mouth. The abdomen is then swung underneath the body and the apex pressed against the little heap of grains of dirt massed against the under side of the mandibles, or between that and the smooth under surface of the head. Thus the dust is compressed into a ball which is of sufficient size to justify deportation.

Kneading the pellets.

The same operation is observed in the side galleries, where the ants work very frequently upon their sides or backs, precisely as I have seen colliers do in Pennsylvania coal-mines. The Figure 49, Plate XII., represents a worker thus engaged in pushing a lateral gallery from the main vertical one. The under part of the body is turned outward, thus showing through the glass jar. The gallery is but little wider than the ant's body, and her head is therefore wedged rather closely into the end. Lying thus upon her side the worker opens her mandibles and closes them with sufficient force to scrape out the clay from the cavities, *c*, *c*, around the point, *p*. An excavation of this shape would naturally be made by such an application of the pincer-like implements with which the ant works. The antennæ and fore-feet are thrust forward into the cavities, *c*, *c*, on either side,

Illustrations of mining.

the former finding convenient stowage therein, and the latter also an opportunity to aid a little in the mining. As the mandibles scrape off the clay, the particles are forced or fall upon the under surface of the head, *d*, in a little heap. Presently the ant turns over, thus throwing upon the floor the pellets, which she kneads into a little ball by the fore-feet and mandibles, and then backs out of the gallery, taking her load with her.

When she returns, she attacks the little projection, *p*, between the cavities. She seizes this with her mandibles, tugs and twists until it is wrenched off. If it resists this operation at first, she turns her head into one of the cavities, *c*, and cuts around the base of the projection, *p*, until it is so far weakened that it will yield readily to the force of her jaws. This process, it will be observed, is precisely the same as that which one continually sees practised by human laborers in all manner of excavations on and under the earth's surface. Frequent observations were made upon these methods of mining, and were recorded and figured in my note-book. It will only be necessary, however, to record here one or two other examples.

The ants often work upon their backs, as shown at Fig. 48. In this position the hind legs are stretched out backwards, the middle legs doubled up out of the way, the fore-legs left free and used for digging as required. Being shorter than the others, the fore-legs are well adapted for such service in contracted quarters. The abdomen is often thrown up and pressed against the gallery roof, as represented, in order to give increased mechanical advantage to the action of the mandibles, which are operated against the roof. The particles of dirt as they fall are received upon the upturned lower face, *d*, whence they are thrown off and treated as above described.

Working on the side and back.

Another interesting position, as represented at Fig. 38, Plate IX., is that of a worker engaged upon the roof, *r*, of a widened chamber, *c*. The height of the chamber was five-eighths of an inch, and the ant, whose body length is about

three-eighths of an inch, was compelled to stand upon the floor on her hind legs and reach well upward, holding on to the roof by her fore-feet and biting out the soil with her mandibles. This observation explained in part the mode by which the large natural store-rooms, already described, are constructed. I had supposed that they were excavated from the top downward, the labor being supplemented, perhaps, by occasional work wrought while the insect hung to the ceiling by her claws. I have not seen ants working in the latter position, and only conjecture that they do so because I feel sure that they can, and that it would greatly facilitate their operations. However, a reference to the measurements of the various underground openings, galleries, store-rooms, and nurseries, will show that nearly all these could be easily made by the modes actually observed and just described.

Working on tiptoe.

The appearance of the galleries when completed is shown at Fig. 38, and Plate XII., Fig. 47. I could not determine any trace of a regular plan of laying off these galleries. The first excavation was sometimes made straight down, and at other times inclined. When the bottom of the jar was reached the ants were of course compelled to work around the glass along the bottom. Here their large cavities were for the most part made, and here they dwelt and stored their seeds. While most of the colony habitually remained below, there were always a few perambulating the surface with no apparent object in view, unless, indeed, they were the regular sentries. The side galleries seemed to be begun hap-hazard, rather than marked out by any design within my comprehension. Some of the observations above recorded were made during the construction of the galleries in Figs. 38 and 47. Those in Fig. 47 measured from one-fourth to one-half an inch, averaging about one-half an inch. The ants began work in this formicary about 12 M., and at 10 P.M. of the same day had excavated 10½ inches in length. Gallery No. 1 was first made, then No. 2 was begun; the greater part of the remainder of the length

Driving the galleries.

Rapidity of work.

named was dug out in two hours, between 8 P.M. and 10 P.M. During this period I did not observe more than six (out of sixteen) ants at work at one time; the rest were making their toilet, eating, or strolling around. The soil within the jar was quite compact. This will give a crude idea of their capacity for work. The average for the ten hours was about an inch of length per hour, or one-sixth of an inch (estimated) for each ant. During the last two hours about six inches in length were made, which would give (say) one-half an inch per hour of a gallery one-half an inch in diameter for each worker. This is, of course, a very rough approximate. The work, moreover, was done in soft, though compact soil, and had no natural obstacles and interruptions. The progress made in their natural site could not well be ordinarily so rapid. But if we consider the vast number of insects in some of the nests, even so rude an estimate as this gives us some approach to a just notion of the vast capacity for tunnelling in a large formicary, especially when located in loose or light soil.

Anatomy of mandibles.

The mandibles and fore-feet are the implements by which is accomplished this work of excavating store-rooms, nurseries, chambers, and halls, clearing away forests of grasses and weeds, and garnering and preparing seeds for food. Unusual interest, therefore, attaches to the structure of these organs. The mandibles or first pair of jaws are palm-shaped organs inserted in the front part of the head, on either side of the mouth. (See Plate II., Fig. 12, *mb.*) They are strongly striated, the striæ extending longitudinally from the articulation to the teeth. The base of each tooth lies between or opposite to two or more striæ, which are forked, as described below.

The mandibles have the same claret-brown color as the body, except at the free end, where the thickened chitine makes them blackish. In repose they clasp or touch each other at the toothed edge, the teeth sometimes interlocking, sometimes overlapping. When the insect is excited these organs are opened as wide as the articulation will permit, thus giving her a fierce and threatening mien. A row of

stout, yellowish hairs or bristles is inserted into the margin of the mandible near the teeth, and a double row of like hairs are similarly placed on the inner surface or palm. These hairs are also placed around both sides, and are sparsely scattered over the entire surface. (See Plate XIII., Fig. 55.)

The teeth of the female and workers are uniformly seven in number, and unequal in size. The first or outer tooth is at least twice the length of any other (except the second, in the worker), and is quite sharply pointed in the winged queens and young workers. It is not situated in the same plane as the other teeth, but is placed a little backward, upon the outer surface or back. The next tooth in order (second) is next in length; the sixth is commonly the shortest of all, and next to it in size is the third. The inner tooth (seventh) is so set that it points inward, that is, toward the face instead of directly outward as do the first three; the fourth points a little outward, and the fifth and sixth appear usually to be set straight. The mandible of the male (Fig. 56) is not wholly smooth, as in some species, but is armed with teeth resembling those of the queen, but feebler. The two inner teeth are scarcely marked at all. The mandible narrows from the free margin toward the base (Figs. 55 and 60), which is rounded upon one side, angular upon the other, has a concavity in the middle which rolls upon a corresponding hemispherical process in the marginal end of the face, permitting the articulation already described.

The teeth are strengthened in their position by an admirable contrivance as follows: they are themselves the outer serrate edge of a strong band of thickened chitine (Plate XIV., Fig. 65), which composes the free margin of the mandible. The inner edge of this band presents the appearance drawn at Fig. 65, which shows a tooth, *bt* (the sixth) magnified about 180 diameters. As has been said, two or more of the mandibular striæ, *sr*, terminate opposite the base of each tooth. These striæ at the inner edge of the marginal band are bifurcated, or trifurcated, and enter the same, penetrating to at least three-fourths the distance toward the base of the tooth. The band evidently overlays them in laminæ or folds, as shown not

only by focussing, but by the wrinkles formed at the topmost fold by alternate ridges, *sr*, and grooves, *sg*, of the striæ. In the figure, the stronger chitine of the ridges is represented by the lines of shade, and the more attenuated chitine of the grooves by the open spaces. These latter take alternately (with more or less regularity) the form of a narrow tongue, *nt*, and the symmetrical mummy-shaped strip, *ms*. The latter, with the interlocking pieces, *ip*, form what carpenters call a "dove-tail." If this be the true interpretation, the economy of the structure would appear to be the strengthening of the dentition for the severe work required of the mandibles. The evidences of wear and tear are seen upon the broken edge, *be*, of the tooth.

Mrs. Mary Treat, who, during the winter of 1877–78, made many important observations of the habits of the Florida harvester, called my attention to the remarkable condition of the mandibles of a number of that species. Many specimens were found with the teeth wholly wanting, the mandibles being quite smooth at the edge. This absence of dentition was especially marked in the unwinged queens (Plate XI., Fig. 47) and large-headed soldiers (Fig. 46). Sixteen queens, all toothless, were taken from as many different nests. The smoothness seemed to be the prevailing condition of the mandible in the soldier. The major-workers showed the same peculiarity, however, and, though rarely, the worker-minors also. Mrs. Treat took pains to send specimens of these various forms to several eminent naturalists in order to obtain an explanation of the facts. Two opinions were advanced: one, that the toothless mandibles were specialized forms developed or in process of development from an aberrant individual.

Obliterated teeth.

The other explanation was suggested by Dr. Forel, and appears, without doubt, to be the true one, viz., that the teeth have simply been worn down by use. The very simplicity and naturalness of the explanation commend it, and, moreover, it is certainly supported by the appearance of the mandibles so far as I have seen them. The specimens sent me were carefully examined, and I feel quite sure that they present no obstacle

to this explanation. It is true that there may be selected from them three classes, which might be described as mandibles with perfect teeth, with rudimentary teeth, and with teeth obliterated. But a careful examination will show that many of the so-called "rudimentary" teeth are simply teeth in various degrees of preservation, and that the mandibles with obliterated teeth are probably but the analogue of the "toothless gums" of aged individuals among mammals.

The interest awakened by the above facts caused me to enter upon an examination of the teeth of Barbatus also. I had a large number of specimens at hand, and upon carefully inspecting the teeth I found them in the same condition as those of Crudelis. Many mandibles were partially and some almost wholly worn away. A group of these, taken almost at random, is presented at Plate XIII. Some jaws—for the mandible is the outer jaw of the ant—had one, two, or three teeth worn, and the others whole, as at Figs. 57, 58. The majority had at least the long outer tooth abraded more or less, as at Fig. 57. Some had but bare stumps of teeth left, as at Figs. 51, 53, while others were quite destitute of teeth, as at Figs. 52, 54, there being but a slight unevenness to mark the site of the dentition. I could not resist the conclusion that I was here observing just such appearances as present themselves to the eye of the dental surgeon as he gazes into the mouths of his patients of various ages.

A number of virgin queens in my possession were next submitted to inspection. Every one had well-developed teeth, in the perfect, normal condition shown at Fig. 55. I had unfortunately no unwinged or fertile queen to compare with these; but the facts, as far as available, confirmed the theory of natural abrasion; that is to say, the young queens, who as yet had not been called upon to use their mandibles, were possessed of perfect teeth. I had no specimens of callow ants, that is, ants just matured, who are readily distinguished by their yellowish hue, but I had a number of naked pupæ or nymphs of workers, in various stages of development, some of them having already partly changed to yellow and being

evidently near maturity. These were also examined, and in every one well-defined teeth appeared, the outlines being very distinctly marked by the darker color of the stronger chitine. These facts, in connection with the others cited, are conclusive to my mind that there is no ground to suppose that we have either in Barbatus or Crudelis a case of development in process from an aberrant form into a new, permanent variation in structure, but that we have simply come across another example in nature of the old and prosaic fact of abraded dentition,—worn-down teeth and toothless gums.

This view receives very strong confirmation, or at least support, from the certainty with which analogous phenomena in other insects are referred to the ordinary abrasion resulting from severe and prolonged use. Dr. Geo. H. Horn, of Philadelphia, widely distinguished for his studies of the COLEOPTERA, has informed me that the teeth (or dentations) on the outer side of the tibia of fossorial beetles are frequently worn to the extent of their entire disappearance. The same is true of the teeth upon the mandibles, which sometimes entirely disappear. Moreover, the surface sculpture will in like manner disappear, the striations upon the backs of individuals so wearing away by rubbing against logs and stones when creeping underneath them, that they are readily known as second-season species. No doubt similar facts will appear in the case of ant species whose habits require as severe use of the mandibles as the above.

Similar abrasion in beetles.

When we stop to consider the service which the agricultural ants require of these organs, it will not appear so remarkable that they should show signs of wear and tear. The galleries, granaries, nurseries, and halls heretofore described are excavated almost wholly by the mandibles. They are the pick, shovel, crowbar, by which the soil is removed, even the "cart," one might say, by which it is borne away. Frequently that soil is piled with sand, gravel, or pebbles, which must wear severely and rapidly upon the teeth. Moreover, in the vast work of clearing off the obnoxious grass and weeds from their disks and cones, the mandibles must act as saws and axes,

pincers and vices, and their contact with the tough silicious fibre of the plants must dull the teeth as certainly as forest work does the steel tools of man. Still further, the work of tearing off the hulls of seeds, some of which are hard as enamel, puts a severe strain upon the jaws. It is therefore not to be wondered at that under such use the hardest material should yield and the older ants be found with defective teeth.

The sixteen toothless queens which Mrs. Treat reports may at first appear to be so many facts wholly irreconcilable with this natural explanation. It is commonly supposed that queens take no part in the ordinary labors of the formicary, and it therefore remains to be explained why they are found to have perfectly smooth jaws. If hard work were the cause of the wearing down of teeth, should not those sixteen queens have had as perfect jaws as those of the virgin queens examined by me? The answer may be found in some points in the life-history of the queen of Barbatus, given in Chapter IX. It will there be seen that the first act of the fertilized queen is to go apart from her fellows and begin the foundation of a new formicary. She never ceases work until she has excavated a gallery from two to six inches in depth. This itself is a considerable task for one insect, and must go some length toward blunting her sharp teeth. But this is not all: the duty of rearing and providing for the first brood of workers falls entirely upon her; and it is highly probable that until the new family has well increased in numbers much, or at least a proportionate share, of the work of excavating, preparing seeds, etc., also devolves on her. In view of these facts, one might predict with somewhat of confidence that the mother-queen of an agricultural nest when discovered will be found to be destitute of teeth.

Work of mother-queen.

The habits of the Florida harvester, so far as they fell under my eye, are in no respect different from those of the agricultural ant. The very full descriptions in my note-book of mining, eating, sleeping, etc., as wrought by one, would apply accurately to the other, names only being changed. It may, therefore, be inferred with good measure of confidence, that

her habits in founding a nest are similar to those just referred to. If so, we have ample explanation of her toothless jaws.

Perhaps the above facts and considerations may open up a new train of inquiry as to the home-life of the queen-mother. The possibility rises that she may, in certain genera at least, have a more active part in directing the internal economy of a formicary than has heretofore been thought. The depositing of eggs may not be all her functions. It may be that the act by which her reign begins may more than once have substantial repetition, and when the exigencies of the growing family demand the enlargement of the home bounds, hers may be the maternal instinct which originates new nurseries and galleries by opening up the work with her own mandibles.

These remarks are based upon the supposition that the females found by Mrs. Treat were fertile, or the mother-queens of their nests. This fact, however, is in doubt. It is known that among the inhabitants of some formicaries may be found unfertile queens, who have lost their wings by friction in working, and have become thoroughly identified with the workers. They are distinguished from the fecundated female by their small abdomens and greater agility. They are apparently not so active in the general out-door work of the community as the worker classes, but there is no reason to doubt that they are industrious laborers within the nest. Should the specimens collected by Mrs. Treat belong to these virgin workers, the abraded dentition of their mandibles is explained as in the case of any ordinary worker.

Anatomy of the fore-foot.

The fore-feet, as well as the mandibles, are actively used in the work of excavation. They serve, at the commencement of a gallery, to loosen and throw back the particles of soil, like the paws of a dog digging in a burrow. This use is continued throughout the whole process of driving a gallery, but not to so great an extent. The foot is well adapted for this purpose. It is composed of five joints. The metatarsus (Plate XIV., Fig. 64), *mtr*, is a long cylindrical piece heavily clothed with golden-colored hairs and bristles, and with a row of stout articulating spines, besides the tarsal

comb, *tc*, described in connection with the account of toilet habits. The tarsus is composed of four sub-triangular joints, *tj*, the apical joint, *atj*, being more elongated than the others. These articulate freely with one another and the metatarsus, thus giving great flexibility to the tarsus. They are armed with bristles, and on the apical end of each joint, as also of the metatarsus, several strong spines are set around the point of articulation. These spines, as do the others upon the leg, point backward and downward in the same way as the claws, although the figure scarcely represents this upon the tarsus, on account of the joints being somewhat flattened and turned round.

There are two curved claws (Fig. 63) fixed upon the end of the apical joint, close to each other at the bases and diverging at the points. They are thickened at the base, which has an angular process or tooth, and is also armed with several bristles. The point of the claw is polished and naked. The two claws appear to have a different mode of articulation: one, which may be called the attached claw, *acl*, appears to be attached to the end of the joint by a strong membrane, *at*, and to swing free in the concavity as figured, with a sort of ball-and-socket movement; the other, which may be called the inserted claw, *icl*, has a bifurcated insertion, *in*, into the apex of the foot. The insertion is deep, and the position is yet more strengthened by serrations, *sr*, upon one edge of each of the fangs of the root or inserted part. These serrations are wrongly represented in the figure upon opposite edges of the two fangs, being in fact upon the same edge. They point upward, thus forming a strong cogged resistance to the withdrawal of the claw from the foot. A large muscle, *fm*, which passes through the centre of the leg is attached to the end of each fang of the root, and is the flexor of the inserted claw. I could not determine any connection of the flexor with the attached claw.

Under and between the claws is the Pulvillus, *Pv*, or sucking disk, that cushion-like organ which so generally underlies the feet of insects, and which enables them to walk upon

smooth and vertical surfaces. By means of this, Barbatus was able to run freely up and down or hang for long periods upon the glass surface of the artificial nests. It is a transparent, spherical, membranous cushion, connected, as shown in Fig. 63, *Pv*, to the bases of the claws. I have observed a marked difference in the relative facility of motion upon glass in various species kept at different times in confinement. While all are able to move with more or less ease and facility over the smooth surface, some species seem to have no sort of embarrassment in such conditions. Without making an examination of the separate pulvilli, I infer that there may be found a difference in their respective development.

CHAPTER VII.

FOOD AND FEEDING.

On Tuesday, July 10, a heavy shower, followed by a pouring rain which lasted from 11 A.M. to 2 P.M., gave me an opportunity to observe the behavior of the ants under such circumstances. At the first downfall there was a universal movement along the roads homeward at several disks. The shower soon ceasing, a counter-movement began, like the return of a tide, the ants crowding out of the gates toward the roads. The rain again began to fall, and the workers once more turned back. A nest near my tent, registered No. 2, was placed under close observation, and others kept in view. Standing at the edge of the disk, I could plainly perceive the actions of the insects. As the rain continued, many ants kept bustling in and out of the gate, under great excitement, but with no object that I could perceive. Were they possibly thus endeavoring to keep the gate open? Gradually, the soil dissolved and washed into the entrance, which narrowed, until it was closed, and finally covered quite over by a pool of water. Before the rising flood entirely hid the gate, the last view that I had of it disclosed several ants wedged within the hole and struggling with the muddy water. After the closing of the gate, a cluster of ants struggled together in the pool above the spot until the water subsided. No. 2 was the first nest closed. Running rapidly to neighboring disks I observed like phenomena; the last nest closed was No. 4, a mound disk (a very slight mound), with two entrances.

Effects of rain.

Behavior similar to that above recorded is attributed by

Lincecum[1] to a deliberate purpose to obstruct the ingress of the water. The impression made upon my mind was that the ants were simply swept in by the flood toward the gate, which they were thus naturally and involuntarily choking up. The sealing of the gate by the mud, however, certainly did prevent, in a measure, the influx of the water; and this sealing was doubtless caused, in part, by the presence of ants within the vestibule and upper galleries. Lincecum says that if the shower continues over fifteen minutes, the ants are found to be dead, still closely wedged in the entrance, where they remain until the "pavement guards," who had found refuge during the shower upon the spires of grass, descend, and remove them. The unfortunates are taken to some "dry place on the pavement," and if they do not revive in due time, are removed from the disk, sometimes to the distance of sixty yards, and left without further care. I was not able to confirm any of these statements. The immerged ants were the workers coming in from the roads and up from the interior, and not special groups of sentinels. Nor was the effect of the rain fatal in any case. Nor were the gates opened by aid of outside parties. At No. 2, a few moments after the cessation of the shower, the pool had run off from or been drained into the disk. Presently the mud in the doorway was penetrated from within, a small opening made through which the ants began to issue, and almost instantaneously a full column of living insects burst out from the gate, carrying before them all traces of the mud-seal, and leaving the door quite clear as before.

Protecting the gates.

The interior of the formicary was of course penetrated by the rain, as shown by excavations made the day following. But the granaries did not appear to have been at all injured, and none of the seeds showed signs of wetting, perhaps with one exception. A granary was found, the seeds of which were covered with a glutinous, shining substance, which had caused them to adhere to one another and to the floor. The mass appeared as if covered with a thin solution of gum arabic.

[1] Loc. cit., 326.

I supposed this to be the result of the water upon the seeds. A fragment of this floor is in my cabinet with the seeds still sticking to the soil. Rains are somewhat rare in Texas during the period of my visit (July), but during the rainy season the seeds must often be exposed to damage, and must require attention and manipulation to prevent sprouting. Mr. Buckley[1] observed an example of this after a heavy rain in Bastrop County. The prairie on which the ant-nests were located in great numbers was covered with water. "We waited with some impatience," he writes, "for the storm to abate, in order to see its damage to the ant." However, he says nothing about the damage done the insects themselves and their homes, but makes the interesting statement that the next day he saw the ants bringing to the surface quantities of seeds to dry. "Every ant-hill in the vicinity had more or less seed strewn around their outer doors. A few days later we visited the same locality, and the seeds had disappeared, having doubtless been stored away again." The same paper records a similar care of the wet seeds which was observed in Dr. Lincecum's garden. A formicary, which it was desirable to break up, was opened to the depth of two feet, and large quantities of water thrown in. The ants "recovered, and for several days after were busily engaged in bringing their store of seeds to the surface to dry." A portion of these seeds were sprouted, and when dry were not taken back to the granaries. Dr. Lincecum's daughter daily visited the ants, to observe this transportation of seeds, and told Mr. Buckley that there "were more than half a bushel!" None of the very thorough explorations of nests which I made would justify the belief that such an enormous quantity as this was stored within a single nest. However, it may be well to remember that the collections made by the harvesting ants of Palestine were of sufficient importance to justify a rule of casuistry in the Mischna, prescribing in what cases

Rain in the store-rooms.

Drying moist seeds.

Quantity of seeds stored.

[1] Loc. cit., p. 446.

the contents of granaries found in the midst of growing grain crops should belong to the owner, and when they should accrue to the gleaners' benefit. (See Chapter IV.) It would therefore perhaps be rash to pronounce the lady's statement incredible, although I am inclined to think that her eye must have been somewhat defective in the faculty of measurement. I may add that Mr. Buckley, whom I visited at his home near Austin, reiterated verbally his printed statements as to the above behavior in caring for seeds, saying further that he had witnessed this process in San Sabe also after violent storms.

Mr. Lincecum records[1] a most emphatic testimony to the same habit. In cases where the rain has continued long enough to wet and swell the grain within the store-rooms, he states that the ants avail themselves of the first sunny day to bring out the moist seeds. After these are sunned a day or two, or are fully dry, they are returned to the nest, except the sprouted grains, which are invariably left out. He had seen "a quart of sprouted seeds" thus left out at one place. Such a statement might almost reconcile us to the "half a bushel" of seeds brought out from a single nest. Another observation noted was made at a nest in a wheat-field a few days after harvest. Workers were bringing out grains of wheat which were a little swelled, but quite sound, a number of which they had already scattered over the disk. On passing this nest in the evening of the same day, the wheat was found to be dried, and the ants were carrying it into the nest again. I had no observation at all of the care of seeds above described. There can, however, be no doubt that the facts are substantially as recorded, and I have therefore referred to them (page 32) as one of the links in the chain of circumstantial evidence which proves that the agricultural ant harvests her seeds for food.

The effects of long-continued rainy seasons upon the ants is, according to Lincecum, disastrous. It is his opinion that they thrive best in dry weather. In confirmation of this he cites[2] the fact that during the first year of his residence in Texas he

[1] Loc. cit., p. 325.

[2] Loc. cit., p. 326.

found numbers of formicaries extinct, "destroyed by a series of rainy seasons." When the succeeding drouth set in, which was prolonged through ten years, the ants rapidly multiplied until, at the close of this period, "their clean little paved cities" were to be seen every fifty or sixty yards. I did not learn that the seasons preceding my visit had been marked by any unusual weather changes, but certainly on the territory within a radius of a quarter of a mile of my camp the nests were far more closely placed than that. It is probable, however, that the highlands are less exposed to the destructive influence of wet seasons than the prairies.

Effects of rainy and dry seasons.

I find in Lincecum's unpublished manuscript (although not until I had myself established the fact, as related below) the record that the agriculturals are particularly fond of natural oats. He observed them, upon one fair day, carrying grains of oats into a nest. As he knew of no field of this cereal in the neighborhood, his curiosity was excited to know where these grains had been found. He therefore took pains to follow a worker, who had just deposited a grain, on her return after another load. After the little pilot had led her human follower a tedious track of four hundred and fifty feet, a parcel of trampled oat-straw was reached. A traveller had bivouacked upon the spot a few days before, and had fed his team with oats, the scattered droppings from which the ants had discovered. The doctor's guide plunged amidst this straw in busy search, and soon found a grain. She turned it from side to side with manifest satisfaction; walked around it; lifted it a number of times from the ground, as if to try its weight and to balance it. Having at length satisfactorily adjusted her load by seizing a projection on one side of the chaff, she set out upon the return journey to her distant home. She accomplished the entire distance without stopping to rest or even change the position of her burden.

Gleaning oats in a traveller's camp.

On the path from the oat-straw to the formicary many other ants were met *en route* for the traveller's camp, all of whom had in some way received intelligence of the prize and

its whereabouts. On the following day the nest was revisited. The chaff was thrown out on one side of the disk in sufficient quantity to indicate that the ants had garnered at least a pint of oats. From the fact that no more workers were moving to and from the camp, it was inferred that the chance harvest had been entirely gleaned.

Insect food.

Seeds are evidently not the only food of our agriculturals. When the ants at disk No. 2 had broken through the slight mud-sediment that sealed up their gate, as described above, they exhibited a peculiar behavior. Instead of heading for the roads and pressing along them, they distributed themselves at once over the entire disk, radiating from the gate to all points in the circumference, from which they penetrated the jungle of grass beyond. In a moment a large number were returning across the roads, out of the grass, over the pavement toward the entrance. They bore in their mandibles objects which I presently found to be the males and females of white ants (*Termes flavipes*), which were filling the air, during and after the rain, in marriage flight. They had probably swarmed just before the shower. The agriculturals were under great excitement, and hurried forth and back at the top of their speed. The number of ants bearing termites was soon so great that the vestibule became choked, and a mass of struggling anthood was piled up around the gate. A stream of eager insects continually poured out of the door, pushing their way through the crowd that vainly but persistently endeavored to get in with their burdens. The outcoming ants had the advantage, and succeeded in jostling through the quivering rosette of antennæ, legs, heads, and abdomens. Occasionally a worker gained an entrance by dint of sheer physical force and perseverance. Again and again would the crowd rush from all sides upon the gate, only to be pushed back by the issuing throng. In the mean while quite a heap of termites, a good handful at least, had been accumulated at one side of the gate, the ants having evidently dropped them, in despair of entrance, and hurried off to garner more.

In due time the pressure upon the vestibule diminished, the laden workers entered more freely, and in the end this heap was transferred to the interior. The rapidity with which the ants were distributed to all parts of their roads, after the first opening of the gates, was truly surprising. I was greatly puzzled, at the first, to know what the cause of such a rush might be. The whole behavior was such as to carry the conviction that they knew accurately what effect the rain would have, had calculated upon it, and were acting in accordance with previous experience. I had no doubt at the time, and have none now, that the capturing of insects beaten down by the rain is one of the well-established customs of these ants. I saw a few other insects taken in, and one milliped, but chiefly the white ants.

Capturing rain-beaten ants.

That very afternoon I found in a formicary which I then opened several large colonies, or parts of one colony of termites, nested within the limits of the disk and quite at home. The next day numbers of the winged white ants were found stored within the granaries of a large formicary. There is no reason to doubt that these insects were intended for food, in accordance with the quite universal habit of the Formicariæ.

Still further, I found that the ants were so far human in their tastes as to enjoy the miscellaneous droppings from our camp-table. Between nest No. 2 and the shaded spot where our table was commonly spread stood my tent, through which a train of foragers was very soon established between the two points. This inter-communication continued during my stay, the ants travelling in the same general path, feeding upon and carrying off the crumbs of bread, cake, sugar, cheese, jelly, etc., which were scattered upon the ground. In this connection the following incident may be related, and may receive such credence as it may seem to be entitled to. A young man, a laborer on a farm a few miles distant, who visited the camp one evening, was thoroughly catechised (as was the fate of all stragglers) with a view to gather all the attainable popular knowledge of our ants. This person informed me that his employer had been "trying to kill off the

Miscellaneous food.

stinging ants from his corn and sweet-potato fields. They don't bother the cotton much, but are very fond of sweet-potatoes, and cut down all the plants within the circle of their nests again and again. The same way with the corn. Mr. R. tried to poison them by putting in their way bread covered with arsenic. That killed the ants as soon as they touched it; but they soon abandoned the bread. The arsenic was then mixed with meal and put to the nests. The ants separated the meal from the poison, though *I* couldn't tell the one from the other, and packed the meal away without touching the poison! Next the arsenic was mixed with molasses and given to the ants, but after a few were killed the others wouldn't touch the molasses at all." I give the young man's statement nearly in his own words, and will add that he was reported by my assistants as a thoroughly honest and reliable fellow, as indeed he seemed to be. If his story be received as true, it certainly shows on the part of the ants very acute senses and no inconsiderable reflective powers.

Detecting poisons.

So far the results of field observations go in determining the nature of the ant's food and the modes of providing and caring for it. A further advance than this is perhaps impossible in the natural environment of the insect. The numerous and spacious subterranean chambers which have been described are not only nurseries, store-rooms, pantries, and bed-chambers, but dining-rooms and kitchens as well. Therein the seeds are hulled and eaten, and the probability of any human observer ever witnessing these acts in nature is therefore exceedingly small. There has been much speculation as to the manner in which these harvesters preserve the grain from sprouting within their underground granaries, and a degree of intelligence in accomplishing this has been attributed to them, which, I am inclined to think, is exaggerated. The whole art preservative, as it seems to me, consists simply in keeping the seed perfectly dry. The rooms are admirably constructed for this purpose, were always with their contents found by me perfectly dry, and in cases where water intrudes, as we have seen, the remedy is in transporting

Preserving seeds for food.

the seed to the air. I have imagined (there is no basis of facts for the thought) that some of the granaries may be sealed up during the winter and rainy seasons in order more surely to protect them. At all events, when food is needed, the seed which is "husked" soon after garnering, is shelled or the shell so far removed as to give access to the kernel, which is eaten in the following manner. I should say that I have never yet seen the husking nor the shelling of seeds, but the feeding upon the kernel has been so thoroughly and frequently observed in my artificial nests as to enable me to describe the process. The seeds fed to the ants were chiefly apple-seeds and Crotons, the hulls of which had been broken open or split in two parts, in order to allow access to the white kernel within. The grains were natural oats, and the broken particles of oat-meal, as prepared for table use. The Crotons were seeds which had been collected from nests in Texas, and were perhaps taken with the greatest eagerness; but the apple-seeds, oats, and oat-meal were eaten very freely. The posture most commonly assumed is as follows: the hind legs are bent as represented in Fig. 69, Plate XV., and extended from the body at an angle of 45° or less. The second pair of legs are extended nearly but not quite in a straight line from the body. These two pair of legs (the third and second) give the entire support to the body, the feet touching the ground at a point which throws the thorax well up, and allows the abdomen either to rest lightly upon the ground, or, by a very slight additional elevation, to swing forward under the thorax to press against the grain in order to aid in steadying or moving it. The first or fore-pair of legs are used exclusively in the manipulation of the food. Sometimes they are placed under one end or the middle part of the material, thus assisting to hold it up, the antennæ being placed a little under or pressed slightly against the outer end. Sometimes the fore-feet are pressed against the sides of the grain or piece of kernel. In short they are used variously as hands to hold, steady, revolve, move back and forth, and otherwise manipulate the food, as the convenience of the eater re-

Body postures in eating.

quires. In this they are assisted by the antennæ, and, if occasion require, by the abdomen, which is swung underneath the body and quite dexterously used as a support or fulcrum for the piece, while the fore-feet change its position. The head is bent down slightly, more or less according to the size of the grain or particle upon which the ant feeds and its position in feeding. The mandibles grasp the food with a degree of force that varies; at times they apparently squeeze with considerable vigor upon the kernel, causing the juices or vegetable oils to exude. Then, and this is the common position, they are held a little apart or lightly together at the exterior tooth, so that the mouth organs can be seen between them. In this position they follow the motion of the head, back and forth, over and around the lump, occasionally, and usually gently (as it seems), pressing the kernel.

