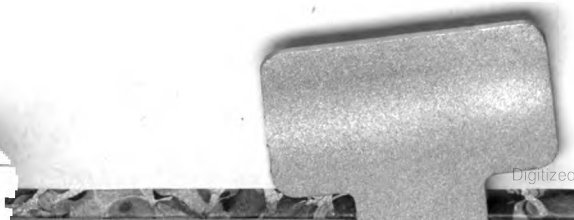

Mound-making Ants

OF THE

Alleghenies.

BY

REV. HENRY C. McCOOK.

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MOUND-MAKING ANTS OF THE ALLEGHENIES, their Architecture and Habits.

BY REV. HENRY C. McCOOK.

In the summer of 1876 I arranged to make a study of the Wood or Fallow Ants (*Formica rufa*), whose "hills" are familiar to all dwellers and visitors among the mountains of Pennsylvania. The experience of brief observations during previous years had satisfied me that it would be necessary to spend several days and nights on the home field of these interesting mound-builders of the insect world, and observe their habits continuously. Accordingly on Tuesday, August 15th, I pitched tent in a grove on the western slope of Brush mountain, about one mile northeast of the beautiful city of Hollidaysburg. My companion was James W. Riddle, Esq., of Bell's Mills, whose generous hospitality and practical aid I have great pleasure in acknowledging. John Smidt our cook and factotum was an intelligent Bavarian who had served in the late Franco-German war. A convenient and pleasant camping ground was found near "Big Pine Spring," where we established ourselves and spent a week very comfortably. My time was wholly given during this period to the investigations, whose results are given below. For the sake of convenience the name which I gave to the locality, viz.: "Camp Riddle" will be retained in the notes.

Number of Hills.—The field in which we were encamped is the property of the Cambria Coal and Iron Company, and is on the southwest base of Brush mountain. About fifty acres are occupied by the ants. At least three-fourths of this land is covered with an open wood, consisting chiefly of black and white oak, with a few pine, maple, dogwood and hickory trees. The soil is sandy, and is literally filled with the flat reddish-brown quartzoze sandstones which compose the surface bulk of this mountain. Many of the ant hills are surrounded by a belt of these stones one to two feet wide, which are quite bare. The soil has of course been transferred from beneath them to the hills, although their peculiar appearance suggests the idea of having been thrown out of a cellar or pit by a human laborer and ranged around the margin. The number of mounds in this "ant city," as it is called by many of the citizens of these parts, is about 1700. An actual count was made of 1300, not numerating the embryo

hills, the remainder being estimated. One acre contained 33 hills, another 25, a fair average (29), of the distribution over the field. Through the kindness of Mr. Edgar B. Kay,* a young gentleman in attendance upon the Mountain Seminary at Birmingham, this may be compared with the distribution at two other points in the north-eastern end of this (Blair) County. At Warrior's Mark one section of 2 acres contained 55 hills; another section of 2¼ acres contained 74 hills. This gives an average distribution of about 30 to the acre. In the second section, however, 20 hills were abandoned, and covered with moss and grass. At Pine Hill the ant colony is quite as extensive as that at Camp Riddle, and the hills even more thickly placed. About 30 acres are occupied, of which 5 were carefully surveyed and found to contain 293 hills, an average distribution of 59 to the acre. The whole colony was estimated to number about 1800 hills, quite evenly distributed over the section.

Colonies.—The fact that these mounds are found commonly if not always in Colonies attracted my attention; but I was not able to find any reason for it, beyond the conjecture that the unequal distribution of farms along the mountains has left certain sections, undisturbed by the plough and the ordinary discomforts of civilization, to these children of nature. It is probable, as suggested to me by Judge Caldwell, a citizen of Hollidaysburg, that the ants follow the sand belt† and keep for the most part to the mountain sides. The colony at Camp Riddle is quite near the foot of Brush mountain, most of the mounds being upon the slopes. A series of ridges and hills runs between Brush and Tussey mountains from the lower end of Sinking Valley beyond Warrior's Mark, along which the ant-mounds appear to be scattered. They are placed on the western and northern faces of

* Mr. Kay undertook and most intelligently conducted a series of observations upon points which I furnished him. The references in this paper to all observations made at Warrior's Mark and Pine Hill are from his notes.

† From the same gentleman I learned that the Brush mountain is a spur of the Cove mountain. Cove mountain is a long range of mountains extending from the northern part of Pennsylvania, southward through Virginia, having various names in different sections. Both sides of Brush mountain correspond in geological characteristics with the western side of Cove mountain; which differs much from the eastern side. On the West is found the sand rock; on the East instead of the sand rock is found slate. I will be obliged to those to whom these lines may come for any information in their possession which will aid in determining the distribution of these ants throughout this State and other States; and also whether they confine their colonies to the sand belt.

the ridges, scarcely any being found on the other sides except where the ridges are broken, and on small knolls. The soil in these ridges is sandy. The farmers near Warrior's Mark have the opinion that the number of mounds is less than many years ago, and that they are now more generally arranged in Colonies than formerly. An old settler at Pine Hill had the same opinion, although the lack of positiveness in the matter would seem to indicate no very notable decrease in the size of the Colonies. The same person declared that here also there are scarcely any mounds on the eastern and southern sides of the ridges. The causes which influence these little builders in the choice of a site for their republics are well worth further attention.