Manipulating the food.

At first I was inclined to think that by this action of the mandibles very minute particles of food were scraped off and taken within the mouth. But it was soon evident that this is not the case. Small particles are sometimes loosened by pressure of mandibles or abrasion of tongue, but they are put aside. Minute particles adhering to the teeth are cleaned off. The juices or oils of the seed, and the fine, starchy powder of the grains rasped off by the tongue, I am entirely satisfied, are all that the harvesting ant feeds upon. I have observed the process very many times, both with the agricultural ant and the Florida harvester, under the most favorable circumstances. My artificial glass nests, placed upon my table, gave me opportunity to observe, with a good pocket-magnifier, as frequently as I chose, and for as long a time, without in the least disturbing the insects. One agricultural was thus observed for fifteen minutes; another for thirty-three minutes, during which time my eye and glass were continuously steadily upon her. This ant, who was at table longer than any I ever noticed, was feeding upon a piece of apple-seed three or four times as large as her head. At the end of the thirty-three minutes, another ant came up to the seed, when

she quietly retired, evidently too well satisfied to care to dispute possession, and began to clean herself in the customary way. The process of eating, as has been intimated, is a *steady licking* of the surface of the seed. The tongue, a delicate, flesh-colored organ, is distinctly seen to be thrust out, then bent under so that the upper surface assumes the position shown at Fig. 67 (which is somewhat exaggerated, though drawn from nature); then is drawn up, and so thrust out again and again, as it is moved along the seed. The palpi move up and down with the tongue, being held away from it slightly. Their function (if they have any) in the act of eating, I have not yet been able to perceive quite satisfactorily; but have reason to believe that they are at least used to test the quality and condition of the food before the tongue is applied to it. They continually flutter around the tongue as though thus guarding it from application to any unwholesome or unpleasant surface, and preventing the intrusion of any disagreeable object.

Use of the tongue.

In thus observing the harvesting ant taking its food, I have been again and again reminded of a dog's use of his tongue in licking a wound, or a cat's use of her tongue in cleansing her fur. Fig. 67, which is given to exhibit this use, was drawn from a worker of Barbatus, which afforded me a most satisfactory opportunity for sketching the tongue in the act of licking; but the process is precisely the same in both Barbatus and Crudelis. This mode of eating may be described briefly, as either the licking up from the surface of nuts or seeds the juices or vegetable oils naturally exuding from them, or expressed therefrom by the mandibles of the ant, or the rasping or licking off from grain and seeds minute atoms of starch.

Two other figures are introduced to illustrate some of the most striking variations in the attitude of the agricultural ant while feeding. Fig. 66 was drawn from an individual engaged upon a large piece of a hickory-nut kernel, of which the imprisoned ants were quite fond. The hind legs of the individual here figured were thrown back against a small clod

of soil which lay near to the nut; the thighs of the middle pair were extended nearly straight out from the body, and bent down at the patella, to clasp the nut with the claws; the fore-feet were in the same position, but inclined a little forward. The ant was engaged in cutting or sawing off a piece from the lump with her mandibles, which were moved back and forth, thus making a little groove, which, when observed, extended quite around the point which she was working off. From time to time the ant drew her head and thorax backward, at the same time pressing forward against the lump with the abdomen, and thus steadily tugged away to loosen the particle by main force. This labor was frequently intermitted in order to lick up the oil which such vigorous measures expressed from the nut. The advantage in leverage which the insect obtained by the novel disposal and use of her hind legs and abdomen, is quite apparent from the figure.

As the next illustration, Fig. 68, will show, our agriculturals sometimes take their food in a nearly erect posture, or in a posture which approaches more or less the erect attitude. The hind legs, in this mode of feeding, are bent and lowered so as to allow the abdomen to be partially turned underneath the body, the back or dorsal part of the same apparently serving to steady the insect. It thus seems to have in some degree the use of the posterior part of the body and tail of the squirrel or monkey while engaged in similar acts. Indeed, the behavior of the ants when taking food in erect posture constantly reminded me of a squirrel or monkey eating a nut. The middle pair of legs are stretched out quite at length, more or less according to the degree of elevation, and are thrown sufficiently forward to bear well the weight of the body. The use of the fore-legs, antennæ, and mouth organs is here also the same as above described.

Eating in erect posture.

These notes complete the observations which I have been able to make on the food and manner of feeding of the agricultural ant. They leave little to be desired, inasmuch as

the process of deglutition cannot well be affected by imprisonment, however much other habits may be modified. At all events, the main point is established beyond question, viz., that seeds are an article of food with these insects. The same careful and extended observations were made upon the eating habits of the Florida harvester (*P. crudelis*), with exactly similar result. There is positively no difference between the two insects in this regard, and every word here written of the one applies exactly to the other.

There still remain for solution some points as to the care and preparation of the seeds previous to eating. The process of hulling and shelling the seed has not been observed. It must be no small enterprise to remove the smooth hard shell from some of the Crotons, for example, or to crack the shell of the grass-seeds which were found in such quantities within the granaries. The kernels of the broken Croton-seeds which I fed to the ants are soft and oily, and need no preparation to adapt them for food. Like all other nuts, they simply need to be cracked and eaten. Is this "cracking" done by simple pressure of the mandibles? Is the seed permitted so far to swell before eating as to partly open the shell? I could obtain no satisfaction upon this point, although entire seeds were placed within the nest. For some time not the slightest effort was made to prepare a store-room, or to accumulate the seeds in any spot, although afterwards this was constantly done by both Crudelis and Barbatus.

Cracking nuts and seeds. Gnawing radicles.

Twice, ants were seen carrying the entire kernels of apple-seeds which had in some way been released from the shell. The impression was left upon my mind by the appearance of these seeds, that they had been separated after exposure to moisture, but this impression has no weight as evidence.

The difficulty with the seeds of grasses is even greater. Unlike the Crotons, there is no oil or other liquid which exudes naturally or upon pressure from the hard, dry, starchy grain. It would seem that some liquid must be secreted from the mouth organs which, applied by the tongue to the dry

starch of the seed, dissolves it in sufficient quantities to permit it to be lapped up for food. I fed to my ants corn-grits, the crushed white Indian corn of the West, and also oaten-grits, the coarse, broken particles of oats which are used so freely in our country for a breakfast porridge. The oats were eaten very readily by the agriculturals, although the Croton was decidedly preferred. The Florida harvesters partook of the oats eagerly; the corn was also taken, but evidently with less relish. The process of feeding was precisely as already described, the surface of the broken grains being licked again and again. The white, starchy powder which covered the oats quite freely, when first put into the nest, could be plainly seen at the beginning of the feeding adhering to the antennæ and mouth organs of the feeders. The fruit of oats is sufficiently near to that of the wild grasses (the grain of the needle-grass tastes very much like oats) to justify the inference that the process, as I have described it, is substantially the natural mode of feeding upon the garnered seeds in the proper habitat of the ants.

Fondness for oats.

I have no direct evidence that the ants feed upon seeds and grain in the milk state, but have conjectured that they may do so. Mrs. Treat seems to have formed the opinion from her observations of the Florida harvesters, that they eat the grains only after or during sprouting, and that their appetite especially affects the saccharine substance, which is only manifest at fermentation.

Among the seeds collected from the nests of Barbatus, I could not detect any that appeared to have been swollen, deprived of the radicle, and then dried. Mr. Thomas Meehan, who examined them with this point in view, also failed to find any traces of such change, and pronounced all the specimens to be perfect seeds. Mr. Affleck, however, in one of his letters reported having seen gnawed radicles. Neither Lincecum nor Buckley hint at any such mutilation on any of the seeds seen by them brought out in such quantities to be dried. Yet sprouted seeds, whose radicles had been gnawed off to arrest growth, were constantly

Gnawing the radicle of seeds.

seen by Mr. Moggridge in the case of *Aphænogaster barbara* and *structor*. It is not improbable that future observers will discover the same behavior, at least to some degree, on the part of our Barbatus.

Mr. Moggridge was not so fortunate as myself in the extent of his observations upon the actual eating of the grain, but succeeded in making several satisfactory records.[1] One evening a black mass of ants had gathered together on the side of the glass formicary, to enjoy the light and warmth. One individual among these was holding a white, roundish mass, about as big as a large pin's head. Having turned a stream of light, passed through a condenser, upon this group, he saw with a pocket-lens the details of the feeding. The white mass appeared to be the floury portion of a grain of millet. Two or three ants at a time would scrape off minute particles with their toothed mandibles, and take them into their mouths, repeating the operation many times before giving place to other ants, and often returning again. The above act appeared to the observer to be a veritable meal. However, he subsequently dissected ants taken in similar action, supposed to be eating, but was unable by the use of the iodine test to find starch grains in their stomachs. The tests were made immediately after disturbing the ants at the meal, and it is possible that the failure may have been caused by not allowing sufficient time to swallow the food.

Moggridge observes ants eating seeds.

Mr. Moggridge also tested this point by feeding the ants seeds. A grain of millet was taken from a heap in front of a nest of *Aph. structor*, which had begun to sprout, and been deprived of its radicle and dried. A similar ball, taken from a sprouting grain of millet, but the growth of which had not been arrested, was also partially eaten. The hard, dry flour, taken from a grain of the same in its natural state, not moistened, was at once rejected and thrown on the rubbish-heap. The fat, oily seed leaves of the hemp were eagerly taken, though not softened by water. Thus it will be seen that Mr.

[1] Harvesting Ants, p. 46, seq.

Moggridge's observations substantially accord with mine, viz., that the juices of oily seeds are lapped by the ant, and the starch of grains licked or rasped off. The treatment of the dry starch-dust or flour was certainly different.

There remain two difficulties which it seems to me very desirable to solve. The first has already been stated, and concerns the manner of breaking open the seed in order to reach the edible substance within. I do not believe that the ants are wholly dependent (if at all) upon the action of heat and moisture for this result. Can we do any better than fall back upon the very ancient theory heretofore cited (see Chapter IV.), and conclude that the grains are gnawed through the middle, and the gnawings converted into food? That the agricultural ants are abundantly able to "grind" or "chop" their grain, I do not at all doubt.

Mouth-sac and moisture glands.

The other point relates to the disposal of the minute, dry particles of flour which were so frequently seen to be licked off by the tongue and taken into the mouth. Is this flour conveyed directly into the stomach? In what condition is it so conveyed? The invariable mode of feeding among ants, as I have observed it, is by *lapping* or *licking*. Lapping is the common mode, and we have seen that Barbatus thus takes her food when eating oily nuts and the juices of insects. The power of chewing, ants do not seem to possess, except that, as already said, they use the mandibles at times to force out the oils of nuts, etc., and that they probably may cut or chop the surface of seeds in order to reach the flour. As Dr. Forel has well expressed it,[1] they can only take into their mouth, by a backward and forward movement, a liquid, or, at the most, a pappy substance,—"ou tout au plus une bouillie." Moisture is, of course, required for the formation of this pappy substance or pulp, and this may readily be supplied by the salivary glands. I did not determine the existence of these in Barbatus, but Meinert has described and figured such, the labial salivary glands

[1] Swiss Ants, pp. 108, 109.

(glandulæ labri), in *Myrmica ruginodis*, *Formica rufa*, and *F. fuliginosa*.[1]

Sir John Lubbock[2] also studied the salivary glands in *Lasius niger*, *Lasius flavus*, and *Myrmica ruginodis*. The principal glands are six in number, the largest situated in the upper and anterior part of the thorax. They consist of a number of branched and twisted tubules, which gradually unite into a single duct, swell into a capacious receptacle, again contract, join a corresponding duct from the other side, pass through the neck into the head, and after a meandering course open at the upper side of the under lip. The cephalic salivary glands are situated on each side of the head, in the space between the supra-œsophageal ganglion, the eyes and the antennæ. They consist of a number of short, stout tubules, some of which are branched at the base. The labial salivary glands lie on the under side of the mouth; they are globular in form, and composed of a number of glandular cells, each with a thin hair-like duct, which, according to Meinert, open into a common receptacle. There are also two pharyngeal glands consisting of about twenty cells, each with a duct which opens directly into the pharynx by a separate orifice in the pharyngeal plate. Lubbock thinks it not improbable that these glands, thus curiously dissimilar in structure, may differ somewhat in the nature of the secretion to which they give rise, as is the case, according to Wolff, in the hive bee.

Meinert, Lubbock.

There is no reason to doubt that these salivary glands exist in Barbatus also. A salivary secretion was quite evident in the act of cleansing the apex of the abdomen by the tongue, and a like secretion may be supposed in the act of feeding, by which the flour is partially dissolved or massed. Moreover, these glands doubtless perform an important function in the extensive mining operations of the ant. That moisture must have been used in plastering and smooth-

Use of glands in mining.

[1] Meinert, op. cit. below, especially Pl. II., Figs. 1 and 2, *bb*, and Fig. 7.

[2] Anatomy of Ants, Micros. Jour. Lond., Plate CLXXXIX., Figs. 1 and 3, CS, DS, p. 144.

ing the nurseries and store-rooms heretofore described is evident. A like secretion seems to be implied in such modes of balling the excavated pellets as are described and illustrated at Plate XII., Figs. 48, 49.

Does the pulp supposed to be formed by admixture of the flour with the secretion of the salivary glands, pass directly into the stomach? In the posterior wall of the mouth is an orifice which leads into a large globular sac, which Lubbock has described and figured.[1] Its membranous walls appear to be firm and elastic, but Lubbock found no muscles attached to it, and presumes that it is kept open by the elasticity of the walls. The orifice of the mouth can be closed at will by a small flap, which is supplied by several muscular fascicles. The cavity generally contains a brown, spongy mass, in which Lubbock, in a specimen of *Formica rufa*, once found a small hematoid worm. I have greatly to regret that, when the opportunity presented, I did not look for this mouth-sac, and search for the presence of the pappy mass of flour within it; for it is probable that, while the liquid juices of oily nuts, upon which my imprisoned ants fed, were conveyed directly into the stomach, the pulp of the grain-dust first found lodgment within this sac.

Anatomy of tongue.

It is a question of much interest by what structure the tongue of Barbatus is adapted for the uses which have been described. The tongue is a soft, white, transparent, discoidal organ, whose general outline may be seen from beneath, when out-thrust, at Plate XVI., Fig. 78, L. A view from the front (above), looking down the face, of a male specimen, with out-thrust tongue, is given at Fig. 72. The lettering of the tongue is unfortunately omitted, but it is easily recognized. Around the sides and upper surface are curved a series of bossed ridges, which do not pass continuously, but are interrupted at intervals more or less regular. These interrupted ridges are shown at Fig. 74, *ir*, greatly magnified. Some of the ridges coalesce, two or three running together, as

[1] Op. cit., p. 139, Plate 189, Figs. 1, 3, M.

at Fig. 77, *ir*. They are all covered with hemispherical bosses or bulbs, which are not in contact, but show distinct separation at the base. So, at least, it appeared to me, although it is possible that the ridges may be simply constricted bands. The arrangement of these bosses gives an appearance to the tongue not unlike the beautifully regular markings on the minute diatom Pleurosigma. In focussing, the object presents at times the optical view shown at the top of Fig. 75. This is a view, magnified 180°, of a portion of the tongue. On the inner edge of the plate the hemispherical bosses are seen. The regular appearance of their alignment, just referred to, is roughly shown at the tip. All the bosses are not drawn into the figure, and at the outer margin only the lines upon which the bosses are arranged are indicated. When the tongue, or any portion of it, as in a fold or wrinkle made in the mounting (which is the case in Fig. 75), is seen in profile, the embossed ridges, as they pass around the curved edge, give to it a marked serrate appearance, so that from certain points of view it quite resembles a section of a circular saw. This toothed edge is shown at *se*, Fig. 75.

The ridges are chitinous, and thus, by reason of their hardness, are better adapted for the uses of a brush or file, to which they seem to be devoted in part. At all events, one can readily see how effective this arrangement must be in enabling the ant to brush or rasp off the dry, starchy substance of seeds, or to irritate or triturate the surface sufficiently to cause the free exudation of oily and saccharine secretions. These ridges, or some portion, or perhaps the whole of the tongue, no doubt have also a suctorial function.

I may venture to add the following note from Dr. Forel, drawn out in private correspondence: "The ridges of the tongue of ants are plaits of the cuticula or chitine skin. This chitine membrane is quite transparent, hyaline, in the inner organs. There are two systems of plaits which cross one another, and between them remain little elevations. The tongue contains blood and muscles. When it is to be protruded, it fills itself with blood and the plaits are extended; when it is

to be retracted, the blood flows back and the plaits are compressed. This is the probable mechanism of the tongue, if one may be allowed to judge from the mechanism of the same organ in the fly and other insects with soft, retractile tongues."

Upon each edge of the tongue, near the tip, is a row of cylindrical or cup-shaped organs, Fig. 73. There are seven of these (or more), apparently differing a little in size. Dr. Forel refers to similar organs,[1] similarly located (upon the tip of the tongue), and also a row in greater number, at the base of the tongue just beyond the chitinous ridges. He considers these (with Meinert) to be organs of taste, and, doubtless, the terminating papillæ of sensible nerves. Dr. Forel writes that these may appear more or less cup-shaped when seen in profile, but when seen from the surface they are rings. They, too, are thickenings of the cuticula (chitine).

I observed a row of entirely similar organs, at least eleven in number, upon the edge of the terminal segment of the maxilla, next the cluster of spikes upon the tip of the same, and between these and the palisade-like row of hairs (Figs. 78, *co*). Some of these are there arranged in pairs and triplets. The extremity of the tongue is supported beneath by the lingual laminæ (Fig. 78, *lm*), a tri-lobed plate, resembling a three-leafed clover. A narrow strip along the median line of the tongue, which is free from the hemispherical bosses, connects the laminæ with a trapezoid plate, apparently the "fulcrum" of Meinert's figures,[2] which may act as a support to the base of the tongue, and upon which it (the tongue) freely moves. This fulcrum seems to unite the tongue (lingua) to the front edge of the labium (ligula) or under-lip. The other two lobes of the ligula, the paraglossæ or accessory tongue, appeared to me as a lanceolate piece. The attached hooks appear in the figure on each side of the fulcrum at the base of the tongue.

[1] Swiss Ants, p. 117, § 3, Fig. 10, *gg*.

[2] Bidrag til danske Myrers Naturhistorie ved Fr. Meinert. Det Kongelige Danske Videnskabernes Selskabs Skrifter. Femte Række. Femte Bind. Kjöbenhavn, 1861. Pl. II., Figs. 16, 19. Libr. Acad. Nat. Sci. of Phila.

The mentum, *m*, or basal portion of the labium, is attached to the maxillæ at one end, the opposite or free end being the ligula, as just described. The mentum is compressed laterally both above and below, and is sparsely covered with bristle-like hairs, rising out of pits somewhat regularly placed. The labial palpi, *lp*, are inserted into the under side of the mentum, and are three-jointed. The terminal joint is club-shaped and is armed at the tip with a cluster of hairs, and has a few hairs upon the side. The other two joints are similarly provided.

The maxillæ are inserted on the under side of the head and just behind the mouth. Their office is to seize the food and retain it within the mouth, and also to aid the mandibles in comminuting it before it is swallowed. This function reminds us of the tongue of vertebrate animals.[1] The maxillæ of *P. barbatus* resemble that of *Myrmica ruginodis*, as figured by Meinert.[2] The basal joint, the cardo or hinge, *crd*, is a short chitinous rod-shaped piece, very like a slipper. It articulates with the stipes, *stp*, of the maxilla, not only by the small intermediate piece, *cap*, described by Meinert, as above, and by Lubbock in *Lasius flavus*,[3] but also, if I mistake not, by a minute process at the thick end, which fits into a corresponding cavity at the extremity of the stipes. The stipes, stem, or foot-stalk, *stp*, is the outer and largest segment of the maxilla. It is elongated, slightly convex on the outer edge, compressed, and bent inward at the free end, making a horn-shaped termination, *hn*. The outer convex edge is armed with two or three rows of spinous hairs, and bristles are distributed over the entire surface. At the base of the horn, *hn*, is the palpifer, *pfr*, upon which is placed a four-jointed maxillary palpus, *mxp*. The basal and third segments are the shortest; the apical segment is bluntly pointed, and all are provided with hairs, particularly at the joints. The blade (lacinia) or apical part of the maxilla, *bd*, is an ovate segment, morpho-

[1] Packard, Guide to Study of Insects, p. 28.

[2] Op. cit., Plate II., Fig. 9.

[3] The Anatomy of the Ant. Sir John Lubbock, Bart. The Monthly Microscopical Journal, 1877, p. 138, Plate CXCII., Fig. 7.

logically more membranous than the other parts of the organ. Stout, sword-like spines, *sbd*, are placed along the edge; next to these is the row of eleven cup-shaped gustatory organs, *co*, already referred to as similar to those upon the tongue. Next is a beautiful, regular alignment of bristles, *hbd*, which Lubbock (on the maxilla of *L. flavus*) well describes as a longitudinal row of palisade-like hairs, very closely apposed and indeed almost touching one another. Beyond and nearly parallel to this row is a mass of papillæ, *pbd*, extending along the base of the blade of the maxillæ. The whole tongue organs are inserted into the anterior margin of the head and are attached to the inner side of the inferior surface, and beyond its margin, by an ovoidal piece compressed posteriorly and rounded off anteriorly into a hemisphere, upon which the slipper-like cardo, *crd*, articulates. On each side is a short process, *act*, which is inserted into what might be called the "ball" of the cardo, and makes an articulation with it. What appeared to be a muscle, *cdm*, was attached to the toe of the slipper.

CHAPTER VIII.

TOILET, SLEEPING, AND FUNERAL HABITS.

THE agricultural ant—and the remark applies to all other ants of which I have knowledge—is one of the neatest of creatures in her personal habits. I think I have never seen one of my imprisoned harvesters, either Barbatus or Crudelis, in an untidy condition. They issue from their burrows after the most active digging, even when the earth is damp, without being perceptibly soiled. Such minute particles of dirt as cling to the body are carefully removed. Indeed, the whole body is frequently and thoroughly cleansed, a duty which is habitually, I might almost venture to say, invariably attended to after eating and after sleep. In this process the ants assist one another; and it is an exceedingly interesting sight which is presented to the observer when this general "washing up" is in progress. In the evening when the gas-lamp upon my table was lit, and I had leisure from professional duties to watch my insect friends, I have many times kept them under notice for protracted periods. They crowd against the glass, and gather in groups upon the earth close up to it and cleanse themselves, cleanse one another, and sleep. The first operation is conducted as follows: the ant to whom the friendly office is being administered (the "cleansed" she may be called) is leaning over upon one side as the observation begins. The cleanser (as we may name the other party) is in the act of lifting a fore-leg, which is licked, the mouth passing steadily from the tarsus up to the body; next, the neck is licked, then the prothorax, then the head. The cleanser now leaves, and the cleansed begins to operate upon herself as will be described hereafter. This process may be

Mode of cleaning each other.

seen throughout the entire group. We take another couple; the cleanser has begun at the face, which is licked thoroughly, even the mandibles being cared for, they being held apart for convenient manipulation. From the face the cleanser passes to the thorax, thence to the haunch, and so along the first leg, along the second and third in the same manner, around to the abdomen, and thence up the other side of the ant to the head. A third ant approaches and joins in the friendly task, but soon abandons the field to the original cleanser. The attitude of the cleansed all this while is one of intense satisfaction, quite resembling that of a family-dog when one is scratching the back of his neck. The insect stretches out her limbs, and, as her friend takes them successively into hand, yields them limp and supple to her manipulation; she rolls gently over upon her side, even quite over upon her back, and with all her limbs relaxed presents a perfect picture of muscular surrender and ease. The pleasure which the creatures take in being thus "combed" and "sponged" is really enjoyable to the observer. I have seen an ant kneel down before another and thrust forward the head, drooping, quite under the face, and lie there motionless, thus expressing, as plainly as sign-language could, her desire to be cleansed. I at once understood the gesture, and so did the supplicated ant, for she at once went to work. If analogies in nature-studies were not so apt to be misleading, one might venture to suggest that our insect friends are thus in possession of a modified sort of Emmetonian Turkish Bath.

The acrobatic skill of these ants, which has often furnished me amusement, and which I shall yet further illustrate, was fully shown one morning in these offices of ablution. The formicary was taken from the study, where the air had become chilled, and placed in an adjoining chamber upon the hearth, before an open-grate fire. The genial warmth was soon diffused throughout the nest, and aroused its occupants to unusual activity. A tuft of grass in the centre of the box was presently covered with them. They climbed to the very top of the spires, turned around and around, hanging by their

paws, not unlike gymnasts performing upon a turning-bar. They hung or clung in various positions, grasping the grass blade with the third and fourth pairs of legs, which were spread out at length, cleansing their heads with the fore-legs or bending underneath to comb and lick the abdomen. Among these ants were several pairs, in one case a triplet, engaged in the cleansing operation just described. The cleanser clung to the grass, having a fore-leg on one side and a hind-leg on the other side of the stem, stretched out at full length, while the cleansed hung in a like position below, and reached over and up, submitting herself to the pleasant process. As the progress of the act required a change of posture on the part of both insects, it was made with the utmost agility.

The ants engaged in cleansing their own bodies have various modes of operating. The fore-legs are drawn between the mandibles, and, so far as could be ascertained, also through or along the lips, and then are passed alternately back of the head, over and down the forehead and face, by a motion which closely resembles that of a cat when cleansing with her paw the corresponding part of her head. Sometimes but one side of the head is cleansed, in which case the foot used is drawn through the mandibles or across the teeth of one mandible after every two or three strokes upon the face. These strokes are always made downward, following thus the direction of the hairs. The hairs upon the tibia and the tarsus, particularly the tarsal comb (as hereafter described), serve the purpose of a brush or comb, and I have thought that the object in drawing the leg through the teeth of, or between the mandibles, is to straighten up these hairs, and thus increase their efficiency for service. Not only the fore pair, but also the other legs are passed—as above described—through the mouth. The second and third pairs are also and oftener cleansed by the fore-legs, as follows: the ant throws herself over upon her side, draws up the middle and hind legs, which are interlocked at the tarsi, and then clasping them with one fore-leg, presses the other downward along the other two. The fore-

Modes of self-cleansing.

legs alternate in this motion. When the legs of one side are cleansed, the ant reverses her position and repeats the process. When the antennæ are cleansed they appear to be taken between the curved spur at the extremity of the tibia and the tibia itself, as one would clasp an object between the base of the thumb and the hand, and are drawn along toward the tip of the flagellum evidently with one pressure. I have thought that I could notice this spur also used as a brush or scraper in the general application of the fore-leg to the body.

Frequently the ant assumes the erect sitting position (Fig. 82), already described as common during the act of feeding, and makes part of her toilet in this posture. The head is drooped and turned over toward the side, giving free exposure of the face to the action of the fore-paw. The paw is then raised and so manipulated that the articulated spur-comb (Plate XIV., Fig. 64, *spr*) is passed over the side of the face from the vertex (or, as one might popularly say, from the back of the head) to the mandible. This is literally a "combing of the head," and reference to the anatomy of this part will show how admirably the spur is adapted for this purpose. The whole posture and mien of the ant in the above act is strikingly like that of a cat "washing her face" with her fore-paws.

The cleansing of the abdomen places the ant in a grotesque attitude, which is represented at Plate XVII., Fig. 81. The hind legs are thrown backward and well extended, the middle pair nearly straight outward from the thorax, and less extended, so that the body is able to assume a nearly erect posture. The abdomen is then turned under the body and upward toward the head, which is at the same time bent over and downward. The body of the ant thus forms a letter C, or nearly a circle. The fore-feet have meanwhile clasped the abdomen, and the work of brushing has begun. The strokes are directed upward toward the apex of the abdomen, and the foot passes around and beneath the under part, which is now toward the sternum. The apex is frequently licked by the tongue, and the feet are occasionally passed through the

mouth (not simply between the mandibles), after which they are again applied as before. Evidently moisture is conveyed from the mouth and rubbed upon the abdomen. I have so frequently observed this action that I can hardly be mistaken in the glossy appearance which showed the presence of moisture upon the surface. Occasionally the leg is rubbed over the head after being drawn through the mouth, and so again to the abdomen. Usually the abdomen is held a little distance from the sternum, but I have seen it pressed up close against the breast, while the outer (upper) part was being cleansed. One ant (Fig. 80) was seen cleansing its abdomen while hanging by the hind legs from the roof of the formicarium. The abdomen was thrown up and between these legs, just as a performer on the turning-bar throws his body and legs upward and between the arms. The head was reached upward from below to the apex of the abdomen, which tongue and fore-feet were engaged upon in the usual way.

The amount of time devoted to these toilet-duties is very great with the imprisoned ants, but is probably not so great in a state of nature. No doubt with ants as with men, an artificial condition of society gives inducement to a larger devotion to personal appearance. I was not able to give them much attention during the day, but whenever they were transferred to the neighborhood of register or fireplace, and thus made unusually comfortable, they at once began their ablutions.[1] Invariably, at night, when the gas-lamp was lit and placed near the glass formicaries, the heat and light, both of which appeared to be grateful to them, tempted them out, as already stated, and they began operations. So also after eating, and when awaking from sleep. In short, whenever they were in a particularly comfortable state they expressed their satisfaction by making their toilet.

The cleansing operations above described are accomplished

[1] This word has been used in a rather loose way as best expressing, in one word, the general act of toilet-making.

chiefly by means of the fore-spur, which is represented at Plate XIV., Fig. 64, *spr*, Plate XIII., Fig. 61. This instrument may with quite sufficient exactness be termed a curved comb with a short handle. It is set into the apical end of the tibia of the fore-leg, on the inner side, opposite the base of the tarsus, within which it articulates freely, seeming to have a lateral motion as well as one backward and forward. It has a rude resemblance to the human thumb in shape, and constantly suggests the action of that member to one who watches the insect manipulating it. The outside surface (next the body) is convex, and is strengthened along the broader margin by a chitinous rod, *rd*. It is here covered, except along the basal portion, with hairs laid thickly one upon another. This rod, which might be said to correspond with what is popularly called the "back" of a comb, is bulbed at the base, where it articulates with the tibia, and gradually tapers down to a point at the apex. The inner surface of the spur is also thickened at the base, though much less so than the back. This thickening is divided, one portion curving into a rib, *r.sp*, which strengthens the back, the other thinning out into the concave edge, *ce*, upon which the teeth are set.

Anatomy of the spur and tarsal comb.

The teeth are in number about sixty-five, regularly placed along the edge, being for the most part of equal length, but are shorter toward the apex. They are spear-shaped, *i.e.*, sharp at the point, gradually enlarging into convex edges, which toward the base are parallel. They are not in contact at the base. They are stiff, but elastic, and when bent over spring back again, as do the teeth of a comb. Several of these teeth are represented at Plate XIII., Fig. 59, magnified 250 diameters. The length of the spur from base to point is a little more than one-half of a centimetre. Its greatest width from edge to back (not including the teeth) is two-fifths of a centimetre. These measurements are made upon the fore-leg of a young queen. Near the base, and between the spur and the metatarsus, there is set into the end of the tibia a thick sword-like spine. The base is also surrounded by a

thick cluster of hairs placed upon the tibia, from the midst of which rise one or two bristles.

A corresponding series of teeth is set into the surface of the metatarsus, opposite the toothed edge of the spur, forming the tarsal comb, *tc.* These teeth are in number about forty-five, less than those upon the spur, but are somewhat larger. They are arranged along the convexity at the base of the metatarsus, and the concavity beyond formed by the bend of the limb, in such manner that they are quite exactly opposed to the series upon the spur; a fact which is permitted by the conformity of the spur to this peculiarity in the contour of the metatarsus. This is shown by Plate XIII., Fig. 61, drawn from an example in which the spur was nearly closed down upon the tarsal comb. When the spur is used, the two series of teeth do not interlock, but appear to work closely alongside of each other. The degree of contiguity is doubtless regulated by the ant, according to the requirements of the object to be cleansed.

The two other pairs of legs are also each provided with a spur, which we may perhaps call the secondary spur, Fig. 62, *spr.* It is not set into the end of the tibia, but upon its side near the end. It is about the same length as that upon the fore-leg, but is much narrower. It is, however, constructed in the same way, being a narrower, chitinous, convex plate, one edge of which is armed with about twenty teeth. A few (six) bristles are placed opposite the secondary spur upon the metatarsus, somewhat regularly, but they are apparently not intended to serve the purpose of the tarsal comb on the fore-leg, or, at least, only to a limited degree.

It will thus be seen that nature has provided our ant with instruments admirably adapted for a toilet-service, whose chief requirements are the removal of particles of dust and other foreign material from the delicate hairs and bristles with which the whole body, but particularly the legs and antennæ, are so abundantly clothed. The reader can hardly have to reflect that for similar purposes, viz., the cleansing of the human hair, man has invented an instrument which, in the most minute details of structure, has its antitype in the fore-spur and tarsal

comb of this insect. A reference to the mode of using this spur in connection with this anatomy will show that the instrument is used precisely as a comb in the human fingers. The tibia holds the spur as the fingers hold the comb, and the articulation of the spur upon the tibia allows it free play and adjustment of the teeth to the head and other parts, just as the various joints of the hand and arm of man allow the application of his artificial spur to his hair and beard.

Sleeping habits.

The habits of ants in taking sleep were quite freely exhibited in the artificial formicaries of harvesters, both Barbatus and Crudelis. Invariably when the gas-lamp upon the table was lit at night numbers of the ants would come out from the galleries and underground cells, where they spent most of their time, and gather in clusters against the surface of the glass or upon the soil next the light. The account of this habit is given as it was written with the ants before me.

As I now write a bevy of twenty-five or thirty agriculturals have grouped themselves, some upon the corks and clods which have been placed for them,—for they like little elevations for this purpose,—others holding upon the surface of the jar at distances varying from a half-inch to an inch and a half above the surface (Pl. XVII., Fig. 83). The latter height is not very secure, as the ants soon drop off when they get asleep. The most of them are near the surface; some are squatted down upon their abdomens and last two pairs of legs; some lie upon their sides; some are resting on the hind legs standing a-tiptoe; most of them have their heads upward, though some have the heads down; some are crouched upon the earth with faces downward; several are piled one atop of another; all have the inferior faces and bellies toward the light. There is continually more or less agitation in the cluster, and frequent changes of position occur.

Some ants sleep long and soundly. This is particularly the case with the big-headed soldiers of Crudelis. New ants join the circle and elbow their way in, jostling the sleepers and partially or wholly arousing them. But in a group whose

members are evidently bent on sleep there is little change, and all the tokens of repose appear which are common to sleeping animals.

The observation upon the ants now before me began at 8 o'clock; at 11 P.M. the cluster had nearly dissolved, only a few being asleep. To illustrate the soundness of this sleep I take the quill pen with which I write and apply the feather end of it to an ant who is sleeping upon the soil. She has chosen a little oval depression in the surface, and lies with abdomen upon the raised edge, and face toward the lamp. Her legs are drawn up close to the body. She is perfectly still. I gently draw the feather tip along the body, stroking "with the fur," if I may so say. There is no motion. Again and again this action is repeated, the stroke gradually being made heavier, although always quite gentle. Still there is no change. The strokes are now directed upon the head, with the same result. Now the tip is applied to the neck, the point at which the head is united to the pro-thorax, with a waving motion intended to produce a sensation of tickling. The ant remains motionless. After continuing these experiments for several minutes, I arouse the sleeper by a sharp touch of the quill. She stretches out her head, then her legs, which she also shakes, steps nearer to the light, and begins to cleanse herself in the manner already described. This act invariably follows the waking of ants from sleep. The above description applies to the general habit of somnolence as observed upon the two named species of harvesting ants for nearly four months. I have often applied the quill, and even the point of a lead-pencil, to the sleeping Floridians without breaking their slumber. There are some other details which have not appeared in the behavior of the individual just put under observation.

Soundness of sleep.

Thus, I have several times seen the ants (Crudelis) *yawning* after awaking. I use this word for lack of one which more accurately expresses the behavior. The action is very like that of the human animal; the mandibles are thrown open with the peculiar muscular strain which is familiar to all

readers; the tongue also is sometimes thrust out, and the limbs stretched with the appearance, at least, of that tension which accompanies the yawn in the genus homo. During sleep the antennæ have a gentle, quivering, apparently involuntary motion, which seemed to me, at times, to have the regularity of breathing. I also often noted an occasional regular lifting up and setting down of the fore-feet, one leg after another, with almost a rhythmic motion.

Duration of sleep.

The length of time during which sleep is prolonged appears to vary according to circumstances and, perhaps, organism. The large head-soldiers of the Floridian harvesters appear to have a more sluggish nature than the smaller workers. Their sleep is longer and heavier. The former fact the watch readily determined. The latter appeared from the greater stolidity of the creatures under disturbance. While the ants of one group are taking sleep others may be busy at work, and these stalk among and over the sleepers, jostling them quite vigorously at times.

Behavior when sleep is broken.

Again, new members occasionally join the group, and, in their desire to get close up to the heat and light, crowd their drowsy comrades aside. I have seen ants who had been at work in the galleries drop their pellets, push thus into the cluster, and presently be apparently sound asleep. This rough treatment is invariably received with perfect good humor, as are like jostlings when the ants are awake. I have never seen the slighest display of anger or attempt to resent disturbance even under these circumstances, so peculiarly calculated to excite the utmost irritation in men. But of course some of the sleepers are aroused. They change position a little, or give themselves a brief combing, and then resume their nap, unless, indeed, they are satisfied. In watching these movements it was quite evident that the Florida soldiers were far less easily disturbed than their smaller fellows. They slept on stolidly while all the others were in agitation around them. Moreover, their very appearance, particularly when awaking out of sleep, indicated the greater sluggishness of their temperament in this respect.

The length of time given to sleep varies, as has been said, and frequent memoranda appear in my note-book, like the following, which give some idea of these variations: Agriculturals.—"Cluster of eighteen or twenty formed at 8.30 P.M. . . . 10.30, combing and cleansing continues with lessened energy. Many of the ants are still asleep." Florida harvesters.—"Some ants have been sleeping more than thirty minutes." . . . "12 midnight, some have now slept one hour. . . . 12.15, a number have awoke and left, but many are still asleep. I go to bed." "7 P.M., ants clustered over outer part of the box resting; they are apparently asleep; won't be disturbed by the feather. . . . 10.30 P.M., a cluster apparently (not certainly) the same, asleep on the edge of the box." This is the longest period, three and a half hours, during which I kept the sleepers under continuous close observation. I did not mark special ants, as I might have done, and the intrusions and movements above referred to greatly added to the difficulty of keeping selected individuals certainly in the eye. Moreover, most if not all the members in any one cluster suffered one or more interruptions,—that is to say, the sleep was broken up into several, more or less, "naps" by incomers and intruding laborers. With this allowance, I venture the opinion that the sleep of ants is, at times, prolonged for three hours. Possibly those who keep habitually underground sleep through much longer periods; certainly those above-ground often take much shorter naps.

Sleep in the natural site.

The conditions under which these observations have been made were especially unnatural and unsatisfactory. In their natural site ants most certainly do not come out to the light to sleep as with my prisoners. The heat of the lamp was one element of attraction, and when the glass was brought quite close to the flame, the satisfaction of the emmets as they clustered upon the warm surface was very great. But even when the lamp was so far removed from the jar as to prevent any appreciable warmth, the simple light drew out the insects and invited them to sleep. I could at any time break up a cluster by simply revolving the jar, thus

turning it away from the lamp. In a few moments the ants would scamper across the formicary and begin to form as before, on the surface nearest the light. I have repeated this several times in succession with the same result. Even the ants who kept underground made the change, and appeared at the openings on the illuminated side, having crossed by the net-work of galleries which penetrates the soil. Whether the heat, or light, or both be the attraction, it is evident that the lamp gives some condition of comfort inducing sleep, which is present under natural, but lacking in artificial environments. In their native homes, I believe the mid-day hours during which, as has been shown, labor is quite habitually intermitted, are devoted to sleep by those who have been active above-ground. Lincecum's statement that they are found at work at 2 and 3 o'clock A.M., but discontinue labor from that hour until sunrise, would raise the suggestion that these admirably wise creatures have also learned the exquisite enjoyment and healthful tonic of the early morning nap!

Mid-day siesta and morning nap.

There is nothing which is apt to awaken deeper interest in the life-history of ants than what may properly be called their funereal habits. All species whose manners I have closely observed are quite alike in their mode of caring for their own dead, and for the dry carcasses of aliens. The former they appear to treat with some degree of reverence, at least to the extent of giving them a sort of sepulture without feeding upon them. The latter, after having exhausted the juices of the body, they usually deposit together in some spot removed from the nest. I did not see any of the "cemeteries" of the agricultural ant upon the field, nor, indeed, observe any of their behavior toward the dead, but my artificial nests gave me some insight of this. In the first colony had been placed eight agriculturals of another nest, which were literally cut to pieces. Very soon after the ants were comfortably established in their new home, a number of them laid hold upon these disjecta membra, and began carrying them back and forth around the formicarium. The

Funereal habits.

next day this continued, and several of their own number who had died were being treated in like manner. Back and forth, up and down, into every corner of the box the bearers wandered, the very embodiment of restlessness. For four days this conduct continued without any intermission. No sooner would a body or fragment thereof be dropped by one bearer than another would take it up and begin the restless circuit. The difficulty, I easily understood, was that there was no point to be found far enough removed from the living-rooms of the insects in which to inter these dead. Their desire to have their dead buried out of their sight was strong enough to keep them on this ceaseless round, apparently under the continuous influence of the hope that something might turn up to give them a more satisfactory burial-ground. It does not appear greatly to the credit of their wisdom that they were so long discovering that they were limited to a space beyond their power to enlarge. When, however, this fact was finally recognized they gave their habit its utmost bent, and began to deposit the carcasses in the extreme corner of the flat, as distant as possible from the galleries on the terrace above. Here a little hollow was made in the earth, quite up against the glass, wherein a number of bodies were laid. Portions of bodies were thrust into the chinks formed in the dry sod. This flat became the permanent charnel-house of the colony, and here, in corners, crevices, and holes, for the most part out of sight, but not always so, the dead were deposited. But, the living never seemed quite reconciled to their presence. Occasionally, restless resurrectionists would disentomb the dead, shift them to another spot, or start them once more upon their unquiet wanderings. Even after the establishment of this cemetery, the creatures did not seem able to lay away their newly deceased comrades—for there were occasional deaths in the formicary—without first indulging in this funeral promenade.

Carrying the dead.

In the formicaries established in glass jars, both of Barbatus and Crudelis, the same behavior appeared. So great was the desire to get the dead outside the nest, that the bearers

would climb up the smooth surface of the glass to the very top of the jar, laboriously carrying with them a dead ant. This was severe work, which was rarely undertaken except under the influence of this funereal enthusiasm. The jar was very smooth and quite high. Falls were frequent, but patiently the little "undertaker" would follow the impulse of her instinct and try and try again. Finally, as in the large box, the fact of a necessity seemed to dawn upon the ants, and a portion of the surface opposite from the entrance to the galleries, and close up against the glass, was used as a burial-ground and sort of kitchen-midden, where all the refuse of the nest was deposited. Mrs. Treat has informed me that her artificial nests of Crudelis behaved in precisely the same way.

An interesting fact in the funereal habits of *Formica sanguinea* was related to me by this lady. A visit was paid to a large colony of these slave-makers, which is established on the grounds adjoining her residence, at Vineland, New Jersey. I noticed that a number of carcasses of one of the slave species, *Formica fusca*, were deposited together quite near the gates of the nest. These were probably chiefly the dry bodies of ants brought in from recent raids. It was noticed that the dead ants were all of one species, and thereupon Mrs. Treat informed me that the red slave-makers never deposited their dead with those of their black servitors, but always laid them by themselves, not in groups, but separately, and were careful to take them a considerable distance from the nest. One can hardly resist pointing here another likeness between the customs of these social hymenopters and those of human beings, certain of whom carry their distinctions of race, condition, or religious caste even to the gates of the cemetery in which the poor body moulders into its mother dust!

Burial-grounds.

The same scrupulous anxiety to be separate from the dead body I have noticed in other species, both in natural site and in confinement. One nest of Pennsylvania carpenter ants (*Camponotus pennsylvanicus*) was placed in the course of an experiment upon an isolated pedestal within a vessel of water

with which the ants had communication, the cover of the jar being removed. Presently the carcasses which had been accumulating during previous imprisonment were carried up and dumped into the water. Thereafter all the dead were thus disposed of.

For the most part, it appears to be the custom of ants to remove their dead fellow-formicarians, without feeding upon them, even though they feed upon other ants, some species of which they capture for that purpose. Such seemed to be the case with my agriculturals. But one or two observations somewhat staggered me, and awakened the suspicion that they are not wholly free from the vice of cannibalism. Once, beyond doubt, I observed two individuals licking the juices out of the separated apex of the abdomen of a dead comrade. In one or two other cases I thought I detected the same act. However, these examples were rare, and I suppose that they may have been produced by the fact that I was keeping my prisoners exclusively upon a vegetable diet in order to determine whether they really can subsist on seed-food. I now consider the cases noted to be exceptions, but the subject invites full investigation.

Cannibalism.

In this chapter of miscellanies reference may be made to another habit which was not observed in the field. During the entire period of their confinement the ants in the large box formicarium, who in their wanderings had climbed to the roof, frequently dropped themselves therefrom to the ground-surface beneath, a distance of from six to eight inches. The act was observed a great many times, so that it was shown to be habitual. It was evidently done with design, deliberately, and without any tokens of terror during or surprise after the act, which would indicate accident. I could, however, observe no reason for the act, or advantage in it. The ants simply appeared to fancy that sort of exercise. The process as observed—and I was quite able to figure the animal (Plate XVII., Fig. 79) in the various stages—was as follows: the body was dropped and hung by the two hind legs; there was a rapid movement of the other legs, as though

Dropping to the ground.

feeling against the glass side of the box, for the ant generally selected a position near the very edge of the roof; then one hind leg was unclasped and bent over slightly, but still outstretched. Sometimes there would be a movement up and down of the body by means of the remaining leg, like that of a ball upon an elastic thread; then the body dropped! The ant alighted on her feet like a cat when similarly dropped, and, after a brief combing and brushing of her person, walked off. I saw one individual, after going through all the above preliminary stages, recover herself and move away.

It will no doubt be found, upon investigation, that Barbatus in her native site is in the habit of thus flinging herself from trees, bushes, and other elevations, perhaps quite persistently, and as a matter of pure economy of time and effort. I have observed other ants do this under provocation. Frequently the repletes of the Allegheny Mountain mound-making ants, when touched while on a branch taking honey-dew from the aphides, or when descending the trunk with laden abdomen, would throw themselves off the tree to the ground. I have seen *Formica fusca* do the same thing, with a great show of vigor. The very ingenious and prolonged experiments of Sir John Lubbock[1] upon *Formica nigra* and *Myrmica ruginodis*, show an unwillingness on the part of those species to drop from even a short height, and when the act would have been greatly to the ant's advantage.

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[1] Journal Linnæan Society, vol. xii., 1876, p. 485, seq.

CHAPTER IX.

QUEENS, AND THE FOUNDING OF NEW COLONIES.

WHILE moving among the formicaries at Camp Kneass, I frequently caught sight of the young males and females. They were readily distinguished from the workers by their greater size, and, of course, by their wings. The females again were distinguished from the males by being larger and of more robust form. Their visits to the outer air were not frequent, were marked by every outward token of caution and timidity, and were evidently made simply for the purpose of health, and enjoyment of the sunshine. These young princes and princesses were seen bobbing in and out of the gates, just peeping forth and quickly withdrawing, and again venturing quite a distance, one and two feet, upon the disk. They rarely, however, went far beyond the gate, and were quick to retire at the first sound or disturbance. One female was seen swinging upon a grass-stalk. At one formicary half a dozen or more young queens were out at the same time. They would climb up a large pebble near the gate, face the wind and assume a rampant posture. Several having ascended the stone at one time, there ensued a little playful passage-at-arms as to position. They nipped each other gently with the mandibles, and chased one another from favorite spots. They, however, never nipped the workers. These latter evidently kept a watch upon the sportive princesses, occasionally saluted them with their antennæ in the usual way, or touched them at the abdomen, but apparently allowed them full liberty of action.

Princesses at play.

That this liberty is, however, held within law would appear

from experiments like the following. A queen was thrown by a quick motion of my hand from the vicinity of the gate to the verge of the mound. She was instantly surrounded by several workers, who appeared to be acting as sentries, and began a determined effort to control her action, trying, as far as I could judge, to compel her to return toward the gate. The queen was confused, or stubborn, and opposed her strength quite vigorously to the purpose of the guard. For some time the party floundered in a confused sort of way among the stumps of grass-stalks. As I had not then time to wait the issue, and wanted the specimen, the refractory queen was captured.

Workers guarding queens.

I made diligent but vain search throughout the dissected formicaries for the apartments of these winged sexes. One or two virgin queens, stragglers apparently, were taken; but notwithstanding a special reward was offered to my helpers, the royal family continually evaded our search. As there are vast numbers of them, as will presently appear, in every nest, they must be concealed and preserved with great care, probably in chambers located at considerable distance beneath the surface, or placed beyond the margin of the open disk. We were even more unsuccessful in our search for a fertile female, or queen proper. Not a single one was captured. Specimens of the virgins and males were obtained by seizing them while enjoying their sun-bath.

I had almost certainly expected to witness a marriage-flight, or "swarming" of the sexes. The period of my visit had been timed with a view to this. Lincecum's description is dated June 27, although he does not otherwise fix the periods of the marriage-flight, which, he says, occur two or three times every year. I began observations on the 4th of July, and as the virgins and males were then found to be still within the nest and apparently fully developed and ready for departure, my hopes were high that, during so long a stay, I should witness a swarming, and be able to settle a number of questions which deeply interested me. However, I was disappointed, notwithstanding the utmost vigilance. No winged ants left their

nests during the month of July at Camp Kneass, or indeed anywhere in the vicinity of Austin, so far as I could learn. It would be a valuable contribution to the natural history of these insects if the periods of the sexual migrations could be determined by some resident observer. I have failed, after much correspondence, to obtain any definite information. Mr. Affleck[1] has given me a brief account of a marriage-flight, which occurred "in the spring," and in its main features resembled that described by Lincecum. It is not improbable that the swarming does not occur at wholly regular periods, but varies according to climatic and other conditions unknown. In the absence of any further information, we are dependent upon Lincecum alone for our knowledge of this interesting phase of the life-history of Barbatus. I shall draw my account from his manuscript, although the most of the statements may be found in the article hitherto cited, from the Proceedings of the Philadelphia Academy of Natural Sciences.

On the 27th of June, 1863, an assemblage of the winged males and females of this species began at noon, and continued until 4 P.M. of the same day. Myriads of insects thickly covered the ground over an area one hundred and seven yards long by ten yards wide. They came from all directions, having evidently issued from many of the surrounding formicaries. The females outnumbered the males at least two to one. All parties were frantically rushing to and fro in amative furor. Each female struggled upon the ground in the embrace of four, five, even twenty males. Multitudes

[1] After receiving instructions as to the points to be studied, this gentleman kept a careful lookout for one of these swarms. He writes me, July 10, 1878: "I regret to say that I have failed to see a marriage-flight, notwithstanding my endeavors to do so. I have not only kept on the lookout, but have had others also on the lookout, with instructions to inform me of any such occurrence coming under their observation. I received a message about a month since notifying me of such, but by the time I reached the place all the ants had disappeared, except a number of dead and disabled. Another time I was notified by a neighbor, the day after he had seen the road covered with ants, all moving in one direction; but I could not find them. It appears that they take advantage of moist, cloudy weather for such movements."

of males, besides, moved eagerly over the ground in search of females who were not to be found. The air also was full of them, flying round and round, going off a little ways and returning. When a queen was satisfied with her crowd of lovers she tore herself from their embrace by a violent effort, and immediately took flight. After 4 P.M. the females began to leave rapidly, and in the course of an hour were all gone.

A marriage-flight described.

The males made no effort to follow. Many of them were already dead, and a greater number lay helpless on the ground. At 6 o'clock P.M. there must have been quite a bushel of these dead and exhausted ants lying upon the ground. However, there were hundreds of thousands, probably those who had not met the females, who were active. These collected together in little depressions and cracks in the surface, and other places that would shelter them from the strong south wind, where they lay perfectly quiet in heaps of from half a pint to a quart or more in bulk. The next morning a large proportion of these males were still living, but appeared to be quite careless of their fate. Great numbers had climbed up the weeds, many of whom were dead and still clinging by their mandibles to some tiny twig or the edge of a leaf. At 5 o'clock of that evening (June 28) all the male ants were dead, and their carcasses, drifted by the winds into the gullies, lay in many heaps. Thousands besides were scattered over the field.

The fate of the male ants.

We may now go back to follow the fate of the young queens. A strong south wind was blowing while they were flying off, and the greater part of them drifted before it into the timbered lands to the northward. Many of them, however, succeeded in forcing their way for a short distance against the wind. Immediately upon alighting the ants began digging holes in the ground, a work which they pushed with such skill and rapidity that they had soon buried themselves from sight. As soon as the wings became impediments to the workers in passing in and out of the opening, they were deliberately cast off. This was done by biting them with their

mandibles, and partly by contortions of the body. Two hours after the queens had commenced flying from their lovers, hundreds of these holes were seen, each with a little circle of black dirt around it. Long before sundown they were thickly set in the roads and paths, and on every clean, hard-trodden piece of ground. Their number was truly wonderful, in some places amounting to as many as fifty to the square rod. In particularly favorable spots many ants were working within a foot of one another.

Having thus secured themselves a hiding-place before the close of day, the queens closed the doors of their gallery and remained shut in during the night. The doors were not yet opened, the next day, when the sun was an hour high, but toward noon the inmates were found busily engaged in deepening their holes. Everywhere around, the little piles of black soil were to be seen, extending northwardly for miles. When the excavation had been carried to the depth of two or three inches,[1] the queens stopped up the opening and employed themselves in widening the bottom of the gallery into a cell, which is the cradle of the future colony.

The queens begin new nests.

Another account of the marriage-flight is thus given in the unpublished manuscripts. There are some enlargement and variation of details, which make it of sufficient value to present here. When the young queens and males are ready to leave the natal nest, they swarm out in almost incredible numbers. Other formicaries in the vicinity being ready to swarm at the same time, the air throughout the whole district is filled with flying ants. They do not remain long upon the wing, but soon begin to settle upon the ground. In a short time the great multitude has settled down, and is spread thickly, for many square rods, upon the surface of the earth, giving it the appearance of being covered with a red carpet. The ants are heaped upon one another and are in constant rapid motion. From every portion of the vast

A second swarming described.

[1] The published account says "six or seven inches." Another manuscript says "from six to eight inches." The distance probably varies.

concourse there arises a distinctly audible sound, closely resembling the creaking produced by grasping in the hand a bundle of soft, dressed morocco leather. This sound is loud enough to be heard by the listener while sitting on horseback. Lincecum was of opinion, as were other local observers to whom he refers, that this was a vocal sound. It was, however, doubtless simply produced by the mechanical agitation of countless wings, and the friction of the hard bodies of so many ants grating against one another and the ground as they rapidly moved about. During the congress of the males and females, which lasted for three or four hours, the turmoil and noise did not cease for a moment. Finally, as the queens became tired of their lovers, and one after another flew away, the hosts of males became more orderly, and, gathering into clusters as the night approached, soon died from mere exhaustion.

Each queen, when a site for a nest had been chosen, wrought apart from her fellows, and interference with one's special territory was resented by the possessor. In order to test her behavior under opposition, a stick was placed in the hole of one of the ants, while she was carrying away a load of dirt. On her return she failed to recognize her own quarters, and in searching for them stumbled upon the tunnel of another ant, into which she plunged without hesitation. The proper owner, however, soon pushed out the intruder, and the two joined battle as soon as they were fairly upon open ground. After they had fought desperately for a minute or two the intruder gave way and plunged again into the hole. The owner followed, and after awhile succeeded in dragging the intruder forth once more, and also, after a severe conflict above-ground, in putting her to flight. The victor resumed work, but had evidently been injured, for every time that she came out with a load of dirt she paused to brush her mouth. She seemed to be in pain, and did not work as vigorously as before the fight.

Battle between two queens.

The fate of the female members of the congress above described seems to have been as unhappy as that of the males.

Eight or ten days after they had shut up their holes Dr. Lincecum dug up quite a number of them, and found them looking well, but in a torpid state. "They seemed to be sleeping." There was nothing in the little cells besides the ants. A month thereafter (July 29), of all the ten-thousands of queens who made so brave a start toward the forming of new kingdoms, not a single one ("but one," says the published account) proved a success. From some unknown cause, perhaps the entire absence of rain since the swarming, the females had disappeared.

Great mortality among queens.

We have, however, a general view of the progress of a successful nest, although dates are not given and the length of the various stages are not recorded. When a gallery has been sunk of sufficient depth to insure safety, and a nursery has been wrought out, no doubt of the same nature as those which have been described, the queen, in due time, deposits her first eggs, which are carefully reared, and the white larvæ nursed and nourished. This first brood consists wholly of workers, and numbers thirty or forty. The mother-ant seeks food for herself and nourishment for her young during the night-time exclusively. Her burrow is kept carefully closed during the day. When the ants of the initial brood are matured they take up the burden of the out-door work, supply the rapidly-increasing family with food, as well as their mother-queen, join in the nursery duties, labor at enlarging the subterranean quarters, and, in short, become, as they continue to be, the real *workers* of the community. These early-born workers, Lincecum affirms, are much smaller than those of the same species in fully-developed formicaries, a fact which for three years so misled the doctor that he thought them to be a different but closely-allied species, which he called the "Concealment ant." The diminutive size was attributed, probably correctly, to the scant amount of food that had been supplied by "the young and inexperienced mother;" although it was perhaps not so much a lack of experience, as unusual difficulties in providing for her brood, that caused the scant allowance of food.

How a formicary grows.

Concealment of nest.

During the first summer this new community carefully preserves its home from observation. One of the earliest tasks assigned to the pioneer workers is to accomplish this concealment, which is done by piling over and around the gate bits of stick, pieces of straw, and such like portable material. This litter is so ingeniously placed that it has the appearance of having been drifted together by the winds, rather than being the work of design. The ensuing spring the ants become more careless in hiding their nest, and by the end of summer begin to trim away the grass and construct a disk. But it is not until the third year that they thoroughly declare their communal independence, and spread their disk boldly and broadly. Not long after this the first brood of males and females may be seen, on some fair morning, spreading their glossy wings and playing upon the pavement in front of the city gate. The young formicary is now ready not only to undertake all duties necessary for growth and defence, but also to wage war upon surrounding communities, if occasion require.

Coming to majority.

The future history of the queen is hidden within the dark subterranean chambers of the nest, which she rarely leaves, if ever. If ever she is permitted to enjoy the open air and a promenade upon the smooth pavement of her domain, it is under the most cautious conditions for her safety, and the closest surveillance of her body-guard. Queen though she is, she is the least free of all within the community. Her life is, doubtless, passed after the manner of others of the family of like estate. She lays innumerable eggs, from which, in order, grow the various forms of workers,—major and minor, and male and female ants; she is fed and cared for by the workers, who continually surround her in a sort of "court"; she probably assists somewhat in the nursing of the young, and may contribute something of her strength to the extension of the formicary bounds.

CHAPTER X.

MIGRATIONS AND MOVEMENTS.

Migrations.

DR. LINCECUM in his unpublished manuscripts records an interesting case of the partial migration of a large formicary. For five years previous to the date (July 12, 1865) there had been located near the family well a very populous nest. The site abounded in suitable supplies of food, and the community had grown to be a great nation, having, in the interval, exterminated several colonies of the same species that had attempted to build up homes in their vicinity. But destiny at last brought them ill fortune. One of the doctor's servants took it into his head to throw waste ashes from the fireplaces upon the disk. The deposit, which soon reached the height of three or four inches, seriously incommoded the ants. They found much difficulty in keeping the gate open, and when the season became dry, and a flock of young turkeys, after their peculiar manner, took to dusting themselves in the dry ashes two or three times a day, the ants were prevented from making their usual excursions in search of food.

Apparently the discovery was at length made that the assault upon their premises was persistent and without remedy, and measures were adopted to save the community from destruction. One day the doctor noticed large bands of workers digging a hole about thirty feet distant from the old city. They were rapidly deepening and widening their subterranean passages and rooms, as could readily be seen by the quantity of dirt thrown out. He filled up the opening with soil, and rammed it in tightly with a pole. The ants abandoned this

site and commenced another gate eight or ten feet farther off. In the mean time, the calamity threatening the formicary drew nearer and became more serious. As the turkeys grew larger they occupied the disk so constantly as a wallowing-place that it became impossible for the ants to collect provisions, and those in store must have been much wasted. The detail sent out to complete work on the new "city"—as Lincecum constantly calls a formicary—was greatly enlarged. In order to facilitate the work, and for the convenience of the workers, three gates were opened. The quantity of dirt brought out and the rapidity of the excavation were truly wonderful. In three days the bulk of soil carried out was sufficient to show that the underground works had been greatly extended; and accordingly they had already begun to carry into the new-made granaries quantities of various kinds of seed.

Transportation of seed and larvæ.

On the third day large trains of ants were seen leaving the old home and entering the new. All bore burdens: some eggs, some larvæ, some younglings, some seeds. But that which seemed most remarkable to the venerable observer, and which sorely puzzled him, was the well-known emmet habit (of which he was quite ignorant) of compelling fellow-formicarians to join a migratory movement determined upon by one part of the community, by seizing and carrying them bodily into the new quarters. I will let the doctor express his wonder (substantially) in his own words: "The most notable thing in this movement was that great numbers were carrying in their mouths dried-up-looking grown ants of the same species. They were holding them by their backs, and in such manner as to turn their feet a little up, to prevent them, as I thought, from laying hold of anything in passing along which would retard their progress. The ants that were being thus carried had their legs all folded up, and in every respect, to the naked eye, had the appearance of dead ones. It looked a little strange to me to see them packing into their new home so many of the dead. I placed a small stick on the body of one of the carriers, and with another stick pushed the dead-look-

Coerced migration.

ing ant out of the mouth. To my surprise it was not dead, but alive and very active! It did not at first seem to realize that it was free, but stared around with mouth wide open in a kind of dubious uncertainty for some seconds. However, it at last awoke to the reality, and instantly bounded away through the thick weeds, making good its escape."

On the 21st of July the ants were still engaged in this deportation of their fellows and of the young in various stages of growth. The next day they were not carrying the larvæ and nymphs, but were bringing provisions and "slaves," as Lincecum had concluded the deported ants to be. "I disengaged several of these slaves," he writes, "who, with two or three exceptions, ran wildly, making their escape. A few of these seemed below the natural size; indeed, none of the slaves were so large and full-looking as their captors. They seemed to be in bad condition. A few of them appeared to be pretty well worn out, and did not attempt to escape. They stood still, or rather sat back on their turned under hinder part (abdomen), holding their heads high, as if they were waiting to see what would come next. Several of the passing ants coming in contact with them while thus sitting on the wayside, challenged them, and although they doubtless recognized them as slaves, after some seconds of pretty close scrutiny, they passed on. In one case I saw perhaps a dozen ants stop and parley awhile with the loose slave. At last one came along, who, after chatting some time with the captive, obligingly took him up, carrying him onward with the drifting hosts. I observed a few individuals who, after being released, suffered themselves to be recaptured, some of them without resistance, others after slight opposition."

Released prisoners.