Size of Hills.—The ant hills are cones of greater or less regularity, the most common size of which is from 10 to 12 feet in circumference at the base, and from 2½ to 3 feet in height. But every size may be found, from the large mounds whose measurements are given below, to the mere embryo hill which is but a handfull of dirt around the door of a ground gallery. The hills represented in the Plates measured as follows: Pl. II, single large hill; circumference at base, 25 ft.; west face, 6 ft. 9 in.; east face, 3 ft. 6 in.; south face, 4 ft. 4 in.; north face, 4 ft. 3 in. The distance along the hill over the summit was thus 10 ft. 3 in.; across it, 8 ft. 7 in. Pl. IV, large hill, perpendicular height 32 in. Pl. V, upper hill, perpendicular height 24 in.; along the base through the centre 7 ft. 6 in. Lower hill, perpendicular height 26 in.; base line or diameter 6 ft. Pl. VI, double hill, western face, 6 ft.; eastern, 3 ft. 6 in.; between the summits 5 ft. 3 in.; total measurement along the top, 14 ft. 9 in.; perpendicular height 27 in.

Largest Hill.—At Warrior's Mark and Pine Hill some of the mounds are larger than the above. One conical hill measured 12 feet across the top and 30 feet in circumference; another 15 feet across the top and 37 feet in circumference. Two double hills measured, one 15 feet (lengthways), along the top and 47 feet around the base; the other along the top 24 feet, around the base 58 feet, and in height was about 42 inches. This last is the largest observed; it was built on an old charcoal hearth which was quite level. These double hills, illustrated at Pl. V, are of frequent occurrence; they appear to be the natural blending of two hills located so near to each other that they necessarily unite when enlarged. The inhabitants seemed to be one family, working together harmoniously as in single hills. The large

double hill at Warrior's Mark, (19 by 47 feet), presented a peculiarity which I have observed in several other hills. On the northern face it was almost entirely deserted. The rains had washed off the outside covering or roof, exposing the inside structure. This part of the hill was abandoned by the ants, with the exception of occasional stragglers; but on the other sides the insects swarmed, and on the western, southern and northeastern faces the work of construction was progressing rapidly.

Abandoned Hills.—At Camp Riddle the number of hills wholly abandoned was quite small; at Warrior's Mark fully one-fourth of the whole number reported were uninhabited. Many a romance of ant life lies hidden within those silent moss-covered mounds. Could one uncover those lost pages of natural history he would doubtless unfold a tale which would sufficiently account for such wholesale and apparently unreasonable migrations. There would appear "moving accidents by flood and field," such as fierce showers and flooded grounds, inroads of neighboring clans pressing siege and waging battle, with the attendant loss of life, treasure and home. Stray cattle, swine, mischievous boys and perhaps foraging bears would render "perils in the imminent deadly *breach*." Besides all these good and sufficient reasons for abandoning old quarters that have become uncomfortable, no doubt ants have their whims and fancies, and probably like their human fellow-workers sometimes "change the place and keep the pains," or even fall upon a worse estate. I have thought that some of these abandoned hills have been reoccupied as they carry a moss grown and ancient appearance, although in full activity. Very much is yet to be learned of the local migrations of these communities, which might give a clue to other unknown habits. But the study requires an observer within easy reach at all seasons of the year.

Family Groups.—We turn our attention now to the growth and structure of the ant hills. Pl. III is a view of a group of eleven mounds, seven of which are represented in the photograph. They are of various sizes, and as will readily be seen are grouped around a central mound, which may be called the mother hill from which they have evidently grown. The same tendency to cast off "shoots," and form a hill cluster or family, is shown in the hill figured at Pl. II. This large hill is surrounded by six others at distances varying from 4 to 15 feet. Pl. IV exhibits the same feature, the two small hills on either side being growths from the large central mound. All these secondary hills were small, from 4 to 6 feet in circumference at the

base. Pl. V again shows the development of two hills of nearly equal size side by side. The same feature is shown at Pl. VI, although in that group the hills have blended.

All this shows a fixed habit in the growth of the hills. As the community increases, new cones are begun, the opening of some gallery perhaps being taken as the centre of operations. I have frequently observed these embryo hills. The commencement of a hill sometimes depends upon the location of the feeding ground. Eight rods from the large hill in Pl. II is an oak tree, which was covered with aphides, and upon which the inhabitants of that republic have established a permanent foraging ground. About a foot from the base of the tree an embryo hill has been begun by a portion of these workers. I observed them closely and have no hesitation in identifying them as of the one family. A number of hills, some of them of goodly size, which are built up against the trunks of trees, have evidently been formed in the same way. Indeed it is highly probable, from observations hereafter recorded, that most if not all the hills have similar connection with the trees which furnish the feeding grounds, by underground galleries.