This account closes with a record under date August 23, from which it appears that Mr. Lincecum had abandoned the opinion that the deported ants were slaves, and had arrived pretty nearly at the true state of the case, although he expresses himself in the language of personification, which is usual with him. Indeed, he evidently believed the ants to have quite as high a social organization as man, and not in-

frequently stops in his manuscript to assert the superiority of the emmet faculties and administration of affairs over those of the "genus homo." "The work of carrying provisions," says the note, "from the old nest to the new has been going on for more than a month (forty-three days). From the great numbers that have been daily engaged at it for so long a time, I am led to the conclusion that a portion of the nation, owing to a political division, have obstinately refused to go to the new home, and remaining at the old place, have been industriously collecting and depositing seeds and grain all the time, which are being seized and confiscated by order of the government. It could not be that there had been such a large surplus deposited in the old city. I have seen some of the ants carrying grain into the old city recently, which almost confirms the conclusion that they have a political split, and that the malcontents are still storing provisions in the old city, and that it is taken out and carried to the new city by order of the government."

Duration of a migration.

These observations show that our agriculturals have substantially the same migratory habits as other ants. These have been more especially observed in several of the species of the genus Formica. Huber,[1] in the early part of the present century, described migrations of the fallow ants (*Formica rufa*), attended by the deportation of comrades. Forel,[2] in his "Swiss Ants," confirms the observations of Huber, with interesting additions, particularly in the case of *Formica pratensis*. The habits of these European species, as described by these eminent naturalists, are exactly repeated among their American congeners. It may serve to illustrate these more fully, as they exist in the agricultural ant, if I add an example that fell under my own notice. There is a large red ant (probably *Formica integra*) which inhabits Fairmount Park, Philadelphia. One enormous community has its headquarters in and around the great cliff

Accounts by Huber and Forel.

[1] Natural History of Ants (Recherches sur les Mœurs des Fourmis), Johnson's Translation. London, 1820, p. 157, seq.

[2] Les Fourmis de la Suisse, pp. 265–67, pp. 285–87.

at Rockland. Another quite large formicary has its nest in and in the neighborhood of a decayed tree, which stands at the foot of the bluffs, on the border of the Schuylkill River drive, not far from the Girard Avenue bridge.

April 16, in digging around the old tree in order to trace the number and position of the galleries, I greatly agitated the nest. The principal gate seemed to be just within the hollow trunk. (See Fig. 87, Plate XVIII.) Galleries extended into the hill underneath and behind the tree, the decayed roots being also apparently used as galleries. After the invasion of the nest, the ants began, in the most excited manner, to carry bits of dry wood, straw, earth, etc., some of them many times larger than themselves, into the main gate and other doors in the hill and under neighboring stones. I could not clearly make out the special object of this movement, although I supposed, of course, that it bore upon the repair and protection of the formicary.

Two hours afterwards I revisited the spot. The same busy dragging of refuse continued. One ant was observed carrying a comrade into the hollow trunk. Searching in the direction from which she seemed to have come, I presently found another, and still another carrier. A slightly-worn path led up the hill, terminating about eleven feet from the old tree, in a gate into the ground. Along this path, and issuing chiefly from this gate, but also from underneath stones near by, moved a column of carrier-ants, every one of whom was burdened with a comrade. In a few moments I counted twenty-one of these passing along the path. The deported ants were seized by the mandibles of the carriers on or below the meso-thorax, the back being downward; their heads were bent forward, the abdomen turned up, the legs drawn up and huddled together. The body was motionless; not the slightest sign of resistance or of struggling to get free was observed. (See Plate XVIII., Fig. 85.)

Deportation of Formicas in Fairmount Park.

I teased several of the carriers until the deported were released. One of the prisoners then made an effort to resist recapture. Another was evidently confused for a moment,

then turned back and ascended the hill. A third was carried quite to the opening in the trunk, when, in pushing under a straw that overhung the path, the carrier stuck fast in the narrow gangway. Before this, such obstacles were readily flanked. Now, however, the carrier abandoned her comrade, thinking, perhaps, that having reached the strong swirl and current of activity that surrounded the main gate, she would need no further coercion. Such, at least, proved to be the case, for the deported ant, after a momentary confusion, passed under the arch and was lost to sight within the cavity. Her captor and carrier, meanwhile, seemed utterly indifferent as to her whilom prisoner and her conduct, but, having paused a little space to repair her toilet, straggled listlessly into the hollow. A fourth ant, when first noticed, was in the act of dragging a comrade by a leg into the cavity, where presently she was left.

These examples will illustrate sufficiently the nature of this movement. It was not a migration, as was that described by Lincecum, but was evidently an effort to bring workers from a distant part of the nest to assist in the needed operations at the tree.

Another observation of this habit was made upon a colony of one of our American slave-making species, *Polyergus lucidus*, MAYR. The nest was found at Bellwood, Pennsylvania, at the foot of the Allegheny Mountains, August, 1878. Mingled with the Lucidus ants, of whom there were males, females, and workers, were large numbers of "slave" workers in three forms,—major, minor, and dwarf,—of a species of Formica which appears to me to be at least a new variety, and which I provisionally name *Formica riddelli*.[1] In order to study the nest architecture, a large excavation was made. Two days thereafter, a portion of the formicary was engaged in an extensive migration. A few of the slaves were carrying their fellows, but for the most part the deportation was confined to the males and females of Lucidus.

Migration of Formica riddelli.

[1] From the late JAMES W. RIDDELL, Esq., of Bellwood.

The manner in which the latter were seized and carried off was well observed, and is as follows. The slave approached the winged queen (for example), and after the usual touching and crossing of antennæ, the mandibles were tightly interlocked; the head of the slave was then raised, and simultaneously the body of the queen drawn back, stretched quite out in a straight line, and then doubled under, the abdomen being thrown upward, apparently resting against the lower part of the face and the fore part of the thorax. In this position the large virgin queens were carried up the perpendicular face of the cutting for eighteen or twenty inches, and then for the distance of six feet over the ground and through the grass. The time consumed in this journey was a few seconds over one minute. I frequently observed this carrying of the workers of Lucidus in the artificial colonies which I afterward formed and brought to Philadelphia. The process was substantially the same, although often the master was simply dragged along the surface. More than once a slight opposition was made to this treatment. The slaves, or at least certain individuals of them (for I am persuaded that ants have their personal peculiarities of disposition and moods like larger animals), seemed, at times, to have a prejudice against the presence of the Lucidus ants above-ground, and would unceremoniously seize them and carry them below. I have seen a master, or, more properly, "mistress," thus served several times, each time returning in a dogged sort of resistance to the will of her servitor. These emmet mistresses, too, apparently know something of the bitterness of bondage to a capricious domestic "help!"

Deportation of Polyergus lucidus.

Bondage to servants.

The wonderful muscular force of the grip which Lucidus takes with her mandibles was thus illustrated: one worker had for some reason fallen under the displeasure of another, who held her firmly grasped by the middle-thorax. Anxious to preserve my colony from unnecessary loss, I lifted the two out on the point of a quill tooth-pick, laid them in my hand, and thrust the fine point of the quill between the jaws of the

aggressor, and so teased her until she released her hold of her fellow. The rescued ant instantly clasped the palm of my hand, threw her abdomen under, and thus, with back curved up like an angry cat, sawed and tugged at the skin until an abrasion had been made. While watching this operation, the other ant was still clinging to the quill, and to her I next turned attention. She was holding fast in her mandibles the point of the tooth-pick, with her body stretched straight out into space, her limbs stretched outward, except one hind leg, which was bent a little upward. Thus without any perceptible support except that which her jaws gave her upon the quill point, she hung outstretched for several minutes. How long she would have kept the position I know not, for I dropped her into the nest by clipping off with scissors the point of the quill, which after hugging fiercely for awhile she finally abandoned as an unresponsive and unworthy foe.

Strength of mandibular muscles.

In the course of the above migration one queen was seen to resist carriage so vigorously that she was finally dropped, and refusing to give the slave a hold upon the mandibles, was seized by the wing and dragged off. The Lucidus ants seemed to have no volition in nor direction of this movement. I released a number from their porters during various stages of the transit, who always wandered about with a confused, aimless, and irritated manner, until again seized and borne off by slaves.

Whatever may be said about the power of ants to communicate ideas by what may be called antennal language, it must be allowed that the above and similar actions indicate a quite limited range of communicating media. The mode of seizing a comrade and bearing her along *vi et armis*, is certainly a good deal after the nature of what we facetiously call an "Irish hint,"—a very broad one indeed,—that the captured insect is needed at a certain point. Such vigorous measures would seem to indicate that the carrier, lacking adequate power of expression, or at least of persuasion, resorts to kidnapping and deportation, trusting the contagious influence

of surroundings and example to enlist the recruit, after her removal, in the movement for which her service is desired.

Deportation submitted to, but not pleasant.

It certainly is curious, however, that this deportation is ordinarily permitted without any show of resistance. I have observed this in the case of our agriculturals as well as other species. A number of newly-arrived ants were placed in one of my small formicaries. The inmates had been domiciled therein for two months, but the more vigorous and numerous interlopers took possession not only of house and home, but of some of the inhabitants also. Several were seized by the upper part of the thorax (back) in a position the reverse of that described in the deportation of *Formica integra*, and so were carried around and around the jar for nearly two days before they were finally released. (See Fig. 84, Plate XVIII.) In these examples I had opportunity to see that the seizure was very deliberate; that the captive might have resisted, but that, on the contrary, she seemed to cower and crouch down at the very first approach, and to suffer her captor to leisurely seize and adjust the burden for the most convenient carriage in the mandibles. It would almost appear that these emmets possess something like a sense of submission to a recognized legal authority, and tacitly acknowledge the fact that they are in the hands of a communal police.[1]

Huber does, indeed, express the opinion that this deportation is usually the result of an amicable proposal and agreement, and is not disagreeable to the deported. My observations lead me to a different conclusion. The deported ants are evidently coerced. They are certainly submissive, but they are not pleased. The behavior of the Fairmount Park *integras*, after their release, and the actions of the released agriculturals as described by Lincecum, show this. It assuredly was the reverse of agreeable to be toted up and down

[1] I have already called attention to this fact in the case of obnoxious or "tainted" ants falling into the hands of the sentries of *Formica* (rufa) *exsectoïdes*. See my "Mound-Making Ants of the Alleghenies," Jno. A. Black, Philadelphia, and Trans. Amer. Ento. Soc., vol. vi., 1877, p. 281.

for many hours in that constrained position which the agriculturals in my artificial formicary were compelled to maintain. Moreover, there seems to be no good reason to suppose that, if the proposal to emigrate had been really made by antennal language, and accepted, the recruits might not have gone off naturally of their own accord, without the necessity of being carried. In short, that which Huber records as the exception seems to me to be the rule. "It sometimes, however, happened," he observes, "that those who were desirous of the change, seized the other ants by surprise, and dragged them out of the ant-hill, allowing them no time to offer resistance."

Absence of leadership.

For the more perfect understanding of these migratory and compulsory movements, it should be remembered that the agricultural ant, in common with all of the FORMICARIÆ of whose habits I have personal knowledge, have no "guide, overseer, or ruler."[1] Communal movements do not seem to be prompted or directed by any "official" individuals. The name "queen" as commonly applied by entomologists to the fertile female of hymenopterous insects (as bees, ants, wasps) is misleading to the general reader. The functions of the queen seem to be limited to the mason-work and other labors necessary to the establishment of the original nucleus of a formicary, to the subsequent increase of the community by the deposit of eggs, and perhaps, also, to some extent, the care of the young. There is really no headship or function of government and leadership analogous to that which the word "queen" expresses among men. The ant-queen is substantially a prisoner, closely confined within the formicary bounds, and continually guarded by watchful workers. In cases of migration she herself, after new quarters are established, is probably, in some cases certainly, deported in the mandibles of the workers. Changes such as have been described above originate with the workers.

[1] Prov. vi. 7. Dr. Forel, in his Swiss Ants, has pointed out this fact and its harmony with the old record; and I have already referred to the same in my "Mound-Making Ants."

The reasons for them are sometimes beyond human ken; but at other times plainly lie in special annoyance, inconvenience, danger, or necessity. They would appear, at times, to be quite spontaneous in an entire community, when small or in a large section of a populous nest. But always, each ant seems to be a law unto herself, and preserves the greatest independence of action. The only sovereignty which she recognizes is that of personal influence and example. When this has become potential, the subject thereof is urged forward in the line of labor, apparently wholly independent of other rule or restraint than those which her task imposes, and in turn she herself comes to wield an influential sovereignty.

I have not had the opportunity to study this phase of ant-history, in examples of large migratory movements. But in several cases where the numbers concerned were not large, and also in imprisoned communities, as well as in natural movements, not migatory, of large numbers of ants in column and at mason-work, I have entirely satisfied myself of the truth of these views. A great movement may result from the independent action of one ant. Here, for example, is a single worker who is engaged upon the ruins of a broken mound. She has at last found her way into the mouth of a choked-up gallery. Her mandibles and paws are plied with new fervor. She drags out pellets of earth with astonishing force and rapidity, bears them off, rushes back for fresh burdens. Scores of workers are aimlessly and confusedly bustling everywhere around her. She strides over them with utmost indifference. But her example at lasts infects a comrade, who joins her in the trench, rather cautiously at first, then with enthusiasm. A third,—a fourth,—numbers follow, until now the gallery is fairly clogged with the mass of lithe, struggling workers, whose zeal has become a very furor. But where is the original worker, the pioneer of this enterprise? Long since she has been lost to my sight in the crowd, and is quite as completely lost to the attention of her enthusiastic co-laborers. She is nothing more to them than any other fellow, and has

Origin and development of migrations.

not been more since the first recruit joined her. It is possible, indeed, that yon worker, combing herself on the summit of an adjoining fragment of broken arches, is she! At least, when she shall retire, as undoubtedly she soon will, for rest and refreshment, or perhaps shall stroll away to begin another new, or to be swept along in an established movement, the work which she commenced in the choked-up gallery will go on, and perhaps develop into the nucleus of the restored mound. Such is the character of the leadership that exists among our mound-making ants, as I have observed it in their architectural labors, and as it is precisely repeated in their column movements toward the feeding-grounds.

Character of leadership.

Among the agricultural ants leadership is exercised in the same way in laying out galleries and prosecuting work upon them. I have given an observation illustrative of this in the remarks upon mining. So also in the work of garnering seeds, and in the clearings and sentinel operations at the disk. The same fact also appeared in the establishment of a new forage-track through my tent, in order to connect a neighboring nest with the refuse of our camp-kitchen and table.

Keeping these facts in mind, we have a key to the solution of the press-gang operations which Lincecum observed among the agriculturals, and which have been fully described in other species. In the absence of any common head or directory, and of all executive officers, a change of location or any other concerted movement must be carried forward by the willing co-operation of individuals. At first sight, the act of seizing and carrying off workers does not appear like an appeal to free-will. It is indeed coercive, so far as the first act goes. But, in point of fact; the coercion ceases the moment the captive is set down within the precincts of the new movement. The carrier-ant has depended upon securing her consent and co-operation by thus bringing her within the circle of activity for which her service is sought. As a rule, no doubt, the deported ant at once yields to the

Why ants are carried.

influence around her, and drops into the current of fresh enterprise, in which she moves with as entire freedom and as independently as any other worker. But she is apparently under no restraint, and if she so please, may return to her former haunts.

We have thus also explained the separation by emigration of one large formicary into two independent colonies, as Lincecum describes it, and the cross-movements and countermigrations which Forel and others describe, and to which Lincecum also refers. No other headship than that which has been described is required to account for all such movements.

During my stay at Camp Kneass I saw only one example of a change of location. This resulted apparently in an endeavor to escape from the shadow of a growing mesquite-tree (see Chapter II.). There was no evidence of any special interest, either favorable or unfavorable, on the part of the natal community. Everything around the disk was conducted precisely as it had been before the beginning of the new enterprise. Harvesters and foragers came and went along the roads, sentinels perambulated the disk, workers poured in and out of the gate with utmost placidity. The new gate was but a few paces removed from the old nest, and was placed within six inches of a beaten ant-road, along which two columns of insects were busily moving, the one engaged upon the new work, the other composed of workers from the old nest. The two lines interblended with the utmost amity, neither interfering with nor indeed seeming to take the slightest notice of the other. Every ant was evidently attending to her own business with the utmost diligence, and was just as faithfully letting other ants' business alone. No trace of a directing head or of guiding officers was to be seen.

In going to and from their nests the ants move with great rapidity. I fancied that there was a pulsation or vibration of the entire body as they hurried along, something like the trembling of a steamer when being forced through water. This may have been an optical delusion,

Rapidity of movements.

caused by the incessant agitation of the antennæ, but I think not, and at least I record my impression. In order to determine the rate of progress, I put a number of individuals under observation. The first noted, which seemed to be prowling about aimlessly, and was moving quite deliberately, took three-fourths of a minute to cross a rough wagon-track, fifteen feet wide. This is at the rate of a mile in 1 hour and 24 minutes. The ant carried no burden. A smooth ant-road was selected, a space of three feet measured off upon it near to the disk, and a large number of insects carefully "timed" over this miniature track. Two averages were taken: one gave five seconds, the other four seconds, as the time consumed in passing over the three feet. Some made the distance in three seconds and a fraction. The first average (five seconds) would give a rate of 2160 feet per hour, or a mile in about 2½ hours; the second average (four seconds) gives a rate of 2700 feet per hour, or a mile in about 1 hour and 54 minutes. These ants were most of them without burdens, but some of them carried small seeds. The rate of progress with seeds seemed to be generally quite as great as without them. With heavy burdens, however, the rapidity of movement was diminished nearly one-half.

Rate of motion under burdens.

The following observation, among others, was made of the rate of progress under a burden of unusual weight. An ant was seen carrying a large piece of quartz gravel, which must have weighed three or four grains, up the steep slope of a ditch or cutting in Austin to its gravel-covered mound at the top. I could not divine the object of the carrier in this unusual and apparently senseless act. The pebble was carried nearly four feet up the steep slope and then dropped. I picked it up to preserve, but after taking it sixty feet beyond the mound, but within the range of its roads, laid it down before several ants who were on the opposite side of the wagon-track above referred to. I had been puzzling over the conduct just mentioned, and it occurred to me to see if other ants would act in the same way with this pebble. I accordingly submitted it to a group of unemployed individuals.

It was almost immediately seized by one of them. She experienced much difficulty in adjusting so large a burden to her mandibles, and took a number of grips upon it at different parts, the abdomen being swung under the body and pressed against the pebble in order to steady it and assist in the adjustment. Finally, she was satisfied, and started homeward. The first ten feet of the journey was over the wagon-track, cut with wheels, rough with particles of black, baked soil and dust. This distance (ten feet) was made in one minute and a quarter. Thus an ant three-eighths (say) of an inch long, and weighing one-sixth (say) of a grain, moved at the rate of one mile in eleven hours bearing a burden at least eighteen times its own weight. If we should compare this with human achievements, and suppose a man five and a half feet long, weighing 140 pounds, to make similar progress with a corresponding burden, it would indicate the enormous speed of 176 miles in 11 hours, under a burden of 2500 pounds. Of course, such comparisons are in many respects misleading and useless; but they may help some minds to take in more readily a just idea of the great muscular endowments and powers of endurance possessed by these insects.

Weight of burdens carried.

I may conclude the history of this achievement. When the carrier reached the ant-road, where her advance should have been much more rapid, it was made much slower by continual interruptions from her fellows. She was frequently challenged with the antennæ, by one, two, and even three ants at a time, each challenge compelling a momentary delay. Twice after such greeting the pebble was dropped, but was again seized and borne forward. The appearance of opposition and remonstrance on the part of the challengers was quite evident. Scarcely an ant passed along the road who did not cross antennæ with the porter and check her progress. Finally the stone was dropped in the middle of the road, and the disburdened worker went home. Thereafter, every ant that passed stopped before the pebble and challenged it, some of them nipping it with their mandibles before they passed on.

The distance which this ant made in this second stage was forty-five feet, the time consumed being eleven minutes, including all stoppages, and considering how numerous these were this was certainly remarkable progress. But why should the creature have carried the gravel at all? Perhaps some trace of animal odor (formic acid, it may be) left upon the stone by the first carrier may have attracted the second. The first may have been attracted in like manner by the accidental presence of some odor that suggested the idea of food. I venture no opinion, however, and the reader may guess as well as I. This apparently aimless deportation of various materials is rare with ants, but not wholly exceptional. However, if, on the one hand, there was the semblance of folly in vain toil, there was, on the other hand, proof of wisdom in the general remonstrance against the act, and its final abandonment.

CHAPTER XI.

THE STINGING ORGANS—ANATOMY IN FULL.

I HAD been frequently admonished that the popular name of our bearded emmet, viz., the stinging ant, was by no means an empty title, and that I must "look sharp" or I should find that she carried a sharp sting. I purposed, at some convenient time, to test both the *modus operandi* in the infliction of the sting and the effects of the wound upon my system. But in view of the precautions which benevolent people and all manner of stragglers to and through our camp so freely volunteered, I thought that I should be likely to have ample opportunity for observation without deliberately seeking it. However, it was not until I came to the work of excavating the nests that I was permitted to prove the ant's defensive and offensive prowess. In my earlier studies I was not molested. Lincecum's account of the hostility shown at every approach to the nest so far from being confirmed was wholly contradicted by my experience. No serious objection was urged against my frequent observations of the habits of the insects in their harvesting grounds, on their roads, and around their formicary disks. They seemed to be aware that my then present intentions were harmless.

The sting and stinging organs.

A few steps from my tent door was a large nest, whose workers established a trail through the middle of the tent to the space beyond in which the daily meals were served. The object of their foraging was the refuse of the table,—crumbs of bread, bits of sugar, etc. They continually traversed the loose board floor, over which I was moving, and upon which

my slippered feet rested while writing up notes and pursuing other such work in the middle of the day. The ants ran around, even over my feet, never once showing any temper, pursuing their task in a steady, good-humored way, quite indifferent to all other things. The lad Harvey went about the camp all day in his bare feet, passing constantly among multitudes of ants, and was not once stung. I therefore conclude that, like other social hymenoptera, as wasps and bees, the agricultural ant is sufficiently good tempered and harmless except when molested, or when she thinks herself to be so.

A peaceful disposition.

When we consider their vast numbers, and their contiguity to the walks and homes of men, it is surprising that so few persons suffer from the formidable weapons at command of these insects. If to possess great power for doing harm and to refrain from its exercise be an evidence of a peaceful disposition, they are certainly entitled to that character.

Nevertheless, their reputation is quite the reverse of that; they are regarded with a wholesome fear by children, and adults have little wish to meddle with them. A bright, stout colored youth visited camp when I was engaged in studying the interior of the nests, and greatly needed a workman. I tried to engage him to assist in the digging, but my offer was rejected with an emphasis and facial expression of horror which was amusing. As he stood and watched me engaged with trowel and knife uncovering granaries and galleries in the trench, while Tindale and Pearson brushed off the angry hordes of assaulting ants, his countenance seemed to indicate serious doubts of my sanity. "What!" he cried, in the peculiar *patois* of a Southern negro, "dig among dem stingin' ants? Why, dere sting's *pisen*,—rank pisen! I wouldn't do dat fur five dollas a day!" He therein uttered what seemed to be the quite general feeling of his class. I presently found that there was some reason for this sentiment.

My first stings—two of them given simultaneously—were received upon the hand while thus working in the excavations. The hand was protected by heavy gloves, except the

ends of the fingers. At these exposed points the stings were received, one on the second joint of the little finger, another, more severe, on the wrist, at the base of the thumb. I immediately ceased work, stepped out of the trench, and gave close attention to my sensations. There was a sharp, severe pain, resembling that of the sting of a bee. Then followed twice, at short intervals, a nervous, chilling sensation, which seemed to sweep upwards, and was felt quite sensibly around the roots of the hair. This was a very peculiar feeling indeed, and appeared to me very like that caused by a sudden alarm, or excitement in which the element of horror predominates. Then followed a steady heavy pain about the wound, which continued for three hours more or less severely, a slight numbness accompanying, but no inconvenience thereafter. The next morning there was a very slight numbness around the wounded part. The sting upon the wrist was surrounded by an inflamed purplish spot, from an inch to an inch and a half in diameter, which was mottled with white. Tindale was stung about the same time in the leg, and said that the sting pained him up to the groin. I was stung thereafter a number of times, once receiving half a dozen wounds at one time. This severe punishment produced a slight nausea, and a flush as of fever throughout the system. No wounds, however, were so severe as to hinder me from work; although it should be said that they were always given at times when my mind was so intently engaged upon investigations that I really could not take leisure to yield to the pain. The most severe sting was one made upon the head. An enterprising ant, who had escaped the vigorous whisking of my attendant, mounted over my collar, explored the capillary thicket beyond, and forcing her way under the hat, by some malevolent fortune made her perch upon the very summit of the crown of my head, where nature had provided her enough of smooth space to afford untrammelled opportunity for her aculeate operations. Down into the wee patchie of bald cuticle sank the remorseless sting. I found it very proper to exercise promptly the grace of politeness,

Sensations of a sting.

and doff my hat! I never cared to kill the ants who thus attacked me if I could avoid it, for I considered that they were quite justifiable in defending, with all the powers which the Creator had given, their homes and progeny. Nevertheless, I thought it necessary to remove *that* particular ant from her high estate. Her sting pained me very much indeed, and was felt more than twenty-four hours afterward.

Mode of giving a sting.

I suffered one ant to operate upon my thumb in order to observe the mode of giving the wound. The process is as follows: the skin was grasped firmly by the stout, toothed mandibles. The foremost pair of legs were thrust out and forward, the second pair a little forward but outward more from the body, the hind legs backward, the feet all holding lightly upon the skin. The body was now forced upward by the legs, particularly the hind pair (apparently), so that the abdomen was elevated, and being drooped was suspended freely. Then came the stroke. The abdomen was thrust down obliquely, and the sting forced into the flesh. The motion was rather deliberate than swift, flurried, and impassioned. The sting was quite visible, a yellowish or livid aculeate organ. A figure of the ant, whose attitude was taken at the time in outline with the free hand, is given in Plate XIX., Fig. 97.

A physician's diagnosis.

I requested Dr. M. A. Taylor, of Austin, a physician of long standing and wide practice in Texas, and a gentleman of considerable local eminence in his profession, to prepare for me a statement of the effects of the poison of the agricultural ant upon the human system. Dr. Taylor kindly sent me the following note, describing the effects of the wound and naming some of the simplest remedies for relieving the same. The above note of my own sensations under the sting was written upon the spot, and Dr. Taylor's letter was not received until six months later. It was therefore with a peculiarly vivid satisfaction that I found my own record of the strange, "wave-like sensation" which follows the wound mentioned in the more technical diagnosis of a skilful and experienced medical practitioner. The feeling

had seemed to me so remarkable, and one so unlikely to be produced by the sting of an ant, that I had really been inclined to distrust the accuracy of my observation and to withhold my note from publication. Perhaps one may be excused for such hesitation as to his accuracy when his own physical pains are the subject of notice, especially when (as in my case) the observer has not had much experience, by reason of uniform good health, in observing the nature and progress of bodily sufferings. At least this will account for the unusual satisfaction with which the confirmation of my record was received. Dr. Taylor's note is as follows:

"The stinging or agricultural ant is among the insects found in this country that secrete a poison which, when instilled into the living tissue, is capable of producing painful and perhaps, under peculiar circumstances, even fatal consequences. The poison of this ant is probably in character like that of the honey-bee, yellow-jacket, wasp, and humble-bee, though not so painful or as active in its results. The substance secreted is highly acrid and acid in character, resembling, if it be not, formic acid. The season of the year seems to have something to do with the activity of this poison. During the hotter months it appears stronger. The passion of the insect seems also to have something to do with the strength of the poison secreted, or it may be that the effort of the ants being stronger when enraged, their stings are driven more deeply into the tissues, and by that means a greater amount of the poison is absorbed, and a stronger impression made on the local part.

"The first sensation is not that of a sharp, pungent, itching pain, but more obtuse, and followed by a wave-like sensation, radiating over a considerable surface. There are often short pauses, followed by still more severe sensations. This character of sensation continues for ten or fifteen minutes, or until the poison has been diffused throughout the surrounding tissues. The local appearance is marked by a circumscribed inflammatory swelling, pale and elevated at the site of the injury. This pallor is soon followed by redness of the part adjacent to the part stung. We rarely find the constitutional

disturbance sufficient to justify the administration of remedies other than local. If stung by a large number of ants we may have nausea and vomiting. With persons of a peculiar idiosyncrasy, coupled with other causes, the symptoms may be severe and alarming, producing dimness of vision, vertigo, nausea, palpitation, and an indescribable sensation of oppression and possible fainting.

"The treatment should be constitutional and local, though the former is rarely necessary. The attention should first be directed to the part stung, in order to ascertain the number of stings and the locality, and to remove any of the insects still hanging on or in the neighboring locality, as they often continue to sting until brushed away or picked off one by one. One of our best domestic remedies is a strong solution of table-salt and water. The parts should be frequently sponged, or cloths wet in the same solution applied to the part stung. Still more efficacious remedies may be resorted to, as sponging the part with alcohol, or alcohol and laudanum. Aqua ammonia and spirits of camphor are still more active measures of relief. The dilute tincture of iodine is probably a remedy of more power. Spirits of turpentine often subserves a good purpose in subduing the pain and dispersing the local inflammation. Bicarbonate of soda softened with water and made into a paste and spread over the part acts well. In like manner a large number of alkaloids may be used.

Remedies for ant-stings.

"The mode of cure is twofold: first, neutralizing the poison; and, second, relieving inflammation. The introduction of remedies should be resorted to when constitutional symptoms manifest themselves. One of the most palatable and best is brandy, in the form of a hot toddy. Ammonia diluted acts promptly, and is regarded as a valuable means to meet the indications. An aqueous solution of iodine and iodide of potassium may be used with marked good effect in all cases where the constitution seems to suffer from the poison.

"Infants may pick the ants from the ground or floor and get them in the throat, or even into the stomach, causing great

disturbance of the stomach. In all such cases the mustard emetic will usually promptly relieve the patient, or the use of salt and water. The latter acts not only as an emetic, but has a profitable influence over the mucous surfaces. Stings in the throat may cause great swelling and sensations of suffocation. If so, the usual remedies should be resorted to at an early moment."

Stinging organs.

The popular interest which attaches to the stinging properties of the agricultural ant, and the annoying, even serious nature of the wounds inflicted, made it especially interesting to know the anatomy of the stinging organs. I therefore undertook to work out some of the details, assisted, as has heretofore been acknowledged, by mountings of the natural objects made by the skilful hands of Prof. Hunt. I also forwarded specimens of the ant to Dr. Auguste Forel, at Munich, with the request that he would assist me in this part of my subject. Dr. Forel is so widely and favorably known for his studies in myrmecology, that it was with peculiar pleasure that I received from him a favorable response. He forwarded to me a drawing (from which Plate XX., Fig. 98, has been made) of the Poison Apparatus, the Sting, Sac, and Gland of the worker of our Barbatus, with the accompanying explanation and remarks. The original Latin explanation of the figure I have retained for the sake of greater clearness in connection with my translation. Only the lettering has been changed to correspond with the nomenclature here adopted.

Dr. Forel's figure of sting of worker.

"I have examined," says Dr. Forel, "as far as it was possible in alcoholic specimens, what specially relates to the poison apparatus, and can say to you that it is constructed precisely as in other *Myrmicidæ* and *Poneridæ*. It has, however, a comparatively large development, as in the European *Myrmica rubida* and the Brazilian *Paraponera clavata*, in which I have also investigated it. I must refer you for the minute details to my forthcoming work upon the poison apparatus and anal glands of ants in the 'Zeitschrift für Wissenschaftliche

Zoologie.'[1] Nevertheless, I give you, according to your wish, a drawing of the poison apparatus of the worker, so far as I was able to do it. It does not enter into histological details. The drawing shows the poison apparatus from below (from the abdominal surface), magnified from forty to forty-five times in diameter. The free gland ducts (*gl.ex*) are constructed exactly as in *Ponera*. On account of their softness I was not able to prepare them quite satisfactorily, and they, as also the glandular accessoria (*acc*), were a little schematized, *i.e.*, completed by art.

"The figure gives somewhat of a rude plan of the poison apparatus of all *Myrmicidæ* and *Poneridæ*. I could not find muscular fibre in the poison sac. The contents of the sac were curdled like milk, as is always the case in *Myrmica rubida*, which also stings violently. There were also several resinous concretions in the sac, as in many *Myrmicidæ* and *Poneridæ*. The stomach is constructed in the same way as that of *Myrmica*, and its contents of similar character. Besides this, I found nothing worth remarking, except several small anal gland cells." (See Plate XX.)