What influence the annual flitting of the males and females, and the chance settlement of the latter after fertilization, may have upon the formation of new hills, I am not able to say, as I have not been so fortunate as to witness a swarming. Some of the fruitful females, it is known, are seized by the workers upon the mounds and others upon the neighboring grass stalks and weeds, and are thence forced into the hill. But there must be some who drop upon secluded spots, and unobserved, begin measures for the establishment of new families, according to their instinct. These families eventually erect independent hills, which in turn become the mother hills of new hill-clusters. Thus ant colonies, like some groves and forests, grow from the parent stock by "shoots." In some cases, it may be added, there is a small abandoned moss covered mound which seems to have been the original capitol of the republic. But like many a now deserted and grass grown village of human inhabitants, formerly the seat of flourishing and active traffic, the tide of fortune has swept away from the once thronged galleries, and busy communities in vastly increased proportions, have sprung up around the original settlement.

Building Materials.—The materials composing an ant hill are various, although the sandy soil forms well-nigh the entire bulk thereof. This soil, so far as I observed, is always brought from the interior of

the mound, through which it must have been carried from the galleries beneath the surface. Besides this, bits of decayed wood, the needle-like leaves of the pine, pieces of grass, and leaves of shrubs are intermixed with the earth. The soft particles of wood, small and freshly cut, were often found distributed during the night over the surface of hills which had been free from them the day before. There was a similar covering up of the summits of hills with bits of straw which seemed to have been taken from the tufts of grass growing out of the base. I have seen ants upon the grass, as though at work, but have never witnessed the actual severing of the stalk. There can be no doubt however of the fact that these straws are collected (if not cut off), and arranged upon the mounds.

Cutting off Foliage.—That the insects do cut off foliage for such uses may be considered as established by the following fact. A hill kept under constant observation was found covered one morning with the black decayed leaves of a wild indigo plant (Baptisea tinconia), which grew within two feet. The upper part of the shrub had been broken partly off, probably by one of our party, and was bent over towards the mound. The leaves upon this portion were black, upon the rest of the plant green. The black leaves upon the hill had therefore been cut off from the bruised top, carried to the cone and distributed over two or three square feet of the surface quite thickly. A very great number of these leaves had thus been disposed of. In cutting into the hills, however, I do not remember to have found any traces of this surface litter, so completely had it decomposed. I observed it afterwards being covered up; but the query was raised in my mind, is not its chief use to form an external protection or blanketing against the weather? Several of the hills opened showed stones from the size of a man's fist to the size of his head imbedded in the heart of the cone, and raised one or two feet above the ground surface. One such stone is shown in the lower mound Pl. V, and another in the angle of the sections at Pl. VI. These stones were probably the remains of bombardments by truant boys, and had simply been covered over by the patient workers and the hill built up above them.

Architecture.—What are the methods (and principles shall I say?) of architecture, by which the Fallow ant prosecutes her immense labors? This was a question which deeply interested my mind. But for the first four days of our stay in camp nothing new or satisfactory presented. The weather was warm and dry, giving no signs of a change. There was little doing in the line of improving the real

estate of the colony. Here and there a hill was being covered over with fresh pellets of soil, which the ants were bringing from the interior, and scattering equally over the surface. This showed that the work of enlarging the galleries, perhaps the underground galleries, was being pushed forward. But this was all. Artificial showers, produced with wisps of grass, failed to create any architectural activity. However, the evening of Friday (Aug. 18), proved a happy exception to the traditional ill omened character of the day, for it brought to our ant city a heavy, protracted shower. From 9 to 10 o'clock P. M., I was out with lantern and umbrella to note the effect upon the ants of the rain, which was then comparatively light. The insects were working much as usual. They crowded in columns along the avenues; they thronged the trees-paths, and covered the feeding-grounds collecting honey-dew from the aphides; they wrought quietly upon the hills. At 4 A. M., at the severest period of the storm, when the rain was falling very heavily, I again went the rounds of the hills, some 8 or 10, which I had marked for close, continuous observation. Matters were very much as before, the ants appearing to be scarcely disturbed.

After daylight, the scene presented was an exceedingly lively and interesting one. The utmost activity prevailed on every hill, and the whole architectural habits of the little builders were uncovered to observation. These may readily be seen by reference to the following figures. The drawings were made upon the ground and are transferred from my note book without change in order to secure entire accuracy in architectural plan and detail. Figures 1 and 2 were drawn from work done upon a small hill which had been cut across the top in order to study the construction of the galleries. On the day before the shower one-half the cone was left standing, the broken cells and clay cleared away and thrown to one side. The work of restoring the ruined half began immediately upon the former foundation. The pellets used upon the works were for the most part brought from within. Squads of workers were continually thrusting their heads out of the galleries opening upon the perpendicular face of the remaining half-cone, and dropping down pellets. These were taken up by squads below and wrought into the galleries and halls represented in the cuts. I remained for a whole day before this and another hill, observing when accuracy required, with a magnifier, which I was able to do without disturbing the busy little architects. The method of observation was to note each step made, changing the

sketch as the work advanced, recording at the same time the changes. Thus my outline grew upon the paper as the work grew upon the ground.

Building Galleries.—Fig. 1 represents a covered way or gallery 6 inches long, which started on the foundation 3 or 4 inches below the surface of the field, and ran up toward the half-cone at an angle a little less than 45°. When first seen it was an open gallery or ditch, and was observed until it was entirely covered over except one door or round hole near the top. The work progressed by the continuous addition of the earth pellets to the outer edge. The pellets

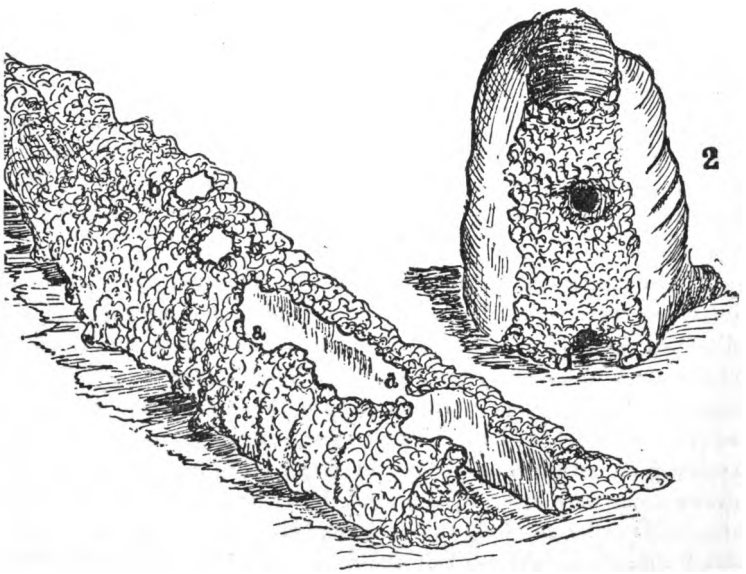


FIG. 1.—Covering Galleries. (1), horizontal gallery; (2), vertical gallery.

were carried in the mandibles of the ants, and were usually pressed into position. The springing of the arch was plainly seen, the two sides slowly approaching each other in irregular lines as shown at *a*, *a*. Gradually two points drew near and nearer, until they well-nigh touched. It was quite exciting to watch now the delicate manipulation of the architects. Here comes a worker with pellet of larger size; she climbs the arch, reaches over, holding the while by her hind feet, and drops the ball of soil into the breach. The bridge is made. And now with surprising rapidity it is widened until the roof of the arch assumes the appearance indicated at *b*, *b*. Circular openings

or doors are habitually left in the work, through which the ants are moving back and forth, apparently working upon the inside to strengthen the arch. As sections of the building are completed these doors are closed, so that they are plainly but temporary arrangements for the convenience of the masons.

On other parts of the foundation similar structures were going up. At 2, Fig. 1 was a section of a vertical column, one side of which had been cut away. It was two inches high, one inch across. The ants were working upon this in the same manner as described above. They built not only from the bottom up, but from the side across. The central opening in the figure was finally closed, leaving, when the work ended, the opening at the foot of the column. The circular gallery thus enclosed was one-half inch in diameter, which is about the usual dimensions. The work of construction was not confined to the space which, as in the above cases, was the original site of the cone. Having occasion to lift up a fragment half the size of one's head, which had been thrown to one side, I saw that the section had already been made the nucleus of a new mound. Columns, corridors and halls, corresponding closely with those outlined upon the under face of the fragment, had been erected, which were thus quite united to the fragment. In one of the halls was a small collection of dead ants. The greater portion of one day was spent in studying and recording the work upon this one hill. Other drawings were made from different positions, but the method and result were the same. As the activity occasioned by the shower continued for the remainder of our stay, I had full opportunity by subsequent observations to verify my notes.

Fig. 2 is another example of architecture drawn from the same broken hill. The figure represents a double gallery which was built up against the perpendicular side H of a hole cut by the spade in removing the cone. The gallery a, a, a, was carried along the base of the side 3 inches, and then upwards toward the surface. The gallery was widened at two points c, c, to $1\frac{1}{2}$ inches, as though intended to serve as store-rooms for cocoons. Galleries opening downward communicated with these enlargements. At e ants were arranging pellets along a projection on the side, for what purpose was not apparent.

My attention was next directed to the large hill Pl. II, which with its surrounding hill-cluster was on my regular "list." I took this plan of keeping several hills under regular, daily, and indeed for

much of the time hourly observation, for the obvious reason that thus I could become "acquainted" with the workers, could trace the work done, and confirm or condemn previous conclusions as the case might be. In this hill a track had been made by one of a herd of cattle grazing in the field. The foot of the steer had left an irregular depression, measuring 9 inches each way, in depth 8 to 9 inches, the lower margin being 6 inches from the base of the hill.