Analogy with other ant-stings.

The preparations from which my own studies were made enabled me to confirm, for the most part, the above representation of Dr. Forel. Some of the organs which he has figured I was not so fortunate as to detect with absolute certainty. My preparations did not show the secretory glands, *gl.ex*, *in situ*, but I marked their entrance into the sac, and saw them detached. Also the terminal lobus, *lob*, in the hollow of the poison sac was not determined by me.

No special importance can be attached to this difference, however, as my investigations here were not satisfactory, and, indeed, my attention was chiefly given to the stinging apparatus proper. In the specimens of workers examined, the accessory organ, *acc*, was not seen entire, the contents having

[1] This valuable paper has since been received from the author. Its full title is "Der Giftapparat und die Analdrüsen der Ameisen." Zeitschrift f. Wissensch. Zoologie, XXX Bd., 1878.

escaped, leaving the enclosing walls in the shape of an irregular ribband, which, however, easily indicated the normal size and probable shape. Dr. Forel referred to the same indistinctness of outline, the figure given by him being partly completed by art, as his knowledge of the anatomy of the ant well enabled him to do. My observations, so far as made, confirmed the accuracy of this sketch. The specimens of young females dissected gave much better results, and showed the remarkably developed accessory gland described farther on.

Forel's observations confirmed.

The stinging organs consist of the poison gland and poison sac, the accessory organ, and the stinging apparatus. These are all situated in the ventral or lower portion of the apex of the abdomen, close to the ventral surface, and are immediately covered by the final ventral plate (Hypopygium), through which their outlines may in part be traced, by a working lens, in the young queens. At Plate XIX., Figs. 91 and 92, is shown the position of these organs, and the appearance presented when the sting is protruded from the cloaca. The cloaca is the transverse slit or opening in the apex of the abdomen which is the common vent for the stinging organs, the rectum, the sexual apparatus, and, when present, the anal vesicle and gland. Fig. 91 is a view in profile, from a specimen in alcohol, of a young queen. *4dp* is the dorsal plate of the fourth segment of the abdomen; *4vp*, the corresponding ventral plate. *Py* is the Pygidium, or anal dorsal plate, the terminal margin of which is bent downward, flattened, and covered with hairs, which project as far as, or beyond the point of the out-thrust sting. The thin membrane, *m*, unites this part of the pygidium with the two parts of the sting-sheath, which it tightly embraces, together with a portion of the rectum, *re*, which is also here seen protruded. The Hypopygium, *hy*, contains the stinging apparatus as the concave part of a shield does the human arm, and in the concavity between its tip and the sheath the sting, *stg*, which is here seen in its case, is thrust out. I could look down into this concavity with a good working lens, and thus

Stinging organs defined.

Views of protruded sting.

seen, the contact of the two lobes of the sheath formed a groove. The sting-case had apparently moved in that part of the groove between the bulbous ends, *shb*, of the sheath, but seemed to diverge from the necks, *shn*, of the sheath. Fig. 92 shows the same protruded sting as seen from below, the outline of the covered part being slightly indicated as seen through the hypopygium. The hypopygium is covered at the tip with short hairs for about one-half its length. Fig. 93 represents what appeared to be a membranous sac, *ms*, immediately enclosing the sheath, and itself enclosed within the apex of the abdomen. It is supported upon a curved chitinous frame, *ct*, which (apparently) is attached to one of the elastic plates of the stinging apparatus.

The word sting, as commonly used, cannot be applied to any one organ, but rather expresses a combination of three organs, one of which, the sting-case (Fig. 96, and *cs* elsewhere[1]), is single, the others, the stinging prickles, *pk*, and the out-sheath, *sh*, are double. They are supported within the apex of the abdomen by the muscles, and are operated by means of a system of levers and muscles hereafter described.

The sting a compound organ.

The out-sheath, *sth*, *sh* (vaginæ exteriores, stachel-schieden), is composed of two similar organs, each of which consists of two parts, the posterior (toward the apex of the abdomen) and anterior (toward the head of the ant). The posterior parts are bottle-shaped, well clad with stout bristles, slightly concaved toward the surfaces which oppose each other, within which concavity the apical half of the case is received and moves. The neck, *shn* (Plate XIX., Fig. 91), and part of the bulb, *shb*, protrude in the act of stinging nearly as far as the case. Their use is probably not only to protect and support the case, but to give it direction, in the

The sheath.

[1] A uniform notation has been preserved as far as possible throughout the figures, and reference letters in one correspond with those in all others. For the most part, also, the notation is drawn from the initial letters of the English names of the objects referred to, and thus may assist memory by being in some measure suggestive of the objects so represented.

manner of "feelers," in the act of piercing, and also to hold and steady the piercing organs in that act. For the two last-named functions the bristles which cover it would be of service. The anterior (*sth*, Plate XX.) parts of the out-sheath are elongated chitinous plates, rounded at the anterior ends, upon each of which is a breathing tube or trachea, *tr*.

The central part of the stinging apparatus is the sting-case, *cs* (Plate XIX., Fig. 96). This organ has, unfortunately, as yet acquired no fixed name. Lacaze-Duthier calls it the gorgeret, a not inapt name, suggested by a comparison that M. Leon Dufour has made with the surgical instrument thus called. The Germans agree upon the name stachelrinne, or sting-ring, which is sufficiently expressive, and is best conveyed by the name which I have chosen, sting-case, or briefly, case. The general description given by Lacaze-Duthier[1] of this organ in the aculeate Hymenoptera would apply with little change to that of Barbatus. It is in shape an irregular cone, whose apex is much drawn out posteriorly. It is shown separate at Fig. 96, and may, for convenience, be divided into four parts,—the throat, *thr*, the trunk, *tru*, the blade, *bld*, and the gouge, *go*. The upper (anterior) part is truncated, the posterior part sabre-shaped.

The sting-case.

The inferior face is traversed by a longitudinal cleft, *cl*, widest toward the base. The edges or lips of this cleft are thickened. The cleft does not extend entirely to the anterior end (base, *thr*), but as far as the entrance of the prickles into the case, at which point it widens into an opening conformed as represented at *thr*, and which we may call the throat. Into this throat are received the prickles, which come in from the side, and the conduits of the poison sac and accessory, which enter from above (anteriorly). (See Plates XX. and XXI.) The projecting walls, *pw*, of the case which enclose the throat are united at the end by a continuous band or ring, *rg*. On either side is a process, *h*, to which is attached

The case-cleft.

[1] Recherches sur l'Armure Génitale des Insectes. Annales des Sciences Naturelles. Zool., xii., 1849, p. 357. Libr. Acad. Nat. Sci. Phila.

a strong muscle. A magnified view of this process and muscle is presented at Fig. 94, *fm*.

The case is hollow, and the interior communicates with the longitudinal cleft. The enclosing walls of this cavity of the case are double; they lie close to each other within the throat, but rapidly separate in the trunk beyond, thus contracting toward the apex the interior cavity (*pc*, Fig. 113), in which the prickles move. The contracting inner wall may be seen in the views of the case at Figs. 99 and 116. Fig. 113, Plate XXIII., gives an interior view of the case, showing the double walls, as exhibited in a fracture. The outer edge of the case, *ec*, is thickened, and within the channel, *pc*, formed by it and the inner wall, the prickles move. The two walls unite at *u*, and a cavity, *cv*, is left, whose use I have not been able to determine. At *b* and b^1 are shown two retrorse barbs (pointed anteriorly), which may have been simply fractures in the inner wall; but they presented such a regular appearance, and were so like the gouge-barbs (Fig. 95, *cb*, cb^1), that I have figured them. If they be indeed normal openings, may it not be that they serve to regulate the flow of the excretions of the poison and accessory glands, and that the cavity, *cv*, is a sort of overflow or relief-reservoir? The cavity, *cv*, continues in its contracted limits to the apex of the case.

Double walls of case.

The case is not straight, but is curved like a sabre in the narrow part or blade, as shown in the several figures. The apex is sharp, presents the appearance of a carpenter's "gouge," and I have ventured to call this part of the case by that name. In the act of stinging, it is this gouge which makes the first incision. The thickened or folded edge of the cleft has two barbs, directed anteriorly, which uniformly appear upon this part of the case. (See Fig. 95, *cb*, cb^1.) The shafts of the prickles, when in repose, are contained wholly within the case, but are thrust out alternately when the ant stings, entering the wound made by the case, aggravating it and injecting the poison. In Plates XX. and XXI., the prickles are shown within their case, which is there in normal relation

The gouge.

to the sheath. They may be seen through the cleft, within which, indeed, they lie in part, quite filling it up.

At Fig. 95, Plate XIX., the end of the case, *cs*, is shown, together with the chiselled edge which forms the gouge, *go*. Within the concavity of the gouge are seen what I at first took to be the terminal attachments of an interior muscle, which helps to operate the gouge, but which afterwards were interpreted as regular striæ or grooves, *gst*, upon the interior of the inner wall of the gouge. These converged shortly within the concavity, into one or a double straight striation, which apparently interlaid the case, extending anteriorly. The terminations of these internal striæ, *gst*, upon the apical margin of the gouge were small circular indentations or pits. I have conjectured that these striæ may serve as channels to aid the outflow of the liquid poison. Fig. 114, Plate XXIII., shows the gouge with the enclosing prickles in the act of stinging. That is to say, the figure is drawn from nature, the barbs being found in this position in several of the dissections, and as the prickles, *pk*, alternate in their strokes, the drawing exhibits the relative position of prickles and gouge in the act of stinging. The prickles lie close to each other, and fill the gouge quite as compactly as in the drawing.

Gouge grooves.

Position of prickles within the gouge.

We may now draw out the two stinging prickles (acus, stechborste, the stylet of Duthier) from their case and examine them in detail. They are similar in structure, each being a slender, bent chitinous rod, of which the shaft or straight part is lodged within the sting-case, and the bow, *bo*, or bent portion rests and moves within a narrow grooved extension (Plate XXII., Fig. 100, *pgv*) of the oblong plate, which is also (apparently) continuous of or connected with the throat of the case. The anterior extremity or bow end terminates upon a small notched deltoid plate, *del*, which is the "Winkle" (angle) of Kraepelin,[1] and which I have called

Prickles explained.

[1] Untersuchungen über den Bau, Mechanismus und die Entwickelungsgeschichte des Stachels der bienenartigen Thiere. Von Dr. Carl Kraepelin. Zeit. f. Wiss. Zool., Bd. xxiii., 1873. Libr. Acad. Nat. Sci. Phila.

the delta. It articulates upon two other plates, forming a system of levers by which the sting is protruded and retracted. The shaft or straight part of the prickle is directed toward the apex of the abdomen, and terminates in a barbed point. The whole prickle is divided longitudinally into two portions by a marked difference in the density of the substance, which portions I distinguish as the needle, *nd*, and the tube, *tu* (Plate XXII., Figs. 105, 110). The tube is diaphanous, the needle of stronger chitine. These portions are shown torn apart at Plate XXIII., Fig. 101. Fig. 105, Plate XXII., shows the shaft, *shf*, and a part of the bow, *bo*, of a prickle drawn out from the case and magnified about 50 diameters. The natural size is shown at Plate XXIV., Fig. 122. The bow end is fractured vertically, and presents a view of the tube and needle *in situ*, and the interior part of the tube protruded.

Fig. 110 is the same end greatly enlarged. The fracture presents a triangular face, which has substantially the natural contour, although the tube seems to be fractured longitudinally also. The needle, *nd*, here shows as one edge or angle of the prickle. It is a yellow chitinous piece, itself triangular, of thicker chitine than the tube. Along its middle part is what may be called a bandlet, *bt*, of grayish hue, which may serve to strengthen it. This bandlet presents under a high power a beautiful series of notches or barbs, on each side (Plate XXIII., Fig. 112), which are of equal length. The notches of either side are placed diagonally opposite those of the other. This bandlet proved to be not a flat, but a bent piece, as seen at the section view, Fig. 103, *bt* and *sbt*.

The Needle.

As the needle approaches the point of curvature, Figs. 105, 110, it divides or widens into distinct strips, between which the ear, E, is placed. These strips interblend again beyond (apically) the ear, and the diaphanous part or tube, *tu*, appears to be merged into the needle, and the fibrous interior padding of the same to be eliminated.

A vertical section view of the needle, Fig. 103, will now show it to consist of the edge or angle, *an*, the bandlets, *bt*, and two ribs, *r*, *r*, of a sub-triangular shape and grooved at the base.

The ribs as here shown are the split parts of a single rib, as shown at Fig. 115, *r*. We have thus a hollow sub-triangular piece whose exterior surface is regularly indented. The use of these indentations is seen at Fig. 117, Plate XXIII., which is a fractured section of the sting-case, showing a part of the case entire, a vertical section at *scs*, a longitudinal section, and the two prickles, *pk*, or rather their needles, in position. It will be seen here that the rib, *r*, fits by its grooved base upon a cylindrical process upon one side of the interior wall of the case, and that the angle, bandlet, and ribs are fitted within corresponding groves, *gv*, in the opposite side of the case. There is a concavity, *cn*, in the case between the needles, and corresponding to the space which the tube appears to occupy near the ear, and before it is merged into the needle. Thus is formed a channel along which the contents of the poison sac and accessory gland may flow. Another concavity, *c*, apparently indicates the space between the outer and the inner walls of the case.

Prickles in their case grooves.

On the concave side of each prickle, upon the shaft not far from its curvature into the bow, is placed a fan-shaped chitinous projection or ear, *e*, Fig. 105, so called because I have conceived it to have a function somewhat similar to the ear or lug sometimes placed upon a piston in machinery to check or reverse the motion of the rod. A detailed view of this ear is given at Fig. 104. At the base where it unites with the shaft there is a thickening of the organ, *tk*, probably to strengthen it. It is apparently further strengthened by a curved chitinous brace, *bc*, which is placed on the anterior or bow side alone, and extends from the side of the ear to the shaft. There also appears on the tip of the ear a well-defined margin, *m*, with delicate but strongly-marked parallel lines, which seem to radiate from lobe-like markings, *lm*, on each side. These lines show in a side view of the ear as fine serrations.

The Ear of the prickle.

There is also a transparent membranous process from the shaft, represented at *fe*, which seemed like a thinning down of the prickle to a feather edge. It was of glassy clearness, but the outline showed through the ear.

The feather edge.

This feather edge appeared to merge gradually toward the apex into one of the yellow chitinous edges of the needle.

The ear is shown in site within the case at Plate XXIII., Fig. 111, *e*, where it is thrown well down against the concave surface of the inner wall of the case at the point where it rapidly pushes inwardly, thus contracting the interior of the case and separating the trunk from the blade. This concavity of the inner wall seems, indeed, to correspond with the convexity of the ear, and it would almost appear that the two parts are thus conformed for some purpose. What is that purpose?

Use of the Ear.

If we suppose that the prickle is thrust out and the ear moved downward to the contraction, these results may follow: first, the prickle will thus be checked by the impact of the ear upon the contraction, and the danger of losing it in the wound of the sting (which is always great) somewhat diminished. This certainly is a very important function, which no other organ or part appears wholly to serve, and to which the ear is structurally adapted. Second, the rebound of the two elastic surfaces would aid in withdrawing the barbs from the wound. Third, the increased pressure upon the ear, as its tip moves along the contracting surface, would cause a lateral pressure against the prickle itself, which might be communicated to the constricted termini (*con*, *acc*) of the conduits of the poison sac and accessory lodged within the throat and trunk, and thus in some way regulate the flow of their secretions. This might be done, first, by squeezing out the contents, and then by closing up the canal, *can*, within which the prickle moves. The position of the parts at Fig. 111 illustrates this point particularly: the constricted terminus of the conduit, *con*, of the poison sac has dropped upon the thickened part of the ear (*tk*, Fig. 104), which organ has moved down through the trunk until it rests upon the contraction of the inner wall, thus being directly under the conduit, and serving apparently to close it. This juxtaposition may have been accidental in the mounting, but at least the preparation shows as drawn, and appears to be a natural position. It will be seen that the prickle, *pk*, is thrown up in the normal posi-

tion taken at the downward stroke, which shows the relative position of the ear at the bottom of the throat to be also normal.

Mr. J. D. Hyatt, in a recent admirable paper on the sting of the honey bee,[1] makes the interesting statement that this ear in that insect is composed of two semi-circular pieces, closely apposed at their straight edges, and having an opening between them to the interior cavity of the prickles. The ear acts as a valve, pushes down through the trunk of the case, and closes the channel between the prickles by striking into the contracted part of the trunk. By this sudden closing of the valve an action comparable to a hydraulic ram ensues, and the fluid virus suddenly arrested is by its momentum injected with increased force, passing out of the prickles by minute canals, which Mr. Hyatt declares to exist between the barbs of the bee sting. This view the author supposes that he corroborated by so manipulating a withdrawn sting as to force fluid through the opening in front of the valve and out of the small canals. The sting of the bee is two and a half times the size of that of the agricultural ant, and such manipulation would hardly be possible in the latter. But the close analogy which is here shown to exist between the two, justifies me in citing this as confirmatory of the views above expressed and independently reached.

The Ear an open valve. Hyatt.

What I have called the tube of the prickle has much puzzled me, and I have not been able satisfactorily to interpret either its structure or function. The Figs. 105 and 110 are, however, camera lucida outlines, and well present what I saw. The tube, it will be seen, is larger than the needle, and is cylindrical rather than triangular. It appears slightly corrugated, and is morphologically of the same chitinous structure as the needle but attenuated. It is probable that the outer wall of the tube is transparent, and the corru-

The Tube of the prickle.

[1] First number of the American Quarterly Microscopic Journal, No. I., vol. i., 1878. I regret that this paper reached me too late to be of service in my studies, as the journal has just come to hand. But I am fortunately able to insert this reference before my publishers had passed this point in my manuscript.

gations are due to the interior structure, which is seen to protrude at *pd*. The tube may be traced (Plate XXI., *bo*, *tu*) along the bow to the very termination at the delta, *del*, and preserves throughout its diaphanous character. As the two prickle-bows bend over into the throat of the case they come in contact, and apparently so continue thereafter. It may be that they supply by their peculiar structure soft, elastic, cylindrical cushions, or "buffers," which give firmness to the pose of the prickles, and yet allow free motion. I suggest this function as quite probable. The end which protrudes beyond the fracture (Fig. 105, *pd*), has a fibrous appearance at the ragged extremity, and indeed appears to be a bundle of delicate fibres contained within the transparent outer wall of the tube. Nevertheless, it certainly must be hollow at and posterior to the neighborhood of the ear, for oil-like globules of various sizes, *o*, there appear. They are massed just under the base of the ear, but do not appear in the anterior part.

It is at this point, as already said, that the tube loses its distinctive form and merges into the needle, apparently preserving only the thickened outer filamentous rim, which continues to the very apex as one of the edges of the needle. Within this rim, or perhaps I should now say, within the needle, the oil-like globules extend all along the shaft to the barbed point. A section view of a prickle (Fig. 115, Plate XXIII., *tu*) shows the rim of the tube just referred to, the distinct internal "padding" having disappeared. Beyond the ear the oil-globules appeared to pass to the opposite, or convex side of the prickle, as though the tube had changed sides; thence they were distinctly traced into the point of prickle.

Barbs.

It would appear that neither Kraepelin nor Dewitz was acquainted with any ant having a barbed sting, and the remark of Kraepelin,[1] that the sting of Myrmica is toothless, led me to infer that the sting of Barbatus was

[1] The sting bristles want the barb. (Den stechborsten fehlen die Haken.) Op. cit., p. 303.

also smooth. However, on placing an example under observation, well-defined barbs were seen upon the point. These appeared in all subsequent specimens dissected. The number of barbs is six, but one specimen was dissected, from which Fig. 102 is drawn, having seven distinct barbs. The barbs are pointed anteriorly, and increase in length from the extreme point anteriorly in the ratio (about) of 1 (less), 1, 1½, 2, 3, 4. The entire length of the barbs is $\frac{3}{25}$ of a millimetre, of which the length of the anterior longest barb is nearly one-third part. The entire length of the sting is $1\frac{4}{10}$ millimetres, which includes both bow and shaft.[1] Length of sting and barbs.

Dr. Forel, whose attention was more particularly fixed upon the poison vessels, had not observed the barbs in Barbatus, although acquainted with the fact that such barbs exist in *Paraponera clavata* and *Odontomachus hæmatodes*.[2] As soon, however, as his attention was called to the fact he made an examination, and saw that both *P. barbatus* and *P. crudelis* had barbed stings. The stings of Crudelis are left in the wound at times, just as with the bee. Mrs. Treat showed me a large larva, probably of some beetle, which contained several of such broken stings. The larva had been uncovered from a formicary which Mrs. Treat was excavating, and being, unfortunately, the first living object within notice and reach of the irate insects, was furiously attacked. I did not observe such parting with the sting in the case of Barbatus, but it probably is also common with her.

In Plate XXII. several figures are given showing various views of the barbed point of the sting of Barbatus. These are camera lucida outlines (except Fig. 109), but as they have been drawn to different scales of amplification, and subsequently reduced by photograph; and as the length of the

[1] A millimetre is nearly one-twenty-fifth of an inch. For natural size of the shaft and part of the bow of prickle, the general reader may see Plate XXIV., Fig. 122. Other parts are also there represented in the same way.

[2] See a note in his recent and most valuable paper, "Etudes Myrmecologiques en 1878, avec l'anatomie du gésier des fourmis. Par Dr. Auguste Forel." Bulletin de la Société Vaudoise des Sciences Naturalles, vol. xv., p. 362, note.

barbed point, which is quite uniform, has been given, the degree of magnification need not be stated. Fig. 108 is a view of the barbs from above, given again much enlarged at Fig. 109, which shows the shape, depth, and width of cleft. There will also be seen at the extremity, in this figure, a bifurcation of the apical barb, or a second barb on another edge of the point, which appears to be a characteristic feature. Fig. 107 is a profile view of another sting, less magnified.

Triangular point of the prickle.

Fig. 102 shows the triangular form which the prickle takes toward the point. The edges, 1, 2, 3, are thickened, but the connecting piece is transparent, the whole suggesting the appearance of a hollow glass prism with framed edges. Edge No. 1 is much more thickened than the others, and it accordingly is the barbed edge. The three edges interblend near the second barb (Fig. 106, b^2), and the point thus appears to be solid. It will be observed that the clefts of the barbs slant toward the point, and are slightly curved apically. I could not determine certainly that the cleft penetrated to the interior. One specimen, carefully examined with this in view, showed the second barb, b^2, to be relatively deeper than the others, and to have an enlargement at the inner extremity of the cleft. It appeared to me that this barb, at least, communicated with the hollow, *can*, of the point.

The point hollow.

Certainly, at least, the point is hollow. This not only showed, in all specimens, beyond any doubt, but, moreover, the oil-globules were distinctly traced in the canal, *can*, as far as the third barb (from the apex), where they ceased. It may therefore be strongly inferred that there must be some place of exit for the globules, and the structure of that part of the point shown at Fig. 106, b^2, indicates that barb as the place. In one example I thought that I detected in the cleft of the barblet referred to in Fig. 109 a slight orifice or pore. The examination was made with a modern one-tenth immersion lens (magnifying 500 diameters), and always with the same result. The fact cannot, however, be confidently stated, and must be left for future investigation; but certainly

the structure of the organ, the mechanism of the sting, and the presence of oil-globules within the hollow point extending as far as b^2, seem to warrant the inference that at or near that point an opening from the prickle must be placed.

Entrance of poison into the prickle.

In addition to this, all the barbs seem to be so deeply cleft into the edge of the needle (see Figs. 102, 106) that one may suspect that the hollow interior is actually penetrated. If so, they may be supposed to act as scoops to take up the secretions within the canal (*can*) of the case as they move upward, which, again, they eject as they pierce the wound. The question, of course, arises, Are the oil-like globules referred to really oil from the accessory organ (*acc*), or are they globules of poison from the poison sac, or both? I am not sufficiently familiar with the character and appearance of the latter to express an opinion.

We may now turn to Plate XXI., Fig. 99, which shows the various organs above described in their relationship to one another. The prickles are in their normal position within the case, which is also in repose within the sheath. The sheath is drawn up within the abdomen, and is lodged within the membranous sac, not here represented, but shown at Plate XIX., Fig. 93. The sheath, which is covered with bristles along the entire extent of the bottle-shaped main part, *shb*, *shn*, is naked upon the upper inclined arm. Upon this arm is placed a pulmonary trachea (Plate XX., *tr*), which is constructed after the pattern common to insects, viz., a tubular, compressed coil (spirally convoluted) of fibre enclosed within an external serous and an internal mucous membrane, forming a tube within which the spiracles or breathing-holes open. Good views of these were obtained on broken pieces of the sheath-arm.

Relationship of stinging organs.

This apparatus is partly maintained in position and its motions regulated by two plates, *ob.p*, *qd.p*, which Duthier has named the anal and lateral scales (écaille anale, écaille latérale), but which the German writers call the quadrate and oblong plates, a nomenclature which I

The Plates.

adopt. According to Kraepelin these plates and the delta (Winkle) in the ant genera, Myrmica, Ponera, Polyergus, etc., are similar to those of the Apidæ. Indeed, he asserts that the entire structure of the stinging organs in these genera differs but slightly from Apis, all the parts being present in the same number, and arranged exactly in the same way. As our Barbatus may be classed with the Myrmicidæ, she is included in this comparison. Kraepelin errs, however, in saying that the case is straight, as it is evidently curved (see Figs. 96, 116), or sabre-form, and also errs, as has been seen, in declaring the prickle without barbs, as Barbatus here also resembles the bees and wasps.

Quadrate plate.

The quadrate plate, Fig. 99, *qd.p*, is a chitinous piece, whose shape is somewhat indicated by its title, with a thickened, rounded border, which articulates at its anterior end with the delta, *del*. It has a broad and a narrow fold, the two uniting and angling upon the round border.

The oblong plate, *ob.p*, is an irregularly V-shaped piece, whose opening is toward the case, with which it is closely united. The two lateral parts or bands, *bd*, of the opposite plates seem to touch and roll upon each other in the act of stinging. (See Plate XXIII., Figs. 111, 116.) They articulate with the flaps of the sting-case, *fl*, by a slender rod, *rd* (see also Fig. 111), that is an offshoot from the bands, and they are attached to the trunk of the case by a strong ligature, *l*, Fig. 111. The anterior margin of the oblong plate is cleft laterally, and the strip thus formed serves as a grooved support, *pgv* (and *grv*, Fig. 111), for the bow of the prickle, which seems to be attached to, if not continuous with, the flap, *fl*, of the sting-case. The prickle-groove unites with the plate at *u*, and again separating from it, terminates beyond the delta in a horn, *h*, upon which is attached the retractor muscle. An enlarged view of the prickle-groove, in fractures, is given at Fig. 100, Plate XXII. Upon the apical side of the groove there appear a number of short hairs, *gvh* (*gh*, Fig. 100), in number seventeen, more or less, placed in circular cavities, and in a row. Kraepelin speaks of an analo-

The prickle-groove.

gous armature in similar position upon the sting of the bee, as stiff bristles arising from small pits. There is a third, smaller deltoid plate, *Del*, which is attached at its anterior end to the bow of the prickle. The two angular processes at the base articulate within corresponding concavities in the thickened borders of the oblong and quadrate plates. As the sting is protruded and retracted this delta rolls back and forth within these cavities. The Delta.

The system of muscles was not traced completely, but the principal muscles for the operation of the sting are indicated in Plate XXI. as follows: No. 1, *mrt*, is attached at one end to the horn, *h*, of the lateral band, *bd*, of the oblong plate, and at the other to the outer border of the quadrate plate, *qdp*. No. 2 is attached to the base or apical part of the delta, and to the inner surface of the border of the quadrate plate. No. 3, *m.pro*, is attached to the oblong plate at the border, near the articulation with the delta, and to the surface of the quadrate plate, extending downward toward the posterior part of the border. No. 4 is attached to the border of the oblong plate near its articulation with the sheath, *shb*, and at the other extremity with the surface of the quadrate plate. This muscle (or another one attached at the same point of the oblong plate) appears to send out its fasciculi also toward the apical edge of the quadrate. No. 5 is the strong muscle attached to the projecting wall, *h*, of the throat of the case, and which grasps with its opposite extremity the oblong plate. Muscles.

The action of these muscles in the operation of the stinging apparatus is doubtless similar to that of the analogous muscles in the bee, as described by Kraepelin, and in a less degree to those which operate the poison apparatus of *Formica rufa* as described by Dewitz.[1] Kraepelin's explanation of the mechanism of the bee sting,[2] if I may judge from the location and relative positions of the muscles of Barbatus, might be

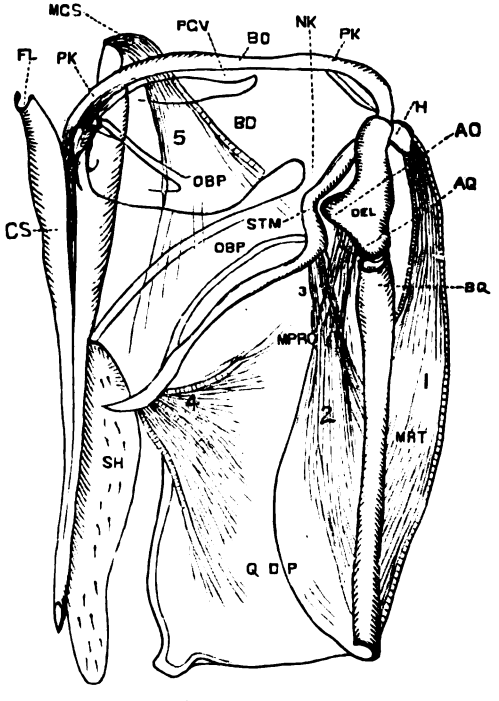
[1] Ueber Bau und Entwickelung des Stachels der Ameisen. Von Dr. H. Dewitz. Zeit. f. Wiss. Zool., Bd. xxviii., 1877, p. 537, seq. Libr. Acad. Nat. Sci. Phila.

[2] Op. cit., page 311.

quite closely accommodated to the interpretation of the same as shown in Fig. 99. Guided by this and by the probabilities of the structure as they have appeared to me from the study of many examples, I present the following hypothetical explanation of the mechanism of the sting of Barbatus. For the convenience of students I have inserted into the text a wood-cut with additional refer-

Probable mechanism of the sting.

FIG. 128.



Mechanism of the sting of *P. barbatus*.

ences. But consult also the plate. Let us suppose that muscle No. 3, *m.pro* (see the right side of the Plate), which is inserted at the stem, *stm*, of the oblong plate, *obp*, to contract its fibres. The contraction will cause pressure upon the quadrate plate,

qdp, to which it is attached at the other end. This pressure will bear upward (anteriorly) upon the delta, *del.* But the basal process, *aq*, of the delta is so articulated with the upper (anterior) end of the thickened border, *bd*, of the quadrate plate, that it is tilted up with a rocking movement.

By this movement the bow, *bo*, of the prickle is thrown upward, as well as the lateral band of the oblong plate, as imperfectly shown at Plate XXIII., Fig. 116, *bo*, *bd*, and at Fig. 111, *pk*. At the same time the other basal process of the delta, *ao*, pushes downward (posteriorly) and laterally upon the stem, *stm*, of the oblong plate, which, being elastic, does not lift up with the band, *bd*, but lengthens at the narrow neck, *nk*, and so causes pressure downward (posteriorly) upon the sheath, *sh*. At the same time we may suppose that the strong case-muscle, *m.cs*, No. 5, by its contraction may force the case downward against the point of attack. Thus there is a general movement downward and out of the cloaca of the sheath and case. The prickle being confined within its groove, *pgv*, at the bow, *bo*, is not only tilted up, but is compelled to move along and within the groove, thus forcing the shaft downward through and within the case until the barbed point projects, as shown at Plate XXIII., Fig. 114.

Protrusion of the sting.