Engineering.—The lower part of this track is shown at Fig. 3, in order to exhibit what seems very much like a deliberate and well planned system of engineering, in filling up the hole. The drawing

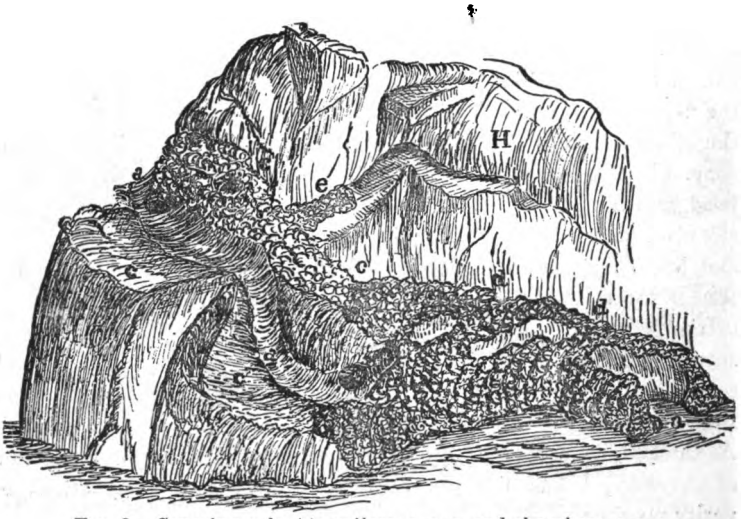


FIG. 2.—Covering a double gallery *a*, *a*, *a*, and chambers, *c*, *c*, *c*.

is one-half natural size. At *A*, *a*, the original hill is shown, marking the southern limit of the foot-print. The work of filling up against this had begun. From the lower point *A*, marking the outline of an arc, were the following works: *b*, a circular column 1 inch high, from the upper base of which, a broad bifurcated plateau was being extended; next to this was an oblong mound *c*, ½ inch high, and beyond that, marking the opposite limit of the track, a lunette *d*, 1 inch high. Beyond this, toward the base of the hill, and parallel with the arc *b*, *c*, *d*, was thrown an arc of like but smaller lunettes *i*, *i*, *i*. At *e* and *f*, were lunettes similar to *d*, and at *g*, a scolloped mound. These elevations, with that at *k*, *k*, surrounded the cavern *h*, which was the deepest part of the cattle-track. The plan of opera-

tions is very plain; from the little raised columns and mounds figured above, the work of covering in could proceed with the greatest advantage. The elevations *b*, *c*, *d*, were evidently guaged by the height of the edge of the hill at *A*, thus marking the depth of the track on that line. The diminishing depth was met by a corresponding lowering of the lunettes *i*, *i*, *i*, and at other points in the excavation the same facts held good.

The above operations began on Saturday morning; on Monday morning the cavity was two-thirds filled. Very strangely the work did not connect with the face of the break towards the summit of

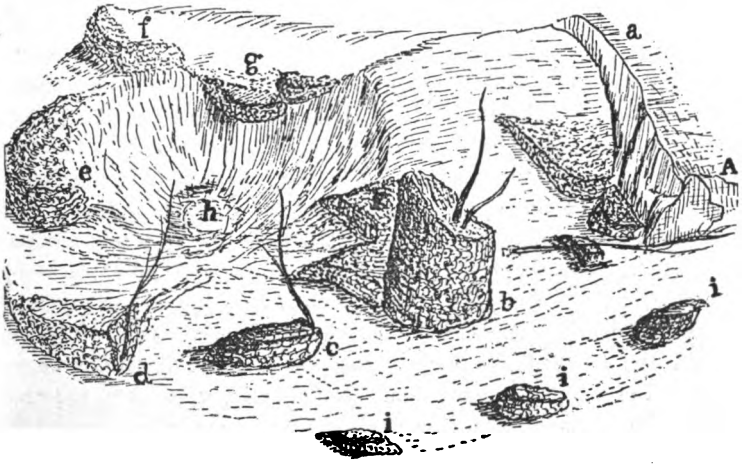


Fig. 3.—Engineering work; filling up a break.

the hill, but a deep trench or gallery had been preserved all the way across, the wall being maintained intact. The photograph was taken on this day, and the track with this trench may be seen in the plate. Nor was there any appearance here of the formation of the galleries above described; it was dead filling in. In one of the little hollows the shells of cocoons, out of which antlings had just been delivered, were piled up, apparently to assist in the filling. I had before observed these being carried from this hill and deposited on the stones outside. A number of straws were worked into the columns, evidently as braces. A few feet from this large mound was a small hill, one of its off shoots, which even before the rain had shown much activity in construction, for the surface was covered with fresh pellets. The shower had inspired the inmates of this young community with amazing zeal.

Adding Stories.—On the east and west sides of the hill several inches from the top, deep fissures had been cut, looking like sun cracks, the lower edges of which were being built up, and the upper bent over. An additional story was thus being added to the cone. Here grass-straws were strewn over the summit, and others which I threw upon the hill were dragged into place and utilized with skill. This story was well nigh completed by Monday morning. The building was carried forward (and such was the case on the large hill and on others observed), by erecting warts or small cones upon the surface and around the openings or doors of the galleries, and filling between them. I could trace evidently the outlines of galleries laid out.