In the withdrawal of the sting, the muscle, No. 4, attached to the posterior part of the stem of the oblong plate, and at the other end to the quadrate plate, contracts, and thus tends not only to pull back the quadrate plate to its former position, but also (probably) to elevate the sheath. At the same time muscle No. 1 contracts, and by pressure upon the projecting horn, *h*, of the band, *bd*, recalls the oblong plate, and with it the prickle, to their former site. In this backward movement the muscle, No. 2, which is attached to the base of the delta and the border of the quadrate plate may assist, its contraction pulling the delta and the attached prickle downward and into normal pose. The muscle, No. 3, *m.pro*, may properly be called the Protrusor of the sting, and No. 1, *m.rt*, the Retractor. The whole movements above

Retraction of the sting.

described are very rapid, and the back and forth play of the prickles is in alternate strokes.

Size of stinging organs.

The measurements of the principal stinging organs and parts are as follows: The sting-case, 1 to $\frac{9}{10}$ millimetre long; the delta, $\frac{2}{10}$ mm. long; the quadrate plate, $\frac{6}{10}$ mm. long, $\frac{3}{10}$ mm. wide; sting-prickle, total length of bow and shaft, $1\frac{4}{10}$ mm., of which the shaft is about $\frac{9}{10}$ mm.; accessory gland of female, $1\frac{3}{10}$ mm. long, about $\frac{7}{10}$ mm. wide; poison sac, $\frac{7}{10}$ mm. long; conduit of the sac, $\frac{9}{10}$ mm. long. The whole width of the stinging apparatus of the worker is about 1 mm., and the length from the point of the sting-case to the end of the poison sac is a little more than $2\frac{1}{2}$ millimetres. The stinging apparatus of the female is about $\frac{4}{10}$ mm. wider, and nearly the same length. The barbed point of the prickle-needle is $\frac{3}{25}$ of a millimetre (about), and the distance from the ear to the extremity of the point is $\frac{7}{10}$ millimetre. On Plate XXIV. several objects are represented in natural size, which will give to readers unfamiliar with the millimetre a good idea of the natural size of the various parts above described. Fig. 121, No. 1, represents the sting-case; No. 2, the whole apparatus figured on Plate XXI.; Fig. 122 shows the natural size of that portion of the prickle figured at Fig. 105; and Fig. 123 represents Fig. 116, showing the size of the accessory gland in the female.

Accessory gland.

The Accessory gland of Barbatus is a pear-shaped (pyriform) organ, situated immediately above the sting-case, into which it discharges by a short duct, or rather by a gradual narrowing of the gland into a neck. This neck enters the throat of the case alongside of the conduit of the poison sac. It is covered with a hard, thick coating, which resists pressure, being thus quite in contrast with the poison sac, which is thin and readily yields. This thickness is given apparently by short muscular fibres or dense epithelial covering, which when scraped off leaves a membranous covering underneath. This epithelial fibre (if it be such) evidently strengthens the walls of the Accessory, and perhaps by its contraction, operates upon the contents as

pressure of the hand does upon the elastic bulb of a syringe, to force them out, and into the case. The contents were not examined, but they are without color.

The Accessory glands are present in all female and worker ants, and correspond with the so-called oil or smear glands of bees and other Hymenoptera.[1] They secrete an oily liquid whose purpose, it is supposed, is to smear the sting, thus enabling it to play more easily. This secretion, according to Meinert, does not dissolve in water, but remains secreted as oily drops. In *Lasius niger* and *Formica rufibarbis*, Forel always found the Accessory well filled, and the contents, as well as the color of the whole gland, clear. So also he found it in *Myrmica lævinodis*, which is classed with the same sub-family, MYRMICIDÆ, as our Agricultural Ant. In the clear contents of the glandular sac of that insect he saw suspended a quantity of strongly refracting drops of all sizes.

The contents. Forel.

In determining the function of the Accessory, these two facts must also be considered: *first*, the gland is often best developed in ants with rudimentary stings, as Camponotus, Formica, etc., while in ants with a strongly-developed sting it is often quite small. In connection with this must be taken the fact that these ants are in the habit of ejecting instead of injecting their poison. For example, I have seen *Camponotus pennsylvanicus* throw a stream of poison from her stinging organs so large as to be easily visible by the naked eye. Lubbock[2] found, after disturbing the nest of some species of Formica in Switzerland, that a hand held as much as ten inches above the ants was covered with acid. Indeed, our American Formicidæ, as I have heretofore shown,[3] do not use a sting, but, having abraded the skin with the mandibles, throw the poison upon the wound. We may infer that the increased

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[1] Forel, "Der Giftapparat und die Analdrüsen der Ameisen," p. 50, seq.

[2] "On Some Points in the Anatomy of the Ant," The Monthly Microscopical Journal, p. 130.

[3] Mound-Making Ants, p. 293.

size of the Accessory in these ants, and the consequent increase of secretion, is to give greater volume and perhaps also force to the secretion of the poison sac, which, being mixed with the oil of the Accessory gland, is thus distributed over a larger surface with corresponding power to injure, and is, moreover, perhaps more likely thereby to adhere to and penetrate within the attacked surface.

Second, the fact must be considered, as already stated, and shown by a comparison of Forel's drawing of the Accessory of the worker of Barbatus (Fig. 98) with my own drawing of the female (Figs. 99 and 113), that there is a marked difference in size, the latter being much the larger. Forel says that in the female of Formica and Myrmica, which alone he has investigated upon this point, the Accessory gland is very perceptibly more developed than in the worker of the same species, although the latter has relatively a much stronger sting as compared with the poison gland. The stinging power of the worker of Barbatus, as I have shown, is in no wise abridged,—at least, it is sufficiently formidable to procure for her species the terrible name of "the Stinging Ant." Meinert observed the same difference in the female and worker of Formica, but, on the other hand, says that the females of *Lasius flavus* possess a *small* Accessory gland. The above facts would indicate that the Accessory gland stands in some relation to the sexual organs, but what that relation may be is as yet undetermined.

Accessory gland in females.

This gland has been found in all ants thus far examined, and has in all the same structure. It differs, however, in size and external form. Often it is tubular; again more spherical or pyriform; then bifid, as in certain genera of the Camponotidæ. It opens into the throat of the sting-case ventral (according to Forel) to the opening of the conduit of the poison sac, and close beside it. Both the ducts pass for some distance into the case, lying close to each other, finally to terminate together. There is a delicate chitinous fold between the two.

CHAPTER XII.

WAR—ENEMIES AND ALLIES.

A YOUNG community has sometimes to struggle into permanent prosperity through many perils. The following example is found in the unpublished Lincecum manuscripts. One day a new ant-city was observed to be located within ten or twelve yards of a long-established nest, a distance that the doctor thought would prove too near for peaceable possession,—for the agriculturals seem to pre-empt a certain range of territory around their formicary as their own, within which no intrusion is allowed. He therefore concluded to keep these nests under close observation, and visited them frequently. Only a day or two had elapsed before he found that the inhabitants of the old city had made war upon the new. They had surrounded it in great numbers, and were entering, dragging out and killing the citizens. The young colonists, who seemed to be of less size than their adversaries, fought bravely, and, notwithstanding they were overwhelmed by superior numbers, killed and maimed many of their assailants. The parties were scattered in struggling pairs over a space ten or fifteen feet around the city gate, and the ground was strewed with many dead bodies. The new colonists aimed altogether at cutting off the legs of their larger foes, which they accomplished with much success. The old-city warriors, on the contrary, gnawed and clipped off the heads and abdomens of their enemies. Two days afterward the battle-field was revisited, and many ants were found lying dead tightly locked together by legs and mandibles, while hundreds of decapitated bodies and severed heads were strewed over the ground.

Territorial jealousy.

Another example, which is given in the published paper, is

quite similar and had like result. In forty-eight hours the old settlers had exterminated the new. The distance between the nests was about twenty feet. While the young colonists remained in concealment they were not disturbed, but as soon as they began to clear away their open disk war was declared.

Young colonies exterminated.

These ants are not always so jealous of territorial encroachments, or at least must have different standards of rights. At Camp Kneass many of the nests were located much nearer than in either of the above instances. Some of those immediately around my tent were within ten, fifteen, and twenty feet of one another. Yet I did not see a single breach of the peace during my entire stay. The members of the different nests must have been continually intermingling upon the harvest-fields, for they wandered off to great distances and took a wide circuit in their foraging. Nevertheless, they kept industriously and peacefully each to her own work. Moreover, I made some experiments as to the fraternity existing between neighboring hills, of the same nature as those made with the Allegheny Mountain mound-makers. By these it was established that the inhabitants of a series of formicaries of *Formica exsectoïdes*, numbering at least sixteen hundred, and distributed over an area of nearly fifty acres, were in entire amity and apparent confederation.[1] The experiments made with the agriculturals were not very extended, as my time was required for more important studies, and the terrible punishment which the stings of these creatures give meddlers with their persons made such investigations difficult. But several trials were made by depositing from broken nests shovelfuls of earth, covered with ants, upon the disks of adjoining formicaries. No quarrels ensued, no opposition was offered to the incomers, who apparently interblended peacefully with the masses of excited insects called out by the violence offered to the disk.

Exceptions. Near neighbors at peace.

Fraternity among adjoining formicaries.

[1] Mound-Making Ants, p. 281, seq.

Again, a number of ants were collected in a basin of water, —a precaution required by the formidable sting,—and poured out in mass upon the nearest disk. No general hostility ensued, although the kidnapped ants showed no little confusion and irritation. One of them was attacked by a member of the invaded nest; two were seized by the petiole from above and so carried off the disk. One of these I followed for fifteen feet, when I unfortunately lost sight of it. It offered no resistance, was not more fatally assaulted, but was simply borne along, being whirled rapidly over, under, or around impeding blades of grass and other obstacles. There seemed to be neither mortal intent nor anger on the part of the carriers. That a wider range of experiment would have uncovered a hostile spirit and acts between some of the nests is quite probable. That neighboring ants, like neighboring nations of civilized men, will fall out and wage war Lincecum's examples show. Perhaps we should be quite as unsuccessful in case of these ants as of our human congeners, should we seek a sufficient reason for these wars, or satisfactory cause for these differences in dealing with neighbors which appear from the comparison of Lincecum's observations with mine.

Majors and minors.

The difference in size between the warriors of the new colony and those of the old, referred to in the first example given above, is a noticeable fact. Lincecum could hardly have been mistaken. He frequently refers in his manuscripts to the same peculiarity; indeed, for three years, chiefly because of this difference, he supposed that there were two species of agricultural ants. The different modes of attack described are further evidence that the doctor did not err in his observation, and increase the difficulty. I can only offer the conjecture that in the new colony the number of minor-workers was very greatly in excess of the majors, and that the warriors of the old settlers were composed for the most part of majors. The worker-majors are somewhat larger in body, and have larger heads than the minors. They appear to take the chief service of patrol and guard, and probably furnish the first contributors in order of time, and

the largest in point of numbers, to the defence of the nest. Like the large-headed forms of the Cutting Ant (*Atta fervens*), though not to the same degree, they are peculiarly the soldier caste of the community. I do not speak confidently upon this point, for my observations, although careful and repeated, were not conclusive in my own mind. However, I believe that the conjecture may not prove to be far removed from the truth. If so, it would be natural that the warriors of a large and long-established formicary should be made up almost exclusively of the majors. As the new colony was compelled to muster all its forces, their minors were also engaged largely in battle, and thus the contrast appeared. It may even be that by some natural variation in habit the queen of the new colony had deposited but few eggs of the major forms. Or, finally, it may prove to be the case that in the early stages of formicary growth the worker-minors are more necessary to the communal welfare than the majors, and are habitually produced in great excess.

Is there a soldier caste?

Another question which future observers may determine is this: do the minors attack their enemies in battle differently from the majors? In Lincecum's account the minors attacked the legs, the majors sought to decapitate. While making up my artificial nests I requested that the ants might all be sent from one formicary, in order to avoid any falling out by the way and consequent loss of life. But in one invoice eight ants from a different nest happened to be placed among those in the box. Mr. Riggs notified me of the fact by letter, and inferred, from the hostile reception given the eight aliens, that there would probably be some injured insects in the box. The prediction was certainly verified. The severed heads of the luckless eight lay in the bottom of the can, among decapitated trunks and mangled limbs. Their own dead comrades (in the artificial nests) are uniformly decapitated. This mode of attack is quite common among ants. I have observed it particularly in Camponotidæ, especially our familiar large black Carpenter Ant, *Camponotus pennsylvanicus*. I am inclined to

Modes of assault.

Decapitation.

think that it is the habitual mode with the agriculturals, both majors and minors, and that the exception noted was rather the result of lack of opportunity, through the superior strength and agility of their foes, than of any difference in habit. However, the subject is one which invites examination.

It would appear that the particular mode of assault is modified by circumstances and numbers. For example, in the battle described by Lincecum, when two or more combatants of one nest were engaged with but one of the other, the single warrior was soon decapitated. On the contrary, the duels between two individuals rarely so resulted. The combatants mutually seized each other by some part of the under side of the head, by the mandibles, or by "the throat," and held on until the death of both ended the struggle without relaxing the fatal grip. Numbers of these duellists were found dead upon the field with mandibles and limbs firmly interlocked. In these cases the intention was very evident on the part of each ant to prevent her adversary seizing the back of the neck, and to present a less vital part of the head. When a third ant joined the conflict, such defence was impossible, and the emmetonion guillotine quickly did its work.

The conflicts of the agricultural with other species of ants are also noticed by Lincecum. One of the manuscripts has a description of a battle between two species of Camponotidæ, our common American Carpenter Ant (*C. pennsylvanicus*) and a species closely allied to, probably a variety of, *C. mellcus*, Say, which Buckley has described as *Formica discolor*, and which Lincecum refers to under the familiar and quite apt name of "red-heads." At the close of the battle numbers of both species were left upon the field dead, dying, and sorely maimed, upon which the little black "erratic ants," a species of *Dorymyrmex* (*Formica insana*, Buckley), and the agriculturals immediately began to prey. The former bore away the mutilated bodies and dissevered heads of the red-heads, the latter seized upon the larger Pennsylvanici. The black warriors, however, were sometimes in condition, maimed as they were, to resist the copper-colored plunderers. What

Plundering a battle-field.

seemed a motionless and mangled corpse would occasionally suddenly revive as it was being borne away, and, swinging around its head, would close the formidable mandibles upon the plunderer. The agricultural is not indisposed to fight when necessary, and the struggle which ensued was severe and often fatal to both parties.

This battle of the Camponotidæ continued during three days, and the great number of slain and disabled strewn upon the ground attracted such hosts of the agricultural and erratic ants, that the contention which arose among them for the spoils finally became a greater and more fiercely-fought battle than the original one. Agriculturals from different formicaries in the vicinity met and fought above the ghastly spoils, until they in turn lay slain in great numbers upon the battle-field. Countless thousands of the little erratic ants, also, were scattered over the ground, gnawing at every carcass, clinging thereto with such tenacity that often they were borne away with the dead body in the jaws of the agriculturals. Multitudes of them were slain in this eager struggle for food, but other myriads recruited the ranks, and the spoiling of the dead did not cease. These incidents seemed to the observer well to illustrate the couplet,

Fighting for the spoils.

> "From hunger's arm the shafts of death are hurled,
> And one great slaughter-house the warring world."

Specimens of the mutilated warriors of the four species who were engaged on that field of strife and carnage were preserved. All the results of relentless war were fully represented in these. Amputated limbs and disfigured forms in all stages and shapes of mutilation showed the action of the malignant passions,—hate, anger, cruelty, destructiveness. Many had the severed heads of conquered foes clinging by the jaws to the legs, most commonly stumps of legs; some were thus burdened with two heads; others lay, themselves headless trunks, with the trunkless heads of enemies attached to some mangled limb.

The agricultural ants had final possession of this fatal battle-ground, which proved to them literally a harvest-field of the

dead. They never ceased to garner the carcasses of the slain until all signs had disappeared of that terrible slaughter which had so recently raged over the field.

These events in the life of Barbatus not only show the perils which daily surround her, and her courage in conflict, but also her strong appetite for insect food, and the part which she plays in the economy of nature, as a general scavenger. The increase of the ant family, which otherwise would prove a formidable annoyance to man, is held in check by these conflicting interests and combative instincts. At the same time, and through the same necessity for food, it is provided that the atmosphere should be preserved from the taint of decaying animal tissues. Man can bury or burn the dead of his own race. To bury the dead of the animal kingdom is beyond his power. Nature has therefore kindly given them a sepulchre in the bodies of the living.

Ants as scavengers.

Nature's living sepulchres.

The above mention of the erratic ant recalls another example of the conflicts in which our agricultural becomes involved. In her foraging excursions she often takes a wide range, and may be found pushing her eager search for supplies at great distances from the home nest. It is frequently her hap to cross the crowded thoroughfares of the erratic ants, whose numerous formicaries and innumerable workers throng the vicinity of the agricultural-ant colonies near Long Point. For the most part these sagacious little braves suffer their gigantic neighbor to pass unmolested, and she, in turn, strides on through their ranks and over their nests with indifference. Sometimes, however, the agricultural trenches upon erratic rights, or the erratics are in a less amiable mood, and the advent of one of the foraging harvesters is the signal for combat. Platoons and companies of the erratics assault the intruder, who at first seems to regard it as a trifling affair, and strikes out carelessly among her diminutive assailants. Some of the most venturesome are crushed in the ponderous jaws and thrown aside, but there seems to be no serious anxiety.

Relations with erratic ants.

Giants may not despise even dwarfs. The erratics have infinite pluck, unlimited numbers, and utter recklessness of life in the service and defence of their community. The news of war and danger flies from sand-hill to sand-hill along the line of confederated nests peculiar to the economy of this species. The rapidity with which such tidings permeates a vast colony of ants is one of the most striking facts which observers of their habits have noted. Accordingly, from every point of the compass, out of many open gates, and from the avenues of ordinary passage, hosts of irate insects converge upon the scene of hostilities. The space around the agricultural blackens with the gathering masses of the invaded nation, and the red monster stands amidst her dwarfish foes like the Man-Mountain of Gulliver among the Liliputians. Now the giant puts forth her strength in earnest. All who come within reach of her mandibles are crushed or slain. Sometimes, by reason of her superior strength, she succeeds in extricating herself from her perilous adventure, although commonly with the loss of one or two feet.

Battle between a giant and dwarfs.

More frequently the daring little blacks bring such multitudes and valor to the strife, that, in spite of immense losses, they prevail. They seize upon every part of legs and antennæ, and finally, literally covered and weighed down by numbers, their bulky adversary is overturned and held at their will. They cut off her feet, they gnaw at her throat, they saw at thorax and petiole, and after a half-day's war and work, succeed in rendering their captive harmless. Now, with an apparent grand parade of numbers and display of triumph they drag the helpless creature about, and end the affair by a banquet upon the carcass. The vital fluids are sucked from the body by the victors, and the dry skeleton is left upon the plain. It is, however, a costly victory, for many of the little warriors perish in the fray.

The liliputian victory and triumph.

A curious fact is given by Mr. Lincecum in his published paper,[1] in the relations between these two emmets, which is in

[1] Op. cit., p. 329.

pleasant contrast with the above scene of war and suffering. It is a phase of insect strife which borders closely on the humorous, and raises the thought that our Barbatus may not be without something like a homologue of that faculty as it exists in man. The erratic ants do not appear to be held as common enemies by the agriculturals, and they are even permitted to establish their formicaries within the limits of the open disk. Sometimes, however, the diminutive hillocks which mark the entrance to an erratic ant-nest multiply beyond the limit of the agriculturals' forbearance. But they do not declare war nor resort to any personal violence. Nevertheless, they get rid of them, oddly enough, by a regular system of vexatious obstructions. They suddenly conclude that there is urgent demand for improving their public domain. Forthwith they sally forth in large numbers, fall eagerly to work gathering the little black balls which are thrown up by the earth-worms in great quantities everywhere in the prairie soil, which they bring and heap upon the paved disk until all the erratic ant-nests are covered! The entire pavement is thus raised an inch or so, and pains is taken to deposit more balls upon and around the domiciles of their tiny neighbors than elsewhere. The erratics struggle vigorously against this Pompeiian treatment; they bore through the avalanche of balls, only to find barriers laid in their way. The obstructions at length become so serious that it is impossible to keep the galleries open. The dwarfs cease to contend against destiny, and, gathering together their household stores, quietly evacuate the premises of the inhospitable giants. It is the triumph of the policy of obstruction, a bloodless but effectual opposition. If there were anything like cachinnation in the possibilities of emmet muscles, we might imagine the Barbatus workers laughing silently within themselves, as they piled pellet after pellet upon the gates of the tiny trespassers, and finally chuckling audibly as they gave up the conflict and marched away to find peaceful quarters beyond the reach of mud-ball avalanches.

The dwarfs at home in the disks.

An amusing mode of warfare.

Triumph of the obstruction policy.

Among the few forms of animal life that have attached themselves to the premises of the agricultural ant, is a minute ant of a reddish color, which, according to Dr. Forel, may prove to be a new species of Mayr's genus Iridomyrmex, near to *I. humilis* and *pilifer*.[1] Numbers of these ants were frequently seen travelling in long lines across or near to the nest of Barbatus (Plate XXIV., Fig. 118). Usually their route was established upon blades of grass growing on those nests which were covered with the Aristida, or along the low tufts of grass on the margin of the disk. They seemed to prefer this elevated transit to moving directly upon the surface, which they touched only when a break in the herbage compelled them to descend. They travelled in single or "Indian" file, one behind another. Fig. 118 represents these little fellows in line of march. The specimens which I preserved were taken from a small colony found within the bounds of a large Barbatus formicary which was being excavated. The agriculturals took no notice of their tiny neighbors, at least never interfered with them, and the two species seemed to be upon the most friendly terms with each other.

Friendly little neighbors.

Mr. Affleck observed in close proximity to, and within, the belt of every flat disk a colony of small brown ants. They appear to be as industrious as their agricultural neighbors, but have no connection with their movements. They never deviate from their course, but go and come along a fixed road about half an inch wide, and their numbers make a continuous line. They appear to annoy the agriculturals, who will retreat, or seem to place themselves in a posture of defence when passing through one of these lines. The entrance into the ground of these small ants is generally through a crevice, but their habitation is within the limits of the open disk of Barbatus. The specimens of these insects which Mr. Affleck sent me were unfortunately lost

[1] Dr. Forel has done me the honor of attaching my name to this species, viz., *Iridomyrmex Macooki*.

during transit, but the description given by him corresponds closely with that of *I. Macooki.* The above habits, however, partially agree with Lincecum's account of the black erratic ant.

The only other natural enemies of Barbatus, so far as observation has yet determined, are the spiders. There is a large Theridioid who is especially destructive of these ants.[1] I found her nest established upon the grass-grown disks in the following manner: several stalks of the Aristida were bent over near the top, or midway of the spire, and firmly bound together by silken cords, as shown in Fig. 127, Plate XXIV. Within this tent, and just below the apex, the strong snare of right lines (retitelarian) was fixed, in the midst of which the spider hung in the usual inverted position. The ants are constantly climbing the grass-stalks for purposes which I could not divine, it may be to gather the seeds in their milk state, or to find insect prey, or simply for amusement, or in the ordinary policing of the disk which belongs to the sentinels. They thus become entangled in the snare and fall victims to the watchful aranean. It is not impossible that the spider, whose snare sometimes hung quite near the ground, swings down and seizes the ants as they pass through the tent. Their dry shells might be seen clinging to the threads, or the yet warm bodies trussed up and swathed for food. Under one of these tents I picked up a small ball of six or eight ant skeletons rolled up and tied together just as they had been cast out of the snare.

Destruction by spiders.

I also frequently found the thick tubular nest of various Saltigrade spiders woven upon the Aristida, and among the surrounding grasses, but I had no further evidence that they preyed upon the ants. It is, however, probable that all the large species of spiders, more particularly the numerous Citi-

[1] Hentz, Spiders of the United States, has described this species as *Theridion lineatum*, p. 154, and Pl. XVII., Fig. 3. As that name had already been used for a spider of the same genus (see Blackwall's British Spiders, p. 176), Hentz's name cannot be retained, and I venture to propose (as retaining Hentz's name as near as may be) the name *Th. lineamentum.*

grages, who pursue their prey on the ground, feed upon them. The beetles, also, must devour large numbers. The foraging habit of this ant, which leads her singly to traverse a wide surface in search of food, particularly exposes her to loss from these and other creatures of prey. Lincecum says that he has observed no animal that preys to any considerable extent upon this species. Chickens and mocking-birds will sometimes pick up a few of them, but not often. If anything else in Texas eats them, he had not noticed it; neither had he observed their nests dug up or bored into as though they had been invaded in order to feed upon the inhabitants. It therefore becomes a question of no little interest what are the most effective agents or means by which the inordinate increase of these insects is held in check.

Rare exemption from natural enemies.

In the neighborhood of towns and in the more thickly settled farming communities Barbatus often finds an active enemy in man. Many persons, indeed, perhaps the great majority of Texans, are quite indifferent to their presence, except when they chance to intrude upon a garden, yard, or lawn. But others are not so tolerant, and wage a vigorous warfare, which is apparently animated as much by the fear of her terrible sting as by serious losses occasioned to crops. The latter item, however, is not so insignificant as represented by Lincecum, who says that the ants are of little disadvantage to the farmer, however numerous. Mr. Affleck writes me that, although they are not numerous in his neighborhood, they are very destructive to the crops. For example, in his own farm, in which are three hundred acres of cultivated land, there is an area of more than one acre in extent composed of open disks, from ten to twelve feet in diameter, dispersed in the midst of cultivated crops. This is certainly an important item of loss, which of course will vary according to the nature of the crop. In the county of Washington, where he resides, he estimates that the number of acres of various crops destroyed by these ants exceeds one hundred. He says that

Destruction by man.

Example of injury to crops.

the damage thus wrought increases every year, and that the ants have become a veritable pest.

In answer to questions as to the effect of ploughing in destroying the ants, and their behavior under the plough, Mr. Affleck reports that as soon as the plough passes through the nest, the ants swarm out in full force, and when the surface is entirely turned up, they seem bewildered for probably half an hour. They then commence work, and the surface is soon honey-combed. They pierce a number of entrances to the underground galleries, but only allow the normal number of gates, one or two, to remain open, these being sufficient, when the galleries are fairly opened, to give them access to the interior. When the permanent gates are established they begin to repair the damage below the surface. The disk, whose circular outline formerly marked the location of the formicary, is not again perceptible until the growing crop has somewhat advanced. Then the spot is revealed by the contrast between the surrounding vegetation and the old circular boundaries of the nest, which soon reappear.

Behavior under the plough.

Much of the planting sowed upon the circle is destroyed by the ants soon after it makes its appearance above-ground. Plants are not permitted to reach more than two or three inches in height. Mr. Affleck has also gathered blighted plants upon the disks, which led him to conjecture that the ants were not directly instrumental in their destruction, but had caused their death in some indirect way, perhaps by the extrusion of formic acid, which may be poisonous to the plants. It would seem more probable that these blighted plants resulted from the cutting away of roots in excavating and enlarging granaries and galleries. Grain, cotton, and garden vegetables all are cut away from the proscribed territory. The devastation, however, is strictly confined to the disk boundaries, no damage whatever being wrought upon the surrounding crop. Indeed, the plants bordering upon the circumference of the disk have the rankest growth of all the crop, a fact probably owing to the wider space and better

exposure to light and rain. Evidently the only purpose of the ants is to maintain their open circle. Any number of ploughings fails to drive them away. They repeat the same labor after each overthrow by the ploughshare, although the position of the gate is sometimes changed. A study of the interior architecture gives the reason for this, as it shows that the plough does not disturb the great mass of store-rooms, nurseries, and galleries, and makes no appreciable destruction of the ants themselves.

Ploughing fails to destroy.

Something more effective is required to exterminate the insects. Carbolic acid, cyanide of potassium, and coal-tar have been used with success. The first two I heard spoken of by persons in Austin as particularly effective. The solution is simply poured into the main gate, and the application continued until the formicary is destroyed. I would suggest mid-day as the best time to use these agents, for, as related in a foregoing chapter, the ants were all found to be habitually within-doors from 12 M. until 1 P.M., and for some time, more or less, thereafter. Poisons applied at that hour would therefore reach the whole population.

Destructive chemical agents.

Best time to apply them.

It is easy to catch an entire colony in three days with a trap made of tin, constructed as in the diagram (Plate XXIV., Fig. 125). A section view of the same is shown at Fig. 126. The ants going out of the nest, pass up through the hole E, in the centre of the circle, which is placed over the entrance to the nest. They enter upon the inclined surface A, A, which is well sanded over tar, in order to allow the insects to move over it readily. This surface has an inclination of 45°. When the ants arrive at B, B, they attempt to crawl down the inclination, which is the prolongation of A, A, and at right angles with it. The surface of this prolongation is left smooth, so that the ants drop into the receptacle C, C, from which there is no escape. The members of the formicary who are out foraging, on their return home, in like manner ascend the outer surface A^2 A^2, which is sanded as is A, A, and on reaching B^2 B^2, drop down its smooth incline

A good trap described.

into the receptacle C, C. The ants in the trap should be destroyed every evening. "In three days," says Mr. Affleck, "the original colony will be destroyed. The young colony is not so numerous, and is caught in a shorter time. The third successors are still less in numbers, and when destroyed the whole colony is exterminated." The reference to a "young colony" and "third successors" Mr. Affleck does not explain. But he is probably true to nature in the note, whatever may be his meaning. The first work of the ordinary callow ant after maturity, is to assist in the care of the larvæ. These antlings may readily be noted by their fresh yellowish color, which is in marked contrast with the normal dark brown. Moreover, the failure of the entrapped workers to return to the granaries and nurseries would soon require those left within to go forth for supplies. Thus, the order of destruction which Mr. Affleck has indicated is that which would naturally be expected to follow,—the young and younger individuals within the nest would push out until the number of those able for duty would be exhausted. Whether this will succeed in exterminating the colony in one season may be doubted. The larvæ would of course perish without the care of their nurses, but unless the fertile queen (or queens) be taken, the foundation of a new community remains. But a vigorous use of this ingenious trap would certainly prove effective in the course of a few years. The instrument is constructed from a thorough knowledge of some of the peculiarities of Barbatus. I could at any time in the course of a few moments obtain a three-ounce vial full of these ants, by sinking it, with mouth open, within the disk. The insects were drawn toward the opening by a strange attraction, peeped over the fatal brim, driven by an irresistible curiosity, and fell in. The smooth surface of the glass, over which they cannot readily walk, prevented their escape.

Emmet curiosity and its penalty.

DESCRIPTION.

The following description of the Agricultural or Stinging Ant is appended:

Family, FORMICARIÆ; Sub-Family, MYRMICIDÆ.

POGONOMYRMEX, MAYR.—Deriv., *πωγων*, the beard, *μυρμηξ*, an ant.

1858. Myrmica barbata[1], SMITH. Catalogue of Brit. Hymenoptera, Part vi., Formicidæ, p. 130.

1866. Myrmica molifaciens, BUCKLEY. Proceed. Amer. Entom. Soc. Phila., vol. vi., 1866–67, p. 348.

1878. Pogonomyrmex barbatus [SMITH].

WORKER-MAJOR, ☿ +.—Length, 8½ to 9 mm. (⅜ inch, nearly). Color, a uniform dark claret-brown. Head.—The mandibles are large, strong, armed with seven strong black teeth, which are found in various stages of abrasion on various examples; they are longitudinally striated, and clothed sparingly with bristle-like hairs. The head itself is quadrate, about 2 mm. long and wide; is concave behind; clothed sparingly with short, stout bristles; is longitudinally striated; without ocelli. The clypeus is nearly flat, deeply notched at the middle of the anterior margin, and from the semi-circular notch a row of bristles project over the closed mandibles. Otherwise the anterior margin of the face is straight but thickened. The frontal area is triangular, smooth, prominent; the antennal fosse prominent; antennæ, 12-jointed, 11 of which are on the flagellum, which is club-shaped, and covered densely with the golden pubescence which clothes the legs. The head underneath is covered somewhat freely with a beard of strong, long hairs, inclined forward, a peculiarity which has given the specific name to this ant, and the present generic name as well. The maxillary palpi are 4-jointed, the labial palpi 3-jointed.

The prothorax is rounded, and is about half the width of the head. The rest of the thorax is narrower, straight, a little compressed in the middle, and, like the prothorax, is laterally striated. On each side of the metathorax is a strong, smooth spine, about ½ millimetre long. The nodes of the petiole are two: the first is sub-triangular, with a well-marked process beneath; the second is cylindrical, is constricted near its juncture with the abdomen, and has a less strongly marked prominence beneath. The abdomen has five joints, is glossy, but covered with hairs. The legs are of a somewhat lighter brown, and are very thickly clothed, like the thorax, with strong hairs of a golden-yellow color.