Pellets.—The question arose, especially in view of such operations as the covered gallery at Fig. 1, by what means are the pellets of earth, used in building, caused to adhere to each other? The fact is beyond question in my mind that the ants proceed with intelligent purpose, directed by experience, to spring the arches of galleries and lay out and conduct other building operations. But I was anxious to know whether the pellets were fixed in their appointed places by "mortar" formed from the natural moisture in the soil or by some secretion from the ant. I feel well assured from the facts above recorded and kindred observations, that the moisture of rain is necessary for the work of construction. The galleries were being enlarged during the dry weather, and the pellets thrown out in large quantities upon several hills; but there was no effort to erect them into stories and galleries for enlarging the hills. The heavy shower was the signal for such work to begin, and it went on energetically and continuously throughout the succeeding period of our stay, during which the effects of the shower upon the earth were apparent. This would seem to indicate that if there be any secretion from the mouth organs of the insect (which I do not think probable), it is insufficient to procure the adhesion of the pellets. A highly suggestive remark was offered by Prof. Köenig, in connection with a verbal communication made to the Academy of Natural Sciences, Philadelphia, of some of the above facts, viz.: that formic acid which is so abundantly extruded by these ants, forms with the silica of the soil a natural cement. Can it be, that these pellets which are composed largely of sand, are thus cemented together? At least, one who may have the opportunity to make observations similar to these here recorded, should pay particular atten-

tion to the use made by the builders while laying the pellets, of their abdomens from which the acid is secreted.

The thought occurred to me that the conformation of the pellets themselves might greatly aid their mutual adhesiveness. A number were therefore submitted to close examination. The figures at Fig. 4 are magnified drawings of a few of these forms. They evidently are each accumulations of small particles of soil, united in various irregular shapes, by the pressure of the mandibles. Some of them present the appearance of being cut down from larger masses, or cut away upon the face. This may simply be the natural result of manipulation under that toothed organ which serves the ant as trowel, chisel, spade, hammer and hand. Whether or no these pellets be wrought into their peculiar shapes with deliberate and intelligent purpose; or, are only an accident of their preparation or handling, it is obvious that their form must greatly facilitate the work of the ant in fastening them together. The irregular faces of the pellets fit into and fasten upon each other, uniting the whole in a way which may not indeed be properly characterized by the terms "dovetailing," and "ball and socket" jointing, but which nevertheless gives one a rude impression of such mechanical contrivance.

After having expressed the above opinion in the Academy, I submitted some of the pellets to Dr. Joseph Leidy for observation under the microscope. He gave me the following opinion: "The pellets, examined by the microscope appear to be composed of several small rounded or ovoidel balls cemented together by the same material. I could detect no special mechanism like facets or 'ball and socket' jointing." This was accompanied by a figure of a representative pellet which is marked *L* in the group. It will be seen at a glance that it does furnish a rude socket into which the projections upon other pellets might readily fit.

FIG. 4.—Group of pellets of soil used in architecture.

Age of Hills.—What is the age of these hills? or more properly speaking, How long does it take a community to erect hills of such sizes as are here represented? There are various conditions which must cause a necessary variation in the progress of the work at different times and places. The condition of the season as to moisture, the nature of the soil, the inroads of enemies, the size and necessities of the community, and other contingencies must make a difference

between the growth of the hills as compared with each other, and in the growth of the same hill at different periods. It seemed possible however to make a rough estimate of the rate of progress. Adjoining the wood in which the ant city is located is a field owned by a Mr. Prough, a farmer long resident in the neighborhood. Several hills had sprung up in this field, since the last crop had been taken from it. This seemed to promise the data for calculation. The field had been plowed in September, 1875. The following measurements were made by Mr. Prough and Mr. John McGinnis, February, 1877, viz.: Hill No. 1, 8 ft. 9 in. around the base, 10 in. high, 2 ft. 11 in. in diameter. Hill No. 2, 11 ft. 4 in. around the base, 14 in. high, 4 ft. in diameter. Also, in a corn field plowed July, 1876, two hills were measured, each of which had the following dimensions: Nos. 3, 4½ ft. around the base, 8 in. high, 1 ft. 6 in. in diameter. Nos. 1 and 2 are the result of but a little more than one year's work, viz.; from September, 1875, to November, 1876, at or before which time the frost stops all work. Nos. 3 exhibit the result of about two months active labor, one-third of the working season. The amount of work done may be thus calculated (roundly); in No. 1, 1¼ cu. ft. per year; No. 2, 3 cu. ft. per year; Nos. 3, each 1 cu. ft. per year.

Hill No. 2 exhibits the most remarkable increase, having attained more than half the average size of the mature hills (if I may use that expression), in little more than a year. It may be that this was simply the re-erection of a hill that had been ploughed over, and of course went on more rapidly as a large community at once centered all efforts upon the work. Nos. 3 seem to be examples of growth on the part of new communities. Making allowance for the varying progress occasioned by varying communal exigencies, we may estimate the time required to complete a mature hill to be from five to seven years. After that the activity of the workers finds employment in the construction of new mounds.

I had hoped with the above data of annual growths, and the dimensions of a number of hills, to obtain by a simple calculation and with reasonable accuracy, the age of any hill. But I am compelled to abandon this hope by the fact that the largest mound reported at Pine Hill, the largest of which I have knowledge, having a cubic contents of about 300 cu. ft., is built upon an old charcoal hearth. It is therefore of quite recent date. The upbuilding of such a cone within so limited a period indicates an immense capacity for accomplishing work under certain favorable conditions. While the above

facts fail accurately to satisfy the inquiry as to the age of the hills, they are interesting as showing to some extent this capacity for work. I have good reason to believe that some of the hills are at least thirty years old. They probably do not grow after having reached a certain bulk.