WORKER-MINOR, ☿ —.—Length, from 7 to 8 mm., otherwise as the ☿ +, except that the head is proportionately smaller.

FEMALE, ♀.—Color, a shade lighter than the workers. Length, 15 millimetres (⅝ inch), as follows: head 3 mm., thorax 4 mm., petiole (about) 3 mm., each of the two nodes being 1 m., abdomen 5 mm. Wings hyaline, slightly clouded, the veins being strong, and of the color of the body, except the pterostigma, which is black, opaque. There are 3 costal, 2 sub-costal, 3 median, 3 sub-median, and 1 intercostal cells. (The figure is here very defective.) The thorax is broad, flat at the top, conformed as at Fig. 5, Pl. II., and has the spines upon the metathorax only as blunted processes. The body hairs are longer and softer than in the worker; the head has three ocelli upon the vertex; the fore-legs are proportionably shorter; otherwise the description conforms to that of worker-major.

MALE, ♂.—Length, 11 mm. Color closely resembles ♀, but darker upon the legs; the abdomen, head, and thorax are freely clothed with long, soft hairs. The head is 2 mm. wide, two-thirds the size of that of ♀; ocelli are present; the mandible has the long, sharp outer tooth, and the three next to it, quite well developed.

Texas, Mexico, probably Arkansas and Indian Territory.

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[1] Smith gave the specific name *barbata*, bearded, from the peculiar beard, which led Mayr to erect for this ant and her allies the genus Pogonomyrmex. The English equivalent of the rather formidable systematic name is "The bearded Beard-Ant." Buckley named the species from its mound-making characteristics,—an evident misnomer, as the absence of mounds is a striking feature of many nests.

PLATES

AND

EXPLANATION OF PLATES.

EXPLANATION OF THE PLATES.

☞ All references in these explanations are to the agricultural ant, unless otherwise stated, The notation, for convenience of reference, is generally repeated upon every plate. But if not, the letters, which have a uniform meaning, signify as previously noted.

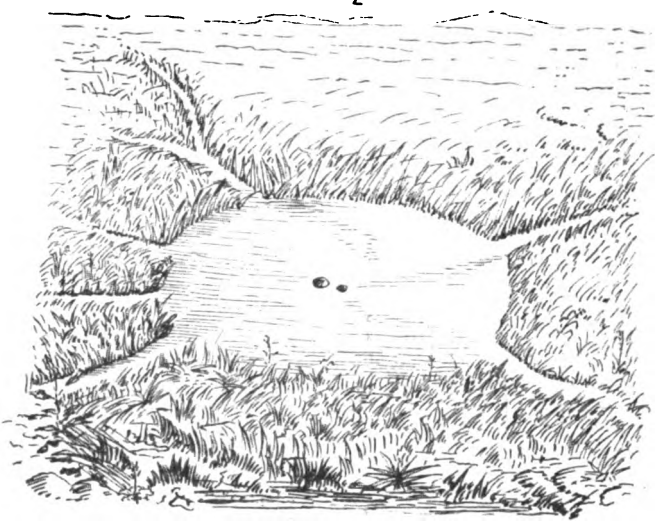
Explanation of Plate I.

Fig. 1. A flat disk of the agricultural ant cleared and maintained amidst high weeds. See p. 24.

Fig. 2. Large flat disk, 10½ feet in diameter, and open roads. The disks are the circular clearings made by the ants above the subterranean formicary. See pp. 26, 64.

PLATE I.

2



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Explanation of Plate II.

Fig. 3. *Pogonomyrmex barbatus*, agricultural ant, winged female, virgin. p. 20.

Fig. 4. Worker-major of same.

Fig. 5. Side view of queen.

Fig. 6. Side view of worker-major.

Fig. 7. Natural size of female; Fig. 8, of male; Fig. 9, of worker-minor; Fig. 10, of worker-major.

Fig. 11. Male.

Fig. 12. Enlarged view of the head of worker. *t*, tongue: *mx*, maxilla; *mb*, mandible; *cl*, clypeus; *fa*, frontal area; *afs*, antennal fosse; *sc*, scape of antenna; *flg*, flagellum; *fr*, frontal ridge; *f fur*, frontal furrow; F, front or forehead; V, vertex; e, eye.

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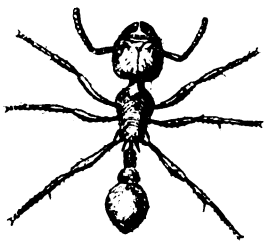

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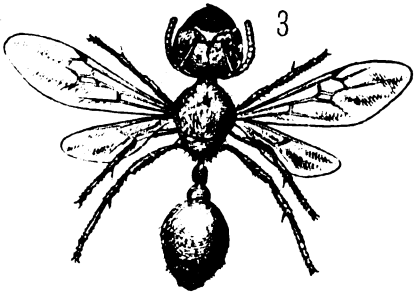

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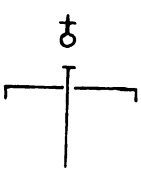

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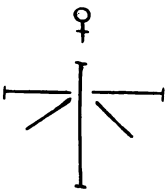

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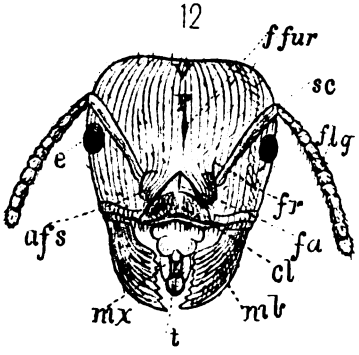

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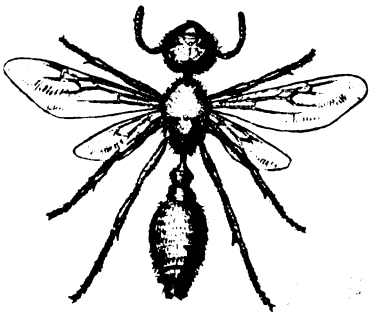


Explanation of Plate III.

Fig. 13. Nest covered with a crop of needle-grass. *Aristida oligantha*. p. 35.

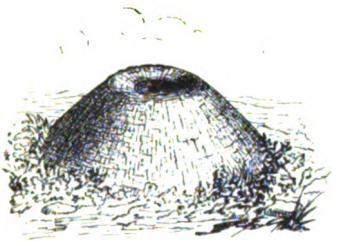
Fig. 14. A cone nest. p. 65.

Fig. 15. A mound disk, with roads. p. 62.

Fig. 16. Chart showing grouping of nest forms. Nos. 1, 4, 5 are cone disks, Nos. 2, 3, flat disks. p. 67.

PLATE III.

14



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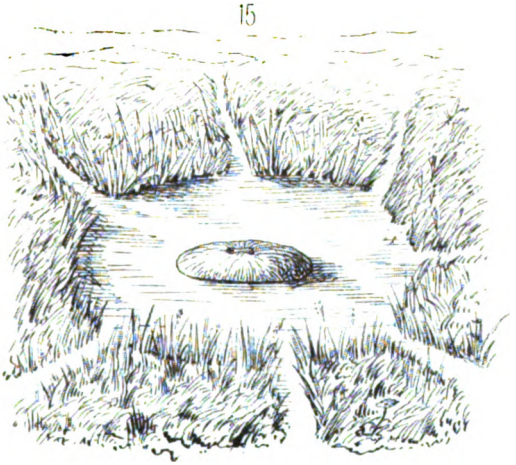

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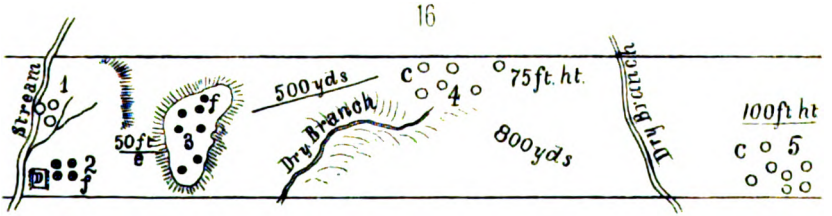

Explanation of Plate IV.

Fig. 17. A stump of grass in a new "clearing" on a disk. p. 21.

Fig. 18. Stalks of needle-grass, or ant-rice. p. 35.

Fig. 19. The seed and prickly awns of same.

PLATE IV.

Explanation of Plate V.

Figs. 20, 22. Double gates upon the surface. p. 71.

Fig. 21. A triangular gate.

Fig. 23. The vestibule, V, of a gate, *g*. p. 72.

Fig. 24. View of the excavation in which Figs. 30 and 39 were made. p. 75.

Fig. 25. The Buffalo-grass *Buchloe dactyloides*, found in quantities within the granaries. p. 31. The figure shows the manner in which this plant is propogated by roots sent out from the stalks, thus making a thickly matted growth.

Fig. 26. Enlarged view of seeds in head.

Fig. 27. A naked seed.

PLATE V.

Explanation of Plate VI.

Fig. 28. View from above of granaries or store-rooms found within the nest, containing seeds. About one-fourth natural size. P, the pave or surface of the disk; *g*, the gates. p. 73.

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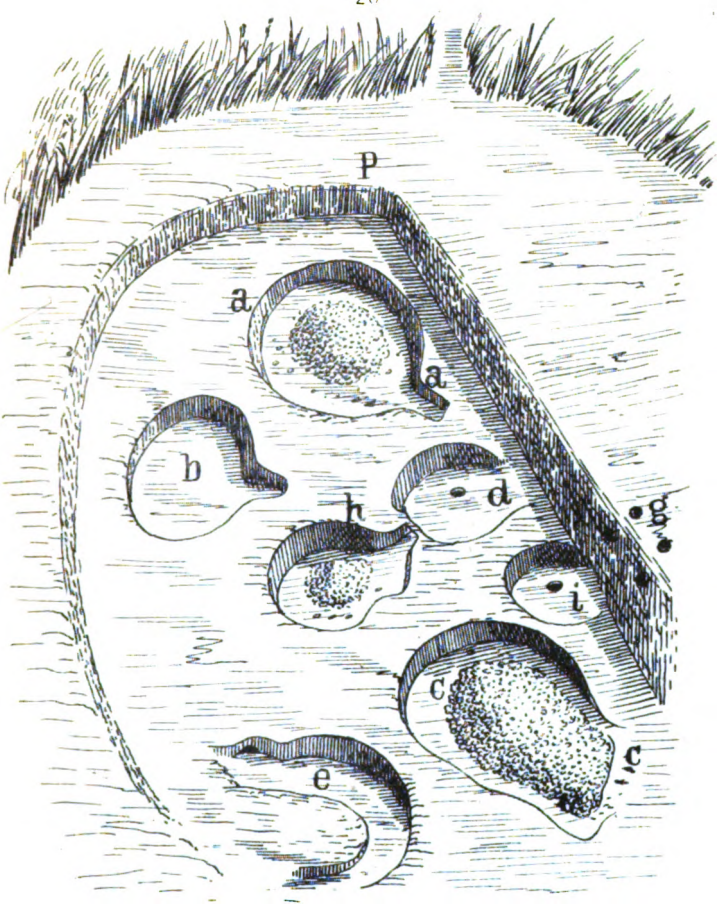

Explanation of Plate VII.

Fig. 29. A crescent-shaped granary or chamber. *g*, a gallery entering it from below. The figure is somewhat enlarged from nature. p. 76.

Fig. 30. A large nursery, about one-third natural size. p. 75.

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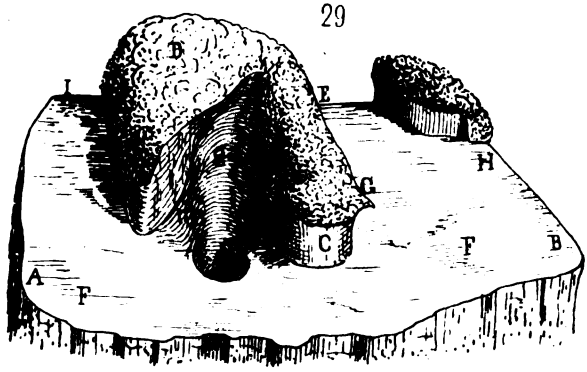

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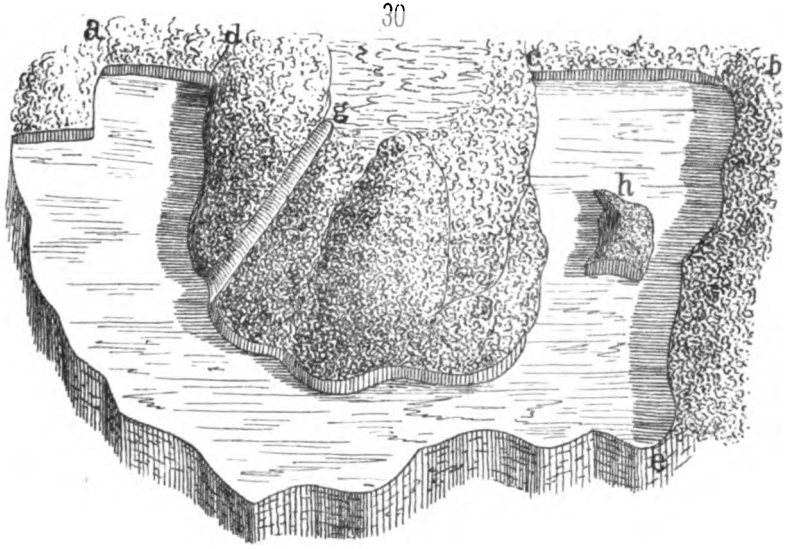

Explanation of Plate VIII.

Fig. 31. Vertical section of a cone-nest. cc, the crater; *mg*, main gate; *g*, gate; *sr*, store-rooms; *s*, surface. p. 80.

Fig. 32. Section of mound-disk. *s*, store-room; *g*, system of galleries. p. 82.

Fig. 33. View of a granary, looking within, slightly reduced in size. p. 78.

Fig. 34. Vertical section of a cone-nest. p. 82.

Fig. 35. Section of a mound-nest. *a*, *b*, crater, with gates at the edges; *g*, gallery; *sr*, store-room; *cd*, surface line.

Fig. 36. Large dome-shaped chamber. Reduced one-half. p. 77.

Fig. 37. Vertical section of a nest showing arrangement of rooms in stories; a little more than one-tenth natural size. p. 77.

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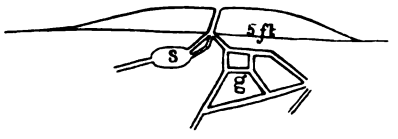

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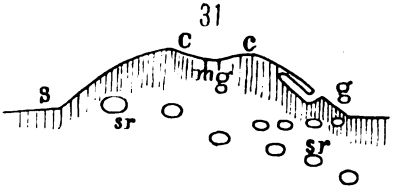

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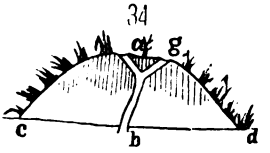

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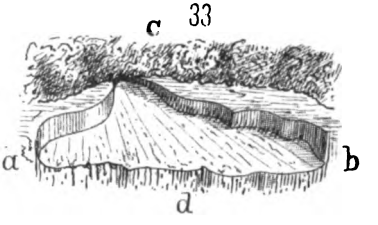

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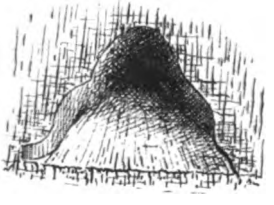

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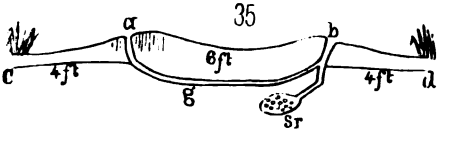

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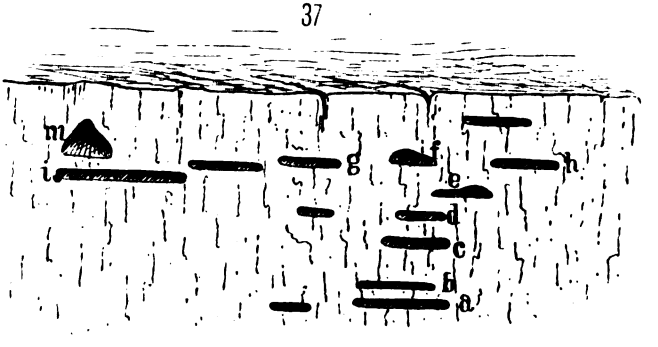
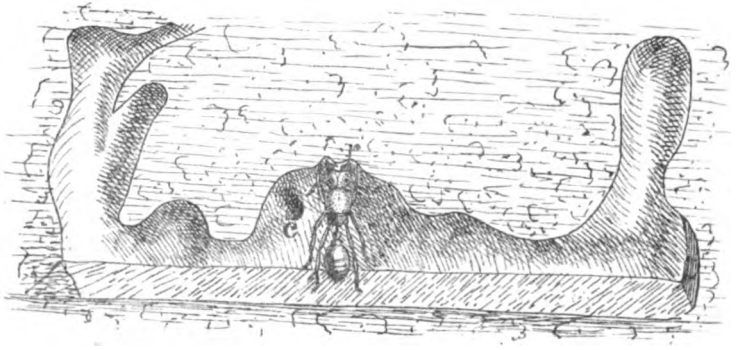


Explanation of Plate IX.

Fig. 38. Galleries and rooms made in artificial formicaries. c, a chamber or gallery-bay, with an ant working at the roof a-tiptoe. p. 90, 93.

Fig. 39. Section showing arrangement of galleries and rooms in stories. A, B, C, D, G, H, are rooms. $g^{?}$, supposed site of first gallery. $g^{I}g^{I}$, gallery connection of second series; $g^{II}g^{II}$, third series; g^{III}, gallery opening downward. g^{IIII}, fourth series. Drawn about one-fourth natural size. p. 78.

38



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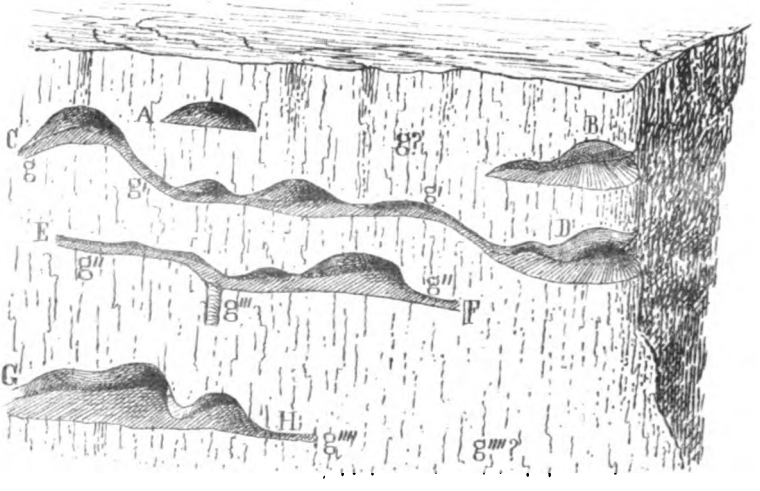
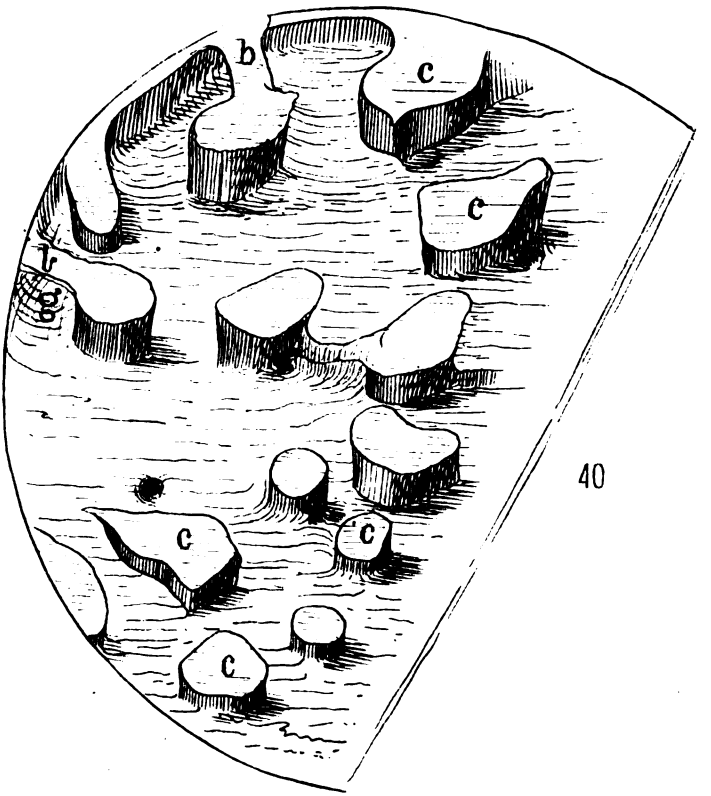


Explanation of Plate X.

The figures show the architecture of the Florida harvester, *Pogonomyrmex crudelis*, wrought within an artificial nest.

Fig. 40. View from above, showing the floor of rooms and galleries, and broken columns *ccc*, which supported the roof. p. 83.

Fig. 40. Section view of same. The numerals indicate the several stories; *g*, a connecting gallery between two rooms. p. 83.



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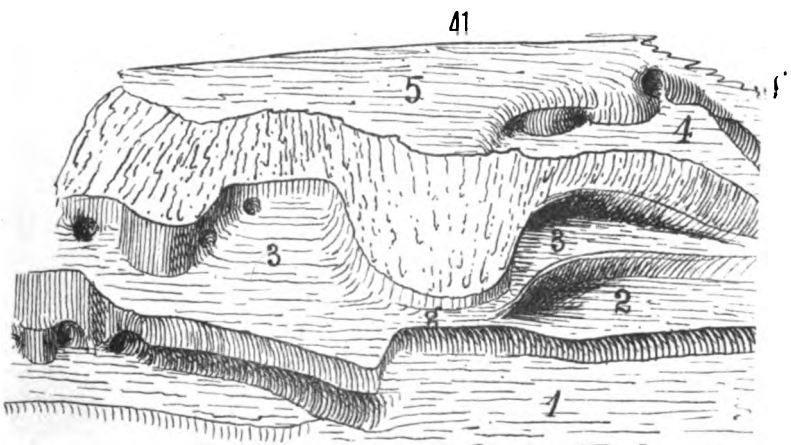


Explanation of Plate XI.

☞Attention is called to an error in numbering this plate, observed too late to be corrected. The numbers 47, 48, 49, 50, are duplicated upon Plate XII, but as the numbers will be used in connection with the plate, no great inconvenience need follow.

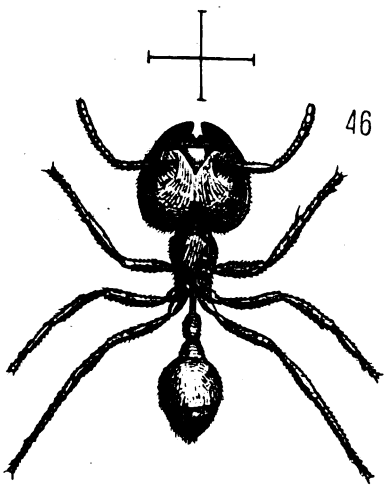
Fig. 46. Large headed worker of Florida harvester, *P. crudelis*. The lines above show the natural size.

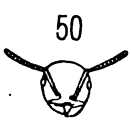
Fig. 47. Profile of Queen.

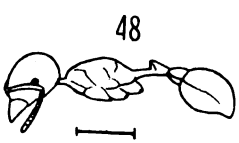
Fig. 48. Profile of worker-minor; Fig. 50, outline of the head of same.

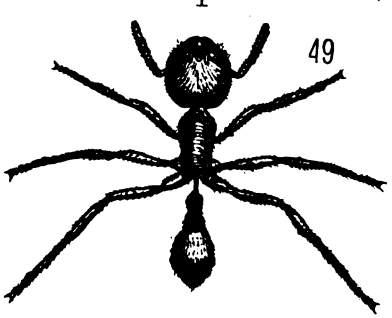
Fig. 49. Worker-major.

PLATE XI.









Explanation of Plate XII.

Fig. 47. View of galleries made by the agricultural ant in an artificial nest. p. 93.

Fig. 48. Ant working upon her back. *d*, the loosened pellets accumulated upon the lower face. p. 92.

Fig. 49. Worker mining upon her side. *d*, as above, *c*, *c*, cavities made by action of the mandibles. p. 91.

Fig. 50. View from above of a chamber in a cone-nest. Natural size. p. 81.

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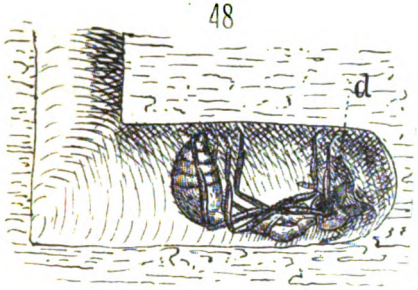

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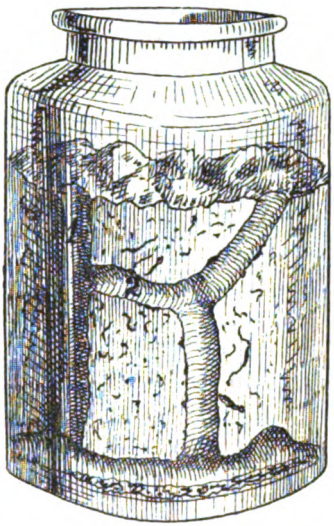

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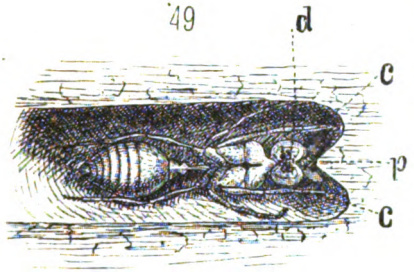

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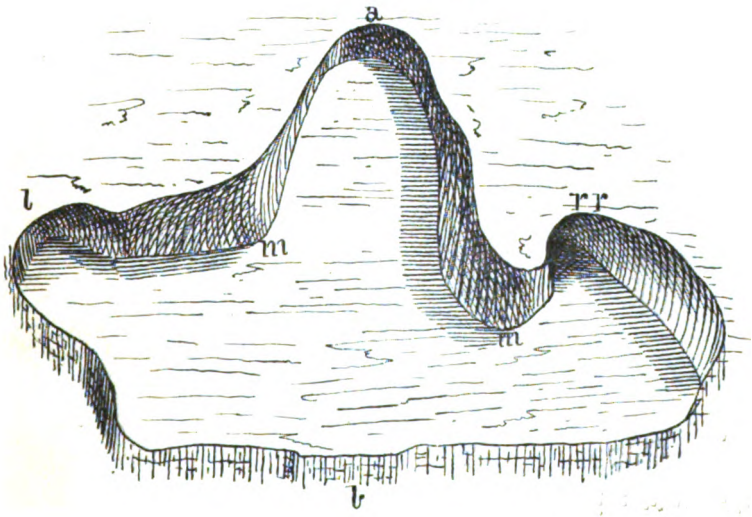


Explanation of Plate XIII.

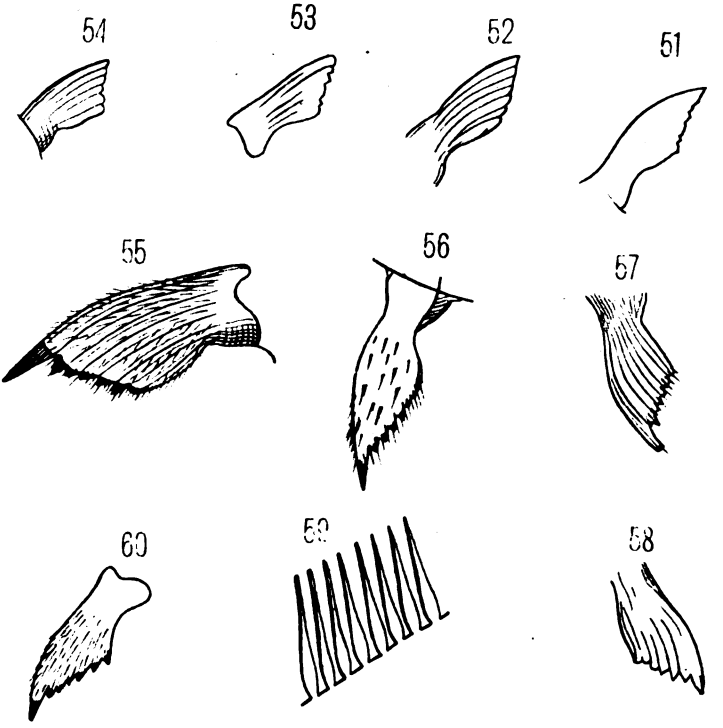
Figs. 51, 52, 53, 54, 57, 58, are mandibles in various stages of abrasion. p. 97.

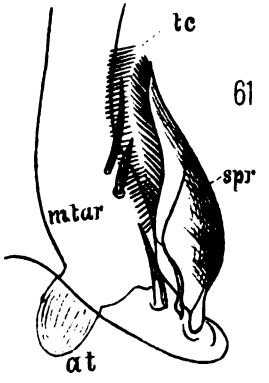
Fig. 56. Mandible of male; 55, of female, both greatly enlarged. Fig. 60, (also 55,) shows the true outline entire. p. 94.

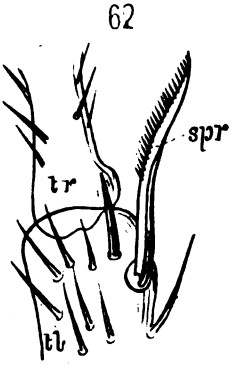
Fig. 59. Group of teeth upon the spur or comb of the fore leg, magnified 180 diameters. p. 130.

Fig. 61. View of the spur *spr*, closing down upon the tarsal comb, *tc*. *at*, articulation of the tarsus with the tibia; *m-tar*, metatarsus. p. 130.

Fig. 62. View of secondary spur, *spr*, on the 2d and 3d pair of legs: *tr*, tarsus, *tb*, tibial bristles. p. 131.







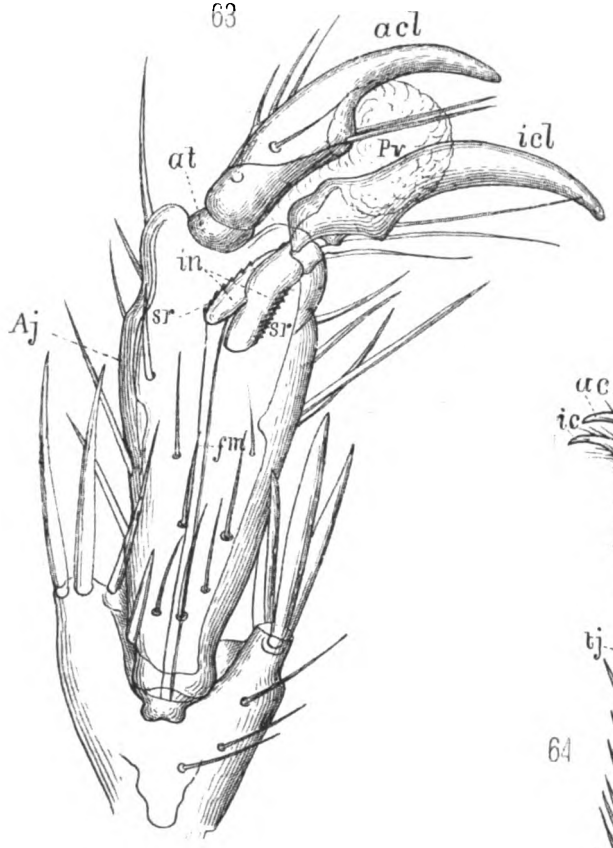
Explanation of Plate XIV.

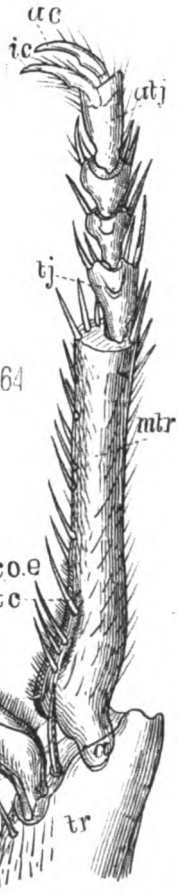
Fig. 64. View of foot, spur, and end of tibia. *spr*, spur, showing articulation upon the tibia, *tr*; *rd*, rod strengthening the back of spur; *hsp*, hairs on spur; *r.sp*, inner rod; *co.e*, the comb edge; *tc*, tarsal comb; *mtr*, metatarsus or long tarsal joint; *tj*, first tarsal joint; *atj*, apical tarsal joint; *ic*, inserted claw; *ac*, attached claw. p. 130.