Building by Compass.—One other point in the architecture of the hills engaged my attention. The mounds were observed very generally to have the longest face of the cone toward the west. Is this merely the result of gravity and the wash of the rains, since the mountain slopes toward the west? Or, is it a characteristic habit of the hill, fixed by the purpose of the ant? I was led into this inquiry by Huber's statement concerning the Yellow ants (Formica flava), of the Alps. Their habitations there take an oblong and almost regular shape. They lie in a direction east and west. Their summit and the greatest slope always faces the east; but they incline also on the opposite side. This peculiarity, which was verified upon thousands of ant hills is not preserved in the plains, probably because of exposure to derangement by men and the lower animals.

Huber's description of the position of the yellow ant hills corresponds with the fallow ant hills at Camp Riddle, except that the position of the greatest slope is reversed; *i. e.*, it is toward the west instead of the east. By the greatest slope I mean the longest slope, as I suppose Mr. Huber also means. Of a large number of hills examined and recorded by myself, 94 per cent. had the long slope westward, the steepest slope eastward. Of the remainder, more than half had the long slope toward the southwest. To determine, if possible, whether a change in their general form would follow a change in the slope of the land, I noted particularly the position of a few hills upon a ravine in the face of the mountain whose sides sloped nearly north and south; also of those upon level ground, and of hills built upon the sides of a deep cutting made by ore miners for purposes of drainage. The result left my mind in doubt. Several cases were noted in which the general tendency had plainly prevailed over such influence as a different slope and gravity might have exerted. On the other hand some hills were found the longest slopes of which appeared to be carried from the general direction by a corresponding slope of the land.* The impression left upon my mind is that the habit of the

* Extract from note book; "1 hill clearly determined by the slope of the gully to face (longest slope), N. W. 2 hills long slope S. W. with tendency to W.; apparent struggle to face W., in one case nearly successful. 1 hill S. E. appa-

hill is to present the steepest slope to the east, the longest slope to the west; in other words, that the ants habitually build their mounds with respect to the points of the compass, the variations being due to opposing circumstances.

In order if possible to settle this question, I requested Mr. Kay to bear it particularly in mind in his observations at Warrior's Mark and Pine Hill. He reported the results as follows:

Section 1. The surface sloping west.

Number of hills with long slope			North	0
"	"	"	South	4
"	"	"	East	3
"	"	"	West	46
"	"	conical		20
"	"	facing East and West		1
Total				74

Section 2. Surface sloping north at an angle of about 20° depression in one part, and about 10° depression in another.

Number of hills, longest slope			North	10
"	"	"	South	3
"	"	"	East	8
"	"	"	West	24
"	"	conical		10
Total				55

Section 3. Surface sloping northwest and west.

Number of hills, longest slope			North	17
"	"	"	South	9
"	"	"	East	17
"	"	"	West	198
"	"	conical		52
Total				293

The percentage of hills facing in the general direction, as compared with the others may thus be presented in one view.

	Long slope W.	E.	N.	conical.
Section 1, slope W.	.62	—	—	.27
Section 2, slope N.	.436	—	.18	.18
Section 3, slope N. W. and N.	.675	.06	.06	.174

It will be observed that in Section 2, where the land slopes north, the general habit of the hill prevails, but the slope of the land has

rently determined by a declivity. 1 hill E. apparently might as well have faced W. 2 hills on a sharp E. slope of cutting looking with long slope W. in spite of gravity. 1 hill on E. slope of gully, with long face W."

exercised an evident diversion, influencing 18 per cent. of the hills to present the longest slope to the north. In Section 3, with the prevailing slope of land toward the northwest, the north gains but a small per cent. of the long slopes of the hill. On the whole, the above exhibit strengthens the impression made upon my mind that the ants have some regard to the points of the compass in building their mounds, although there is certainly nothing like the regularity that Huber attributes to the Swiss yellow ant hills, which makes them a safe compass to the mountaineers in foggy weather.*

Galleries.—Much attention was given to the structure and extent of the galleries. The mode of erecting them above ground has already been fully illustrated. I had half sections of a number of hills sawed down and cut away in order to study the arrangement of the galleries; and to obtain accurate figures for comparison and more favorable study, I had a few of these section views photographed. Some of the hills were cut east and west, some north and south, others at random. I found that quite generally the greatest regularity in the direction of the galleries was north and south, although one hill showed equal regularity east and west. This fact may be observed by examining carefully the two hills of Pl. IV, the lower one of which is cut north and south, the upper east and west. The double hill at Pl. V will illustrate the same feature. The lower hill is cut east and west and a quarter section taken from the upper one thus exposing in one view the result of both the north and south, and east and west cutting. The tendency of the galleries is to cross the hills at right lines. They have the appearance of being laid regularly one above the other. This feature may be noted most satisfactorily in Pl. IV, lower hill, in the shaded portion of the perpendicular section, at the right and toward the base of the cone. The openings of the galleries were carefully cleansed of soil, so that they might present as natural an appearance as possible before they were photographed. Nevertheless, much to my regret, the plates fail to show perfectly the peculiar structure of the interior of the hill. A tolerably accurate knowledge, however, can be formed from the plates.