Fig. 63. Apical joint of foot, *Aj*, enlarged 180 diameters. *acl*, attached claw; *at*, articulation of same with the joint; *icl*, inserted claw; *in*, the inserted prongs; *sr*, serrations upon the same. (N. B. The serrations are on the corresponding edges of the prongs. Those on the right hand side of the figure are correct.) *fm*, foot muscle; *pv*, pulvillus.

Fig. 65. Mandibular tooth, ×180. *sr*, striæ ridges: *sg*, striæ grooves; *ms*, mummy shaped roots of the striæ, apparently dovetailed into the margin of mandible; *nt*, narrow tongues of same; *be*, broken edge of tooth; *bt*, border of tooth. p. 95.

63





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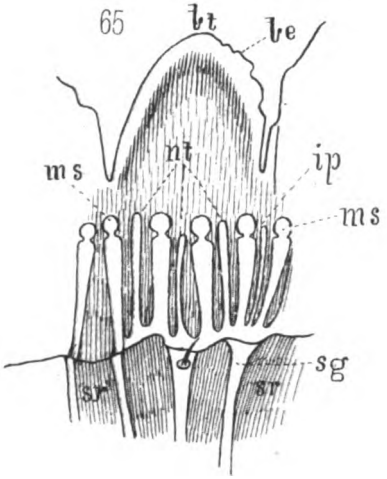

Explanation of Plate XV.

Fig. 66. Ant cutting out a piece from the kernel of a nut. p. 113.

Fig. 67. Out-thrust tongue in lapping food.

Fig. 68. Ant eating in erect posture. p. 114.

Fig. 69. Ordinary posture in eating. p. 111.

Figs. 70, 71. Positions of Florida harvester in cutting millet seeds from the stem.

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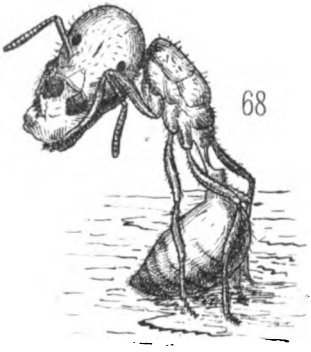

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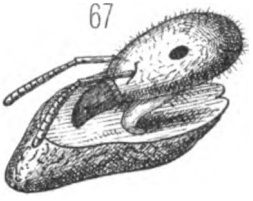

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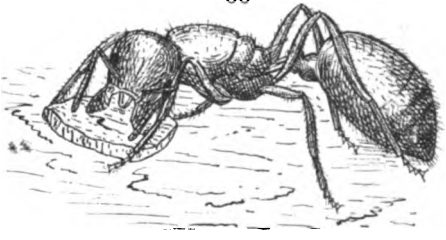

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Explanation of Plate XVI.

Fig. 72. View of out-thrust tongue from above. *md*, mandible; *mx*, maxilla; *cl*, clypeus, with the triangular frontal area above. p. 120.

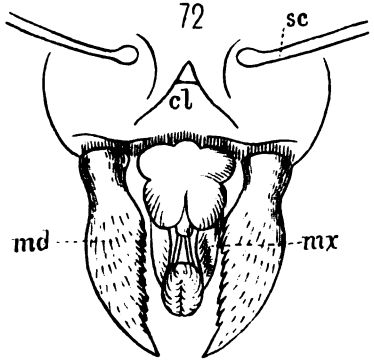
Fig. 73. Cup shaped gustatory organs on tongue and maxilla. p. 122.

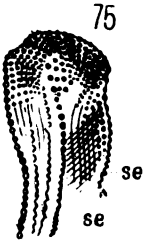
Figs. 74, 77. Hemispherical bosses upon the surface of tongue.

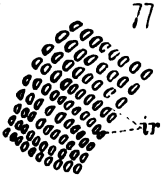
Fig. 75. A wrinkled portion of the tongue, ×180, showing regular alignment of bosses, and the appearance of serrate edges, *se*. p. 121.

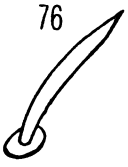
Fig. 76. Sword-like bristle on maxilla.

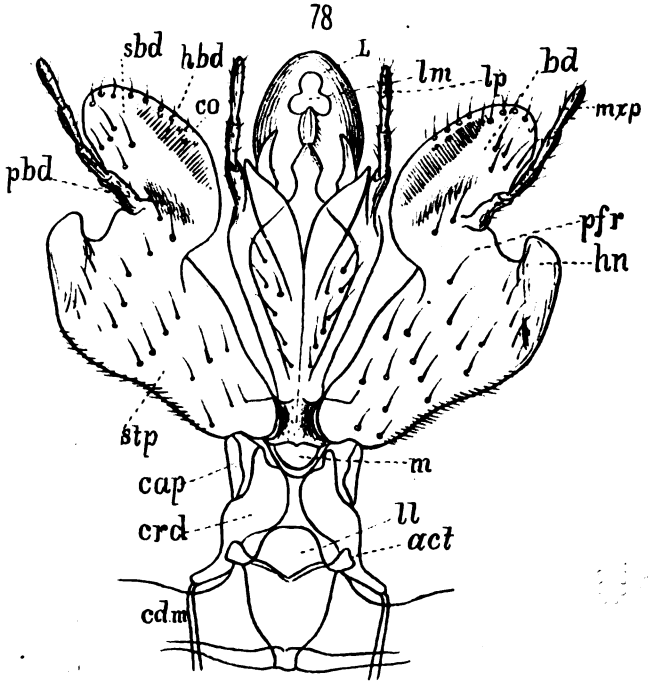
Fig. 78. Mouth organs. L, lingua, tongue; *lm*, laminæ; *lp*, labial palpi; *mxp*, maxillary palps; *bd*, blade of maxilla; *pfr*, palpifer; *hn*, horn-like process; *co*, cup-shaped gustatory organs; *hbd*, pallisade hairs; *pbd*, papillæ on blade; *stp*, stipes or footstalk of maxilla; *m*, base of mentum or chin; *crd*, cardo, or hinge by which the above organs articulate with and are attached to the lower lip *ll*; *cap*, articulating piece of the cardo; *act*, a hammer-headed process from the lower lip, by which it articulates with the cardo; *cdm*, muscle attached to cardo. p. 122.











Explanation of Plate XVII.

Fig. 79. Ant in position of dropping from the roof of artificial nest.

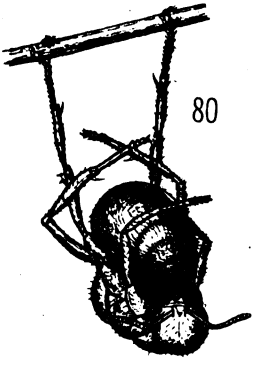
Fig. 80. Ant hanging by hind feet cleaning the apex of her abdomen.

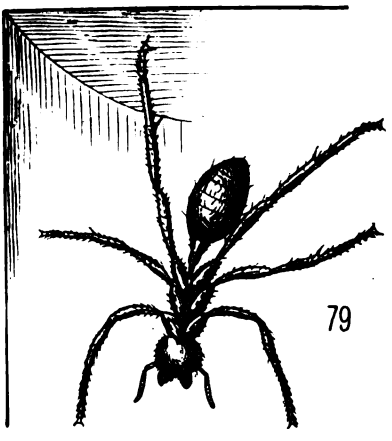
Fig. 81. Ant cleaning apex of abdomen. p. 128.

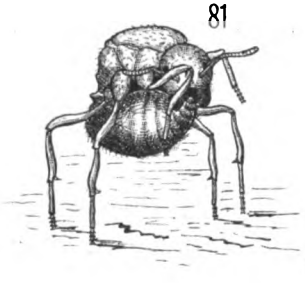
Fig. 82. Ant in erect posture brushing her head, and combing her face-hairs with her spur. p. 128.

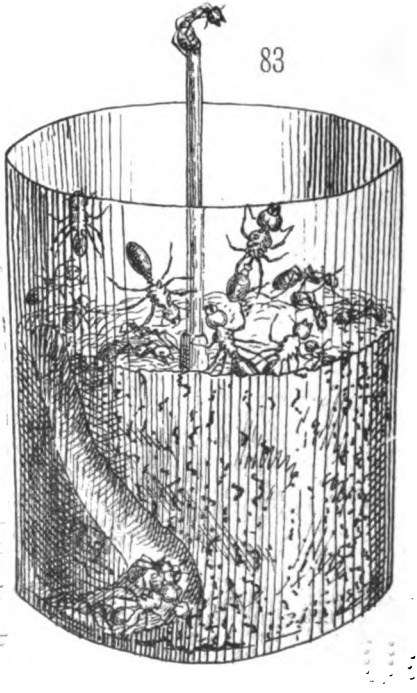
Fig. 83. Ants hanging upon glass formicary in sleep.

PLATE XVII.









Explanation of Plate XVIII.

Fig. 84. Agricultural ant deporting one of her fellows. **p. 157.**

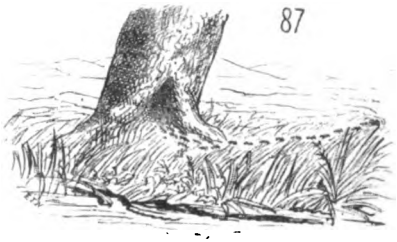
Fig. 85. *Formica integra* in same act. p. 153.

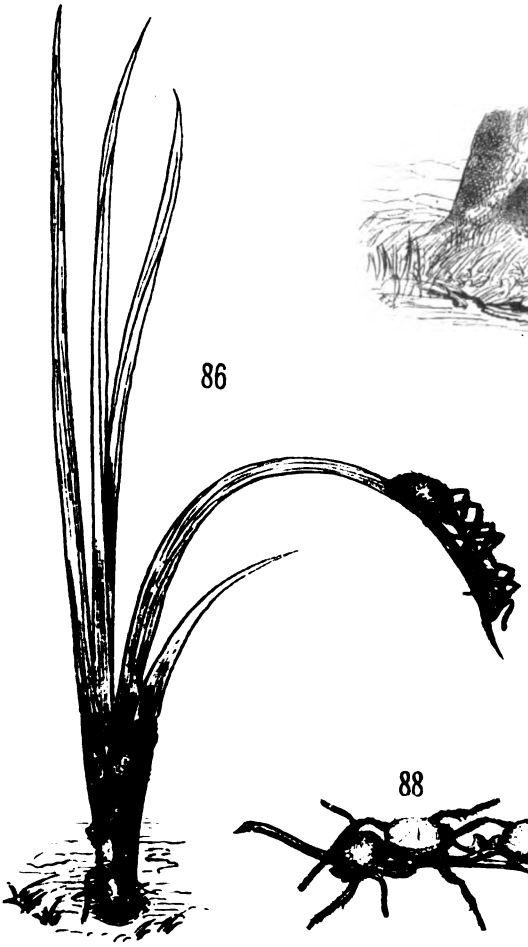
Fig. 87. A column of *Formica integra* engaged in deporting fellows. p. 153.

Fig. 86. Agriculturals cutting down obtruding grass; one ant cutting at the root, one swaying down the leaf. **p. 23.**

Fig. 88. Worker carrying a large straw, astride of it. **p. 85.**

PLATE XVIII.





Explanation of Plate XIX.

Fig. 89. *sc*, scape of antenna; *h*, hairs directed downward upon the extreme margin of the articulating end. *asc*, articulation with antennal fosse. Length of scape, 1½ mm.; of flagellum, 2 mm.

Fig. 90. *afl*, articulation of flagellum *fl*, with scape.

Fig. 91. Apex of abdomen in profile, showing stinging organs thrust out. *4dp*, fourth dorsal plate; *4vp*, fourth ventral plate; *py*, pygidium; *hy*, hypopygium; *stg*, sting; *shb*, bulb of sheath; *shn*, neck of sheath; *re*, rectum. p. 173.

Fig. 92. Same from below; *bo*, bow of the sting and other parts showing through hypopygium. Other letters as above. p. 174.

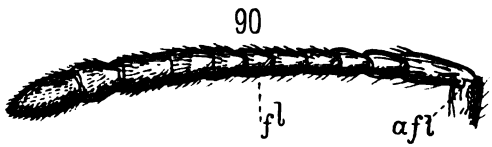
Fig. 93. Lower part of sting enclosed within a membranous sac *sc*, attached to a chitinous frame *ct*, and hung within the apex of abdomen. p. 174.

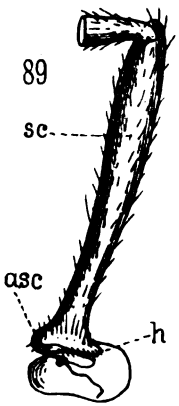
Fig. 94. Fasciculus of muscle.

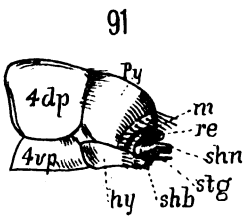
Fig. 95. Terminal part or gouge *go*, of sting-case. *cs*; *cb*, *cb*^{1}. barbs or serrations in the edge of the gouge; *gst*, striæ on the interior surface of the gouge. p. 176.

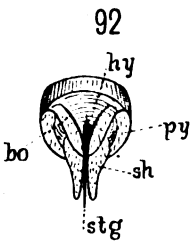
Fig. 96. Sting-case; *go*, gouge; *bl*, blade; *tru*, trunk; *thr*, throat; *cl*, cleft; *fl*, flap; *pw*, prolongation of the walls; *rg*, ring uniting these prolongations; *h*, horn to which the case muscle (fig. 94) is attached. p. 175.

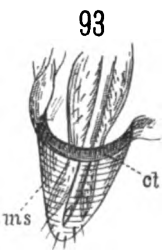
Fig. 97. Position of ant in act of stinging. p. 168.

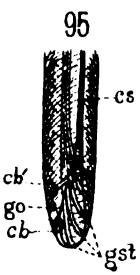


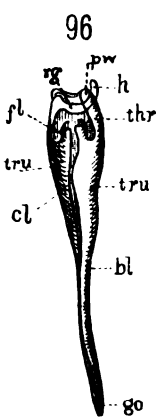


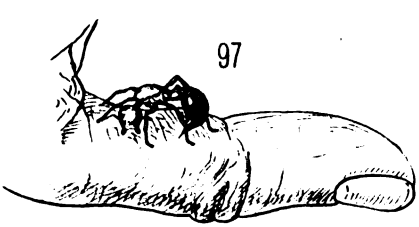












Explanation of Plate XX, Fig. 98.

Both Plate and Explanation have been contributed by Dr. A. Forel.

sth, Exterior parts of the sheath of the sting. (Vaginæ aculei exteriores.) See p. 171.

stg, Apex of the sting. (Apex aculei.)

tr, Air tubes of the sting. (Trachea aculei.)

pk, Stinging prickles. (Acus.)

cs, Furrow or case of the sting. (Sulcus aculei. [Vagina acuum].)

acc, Accessory gland or oil sac of the poison gland. (Glandula venefica accessoria seu olifera.)

con, Conduit of the poison sac. (Vas efferens vesiculæ veneficæ.)

sac, Poison sac. (Vesicula venefica.)

mb, Membrane proper of the poison sac. (Tunica propria ejusdem vesiculæ.)

in.mb, Innermost membrane of the poison sac. (Tunica intima ejusdem vesiculæ.)

gl.in, Internal part of the poison gland, situated in the hollow of the poison sac. (Pars interna glandulæ veneficæ; in vesiculæ veneficæ vacuo sita.)

gl.ex, Free or external part of the poison gland. Free gland ducts. (Pars libera (externa) glandulæ veneficæ.)

pro, Part of the innermost membrane of the poison sac prolonged to the free part of the gland. (Pars tunicæ intimæ vesiculæ veneficæ ad partem liberam glandulæ producta.)

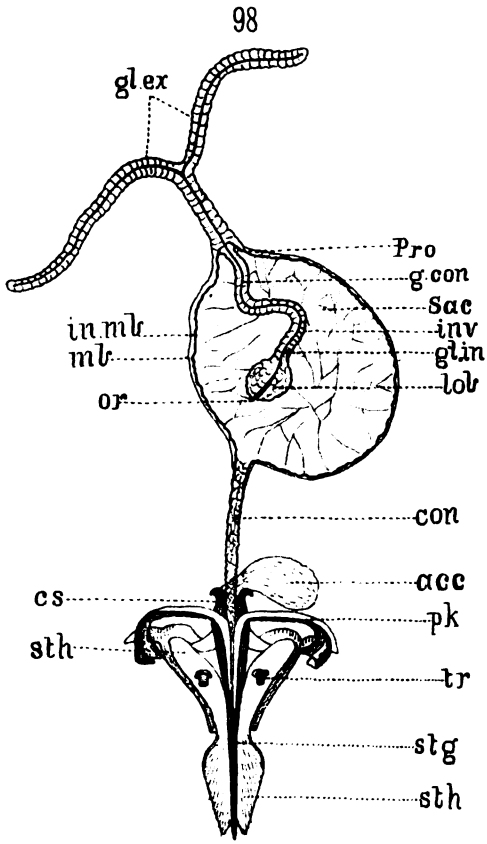
lob, The lobus, the thickened terminal bulb of the poison gland, placed in the hollow of the sac. (Lobus terminalis incrassatus glandulæ veneficæ; in vesiculæ vacuo situs.)

g.con, Conduit of the poison gland. (Vas efferens glandulæ veneficæ.)

or, Orifice of this conduit into the poison sac. (Orificium ejudem vasis in vesiculam veneficam.

inv, Innermost membrane of the poison sac invaginating around the internal part of the gland. (Tunica intima vesiculæ veneficæ circum partem internam glandulæ invaginata.)

PLATE XX.



Explanation of Plate XXI, Fig. 99.

Stinging organs of agricultural ant, female, which are identical with those of the worker, except in the accessory gland. p. 185.

shb, Bulb of sheath; *shn*, neck of sheath.

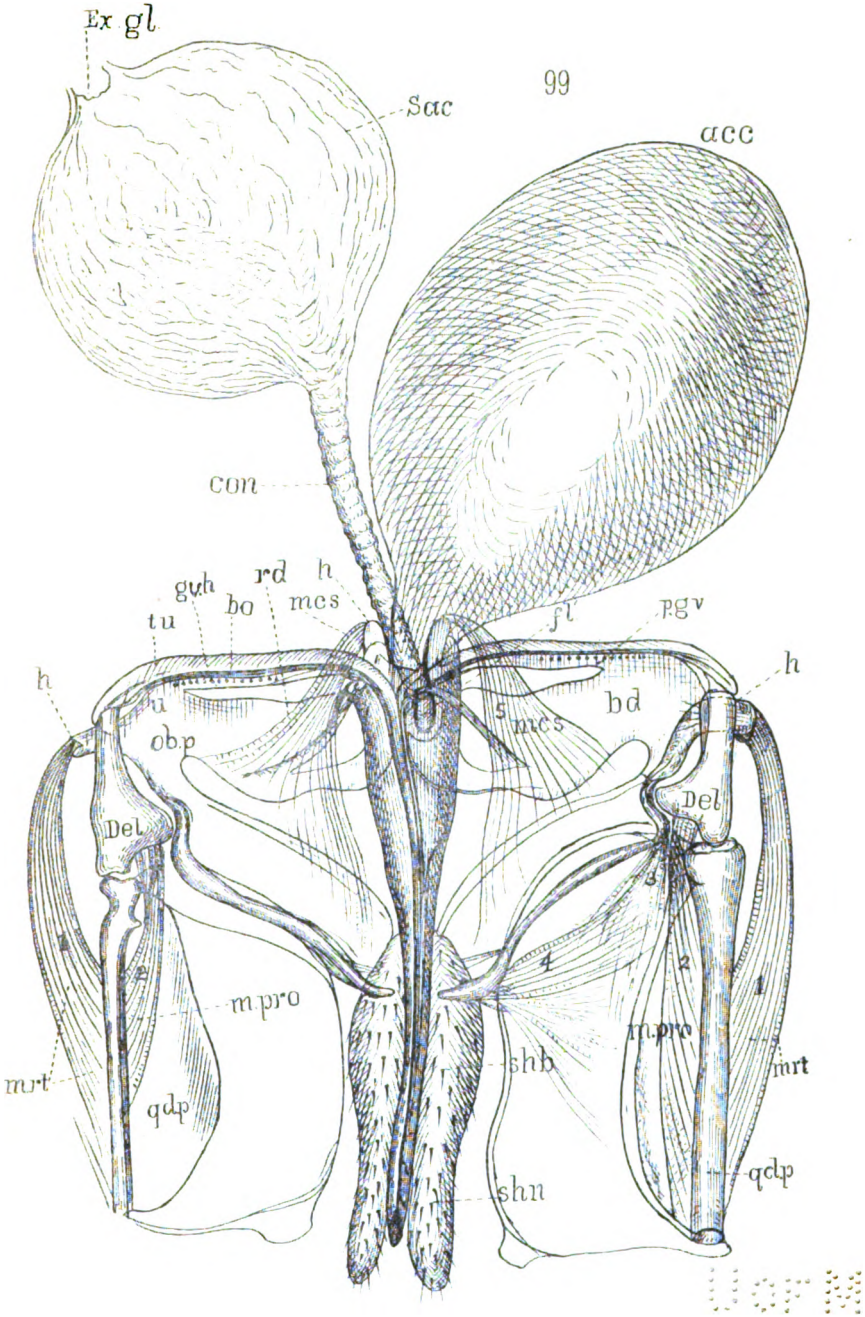
qdp, Quadrate plate; *obp*, oblong plate; *bd*, band of oblong plate; *del*, deltoid plate, delta; *pgv*, prickle groove; *u*, union of the oblong plate with prickle groove; *tu*, tube of prickle; *bo*, bow of prickle; *gvh*, groove hairs.

fl, Flap of case; *rd*, rod on oblong plate attached to flap. (The dotted line from *rd* should extend farther down.)

mcs, No. 5, muscle attached to projecting wall *h* of case, and to oblong plate; No. 4, muscle attached to posterior stem of oblong plate, and to the quadrate plate; No. 3, muscle attached to anterior stem of oblong plate and to the border of quadrate plate, the protrusor muscle of the string; No. 2, muscle attached to delta and to border of quadrate plate; No. 1, retractor muscle of sting attached to the projecting horn *h*, of oblong plate, and to the border of the quadrate.

acc, Accessory organ or oil sac.

sac, Poison sac; *ex.gl*, site of excretory ducts; *con*, conduit of poison sac, emptying into the case.



Explanation of Plate XXII.

Fig. 100. View of fractured prickle groove *pgv*, showing the groove hairs *gh*, and a section of the prickle *sp*, within. p. 177.

Fig. 101. *pkc*, chitinous portion of prickle; *pkd*, diaphanous part.

Fig. 102. Triangular barbed point of prickle. 1, 2, 3, the three edges; No. 1 is the cutting or barbed edge. p. 184.

Fig. 103. Part of prickle fractured longitudinally; *r*, *r*, parts of the rib; *an*, angle of tube; *sbt*, section of bandlet. p. 178

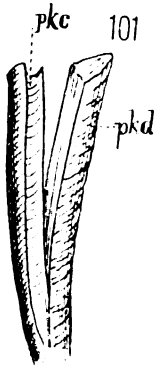
Fig. 104. View of the Ear *E* of prickle; *m*, serrated margin; *lm*, laminæ on sides; *tk*, thickened (or open?) middle part; *bc*, brace; *fe*, featheredge; *bo*, bow of pickle; *sh*, shaft; *o*, oil globules. p. 179.

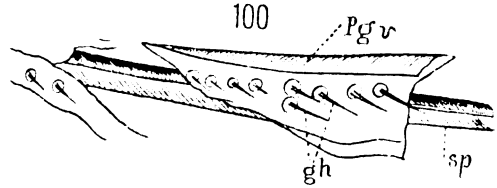
Fig. 105. View of a part of naked prickle. For natural size, see plate XXIV, figure 122. *nd*, needle; *tu*, tube; *shf*, shaft; *b*, barbed point; *pd*, fibrous interior padding of tube. p. 181.

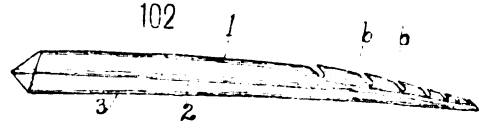
Fig. 110. Part of same, more enlarged; letters as above.

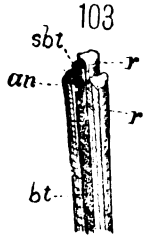
Fig. 106. Point of prickle; b^1, b^2, barbs; *u*, union of the three edges, 1, 2, 3, into a chitinous point; *can*, canal or hollow. p. 184.

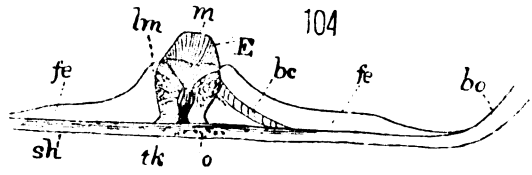
Fig. 107. Profile of barbs; 108, front view; 109, same enlarged. p. 184.

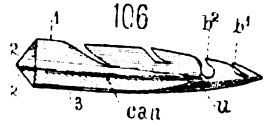


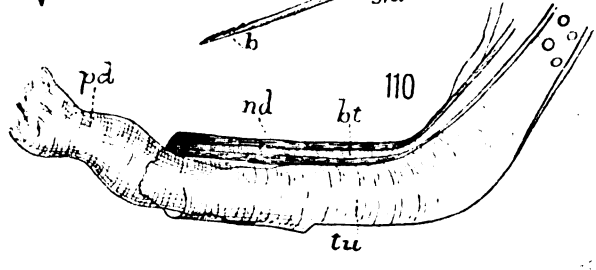












Explanation of Plate XXIII.

Fig. 111. View of throat, *thr*, and trunk of case, showing entrance of poison conduit, *con*, and accessory, *acc;* position of the ear, *e*, within the narrowed wall and over the canal, *can*, of the prickles; the attachment of the band *Bd*, of oblong plate, by a ligament *l*, to the flap, *fl;* the attachment of the prickle groove, *grv*, and position of prickle *pk*, when the sting is thrust out. p. 186.

Fig. 112. Barbed appearance within the bandlet of the prickle.

Fig. 113. Section of case showing outer and inner walls. *ec*, edge of case; *pc*, cavity in which prickles move; *cv*, cavity between inner and outer wall; *u*, union of walls; *b*, b^1, natural slits (or fractures?) into *cv*. p. 176.

Fig. 114. Prickles projected from the case. p. 189.

Fig. 115. Section of prickle, *r*, rib; *tu*, tube; *nd*, needle; *bt*, bandlet. p. 182.

Fig. 117. Section of case, *scs*, showing prickles as they move within grooves *gv*, in the wall, with canal *cn*, for flow of poison between them.

Fig. 116. Accessory organ entering the case, and probable position of the prickle *bo*, and the band of oblong plate *bd*, when the sting is thrust out. p. 192. (The reference on page 192 to Fig. 113 should be to this figure.)

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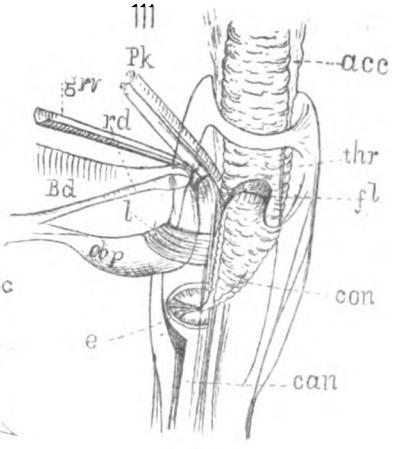

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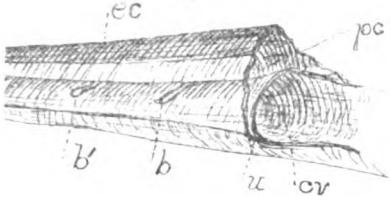

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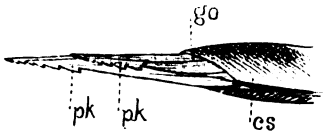

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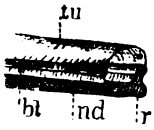

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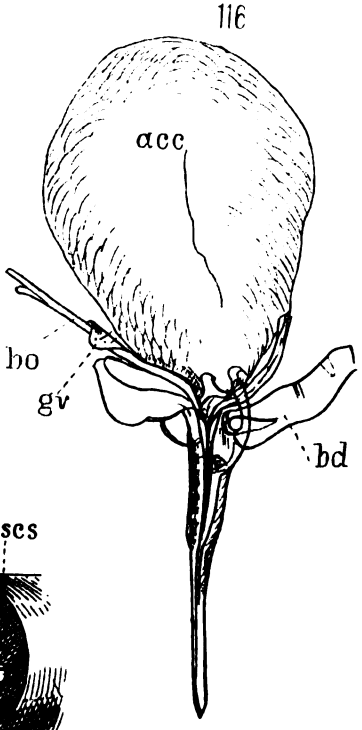

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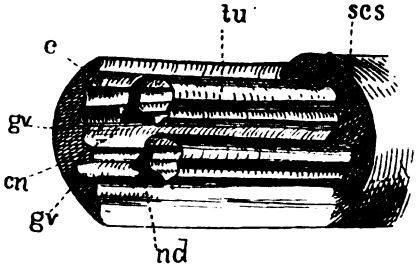

Explanation of Plate XXIV.

Fig. 118. Small ants. *Iridomyrmex Macooki*, in line of march.

Fig. 119. Natural size of the mandible: Fig. 120, of leg and spur; Fig. 121, No. 1, of sting-case, No. 2, of entire stinging organs; Fig. 122, of part of the prickle; Fig. 123, of accessory organ; Fig. 124, of mouth organs.

Fig. 125. Ant trap; Fig. 126, section of same.

Fig. 127. Tent of a spider *Theridion lineamentum*, upon an ant disk; dry shells of ants underneath. A snare of a Saltigrade spider is shown upon one of the spires on the right.

PLATE XXIV.

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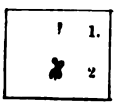

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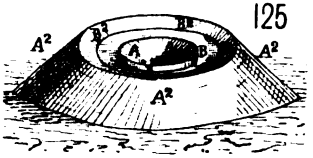

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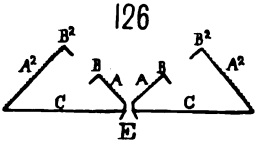

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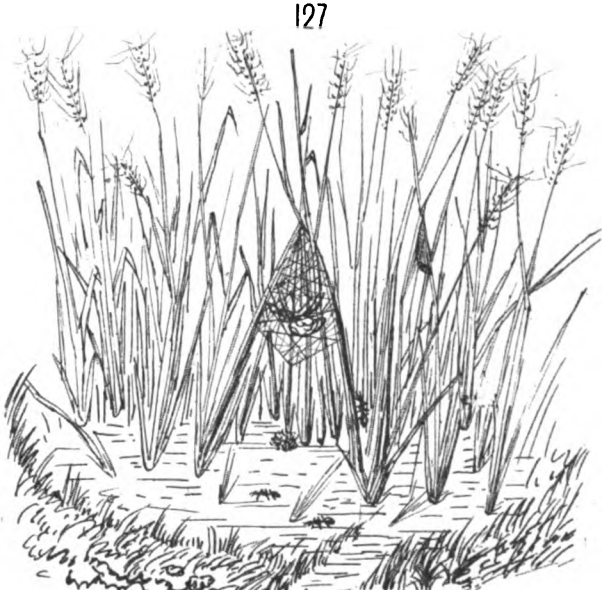

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THE END.

ERRATA.

1. Page 24, line 11 from below (bottom of page), for "Fig. 2," read "Fig. 1."
2. Page 31, line 2 from below, and page 32, line 7 from top, for "Buchlœ," read "Buchloë."
3. Page 36, line 16 from below, for "free, choice pasturage," read "free choice of pasturage."
4. Page 63, line 6 from below, for "millimetres" and "millimetre," read "milligrams" and "milligram"
5. Page 73, line 11 from below, for "gallery," read "granary."
6. Page 130, lines 4 and 6 from below, for "centimetre," read "millimetre."
7. Page 192, line 11 from top, for "113," read "116."