Underground Galleries.—Thus far we have been dealing with

* I had intended to withhold the observations bearing upon this interesting point, (and indeed other details herein recorded), until further investigation should lead to some definite conclusion. But, in the hope of stimulating some one nearer the field to take up the inquiry, and influenced by the publicly expressed wishes of several eminent naturalists for all the information to be had concerning the habits of ants, I have thought it better to submit my notes even at the risk of burdening this paper with matter that may be valueless.

that part of the formicary which is above ground and is apparently the most considerable. There is however a hidden portion which is immense in extent, and must have vast importance in the economy of the community. Every hill furnishes a fair measure of the extent of the underground system of galleries connected therewith; for it is reasonably certain that the entire bulk of soil in each mound has been excavated and brought up from the galleries beneath the surface. The average width of the upper galleries is about three-eighths of an inch; the maximum width not exceeding one-half inch. The underground galleries are probably of the same size. A glance at these mounds, therefore, at once gives indication that an extraordinary system of subterraneous galleries must be connected with each formicary, I made no satisfactory examination into the arrangement of this system; this might have been done, perhaps, by sinking a deep trench close to a mound and extending it for some distance. But the soil is so very full of stones that even thus the results might not be satisfactory. No doubt the ants descend to considerable depths utilizing the stones in various ways, for example for roofs and walls, as they do upon the surface. It would hardly seem possible to preserve any great regularity in the course of these underground ways which must constantly be diverted by the stones. But they undoubtedly can be held to a general course, and are carried with great directness from point to point when it is desired to communicate with the trees and feeding places. I was able in one case to trace the extent of the galleries near the surface in the following way. Tapping upon a hill whose inmates were in a particularly "nervous" condition. the ants issued in excited hordes not only from the doors of the mound, but from various points on the surrounding surface. Taking a principal centre of excitement, four or five feet distant, a stone underneath which was an entrance to the galleries, I again agitated the ground. The ants as before issued from the surrounding surface, chiefly upon a line running eastward, up the slope. At the limit of excitement, which was something less than before, I once more agitated the stones and earth with like results. Thus I traced this surface gallery eastward about 60 ft., where the excitement under the above treatment ceased at an oak tree. I am satisfied that as a rule the central formicary or hill communicates with the trees which serve for feeding grounds, by galleries as long as or much longer than this.

Entrances or Doors.—The principal entrances to the formicary are at the foot of the hill. They are commonly placed around the entire circumference of the mound, and are arranged in two, three,

or more circular rows, one above another. At certain points where, apparently, there is need of especial vomitory, the gates are much multiplied. Besides these, there are openings at irregular intervals upon the entire surface of the cone. These are not numerous, but sufficiently so to allow easy approach to and exit from the more elevated portions of the mound. The main dependence appears to be upon the lower gateways. It would seem, at first thought, that there could be no real necessity for so many doors; but one who has witnessed the rapidity with which the myriads of workers swarm upon the surface when their nest is attacked will at once perceive the economy of these numerous gates. The doors are simply the surface openings of the galleries with which they correspond in size.

Huber declares it to be one of the fixed habits of the fallow ant (F. rufa), of Switzerland to close the gallery-doors at night and reopen them in the morning. The most careful attention could discover no such behaviour among the ants at Camp Riddle. At no time during the whole week was there observed any sign of attempt to close up the galleries. Even during the heavy storm of rain referred to, the doors which were closely examined at various hours of the night, remained open. It would have been more satisfactory could an observation have been made during a fall of rain in the day time, but I have little doubt on this point, and none at all on the ordinary night-condition of the doors. This is certainly a remarkable variation in habit. It may possibly be accounted for by the presence in Switzerland of some nocturnal enemy, from which the American congeners are free.

Before taking up in detail the life habits of our mound builders, a comparison and contrast may be allowed which may give a popular illustration of the immense labors of the fallow ant. I have calculated the cubic contents of one of the largest hills to be, in round numbers, two millions of cubic inches. Let us estimate the bulk of an ant equal to that of a cylinder three-eighths of an inch high and one-sixteenth of an inch in diameter at the base. We have thirty-five one hundred thousandths of a cubic inch as the bulk of a single ant, or two thousand eight hundred and sixty insects to the solid inch. The size of the builder is therefore to the size of the edifice as *one* to *fifty-eight thousand millions*. Let us compare this with a corresponding estimate of the work of man (taking his bulk at four cubic feet), as wrought upon the great pyramid, reckoned to contain two hundred and seventy-six millions of cubic feet.

Man's bulk to his building is as 1 : 69 millions.
The Ant's bulk to her building is as 1 : 58000 millions.

The figures are given roundly, without strict verification; they show vastly in favor of the mechanical energy and industry of the insect, if such comparisons may be allowed to show anything, which is perhaps doubtful. They may serve however to impress some minds more vividly than other methods, with the immense activity which marks the wonderful realm of insect life. The advantage is yet more striking when the period of time consumed in erecting an adult hill, as heretofore shown, is compared with the thirty years which one hundred thousand men spent in building the pyramid. Moreover, as will also appear, the superstructure or hill, is by no means the whole of the formicary. A vast system of subterraneous galleries penetrates the earth to unknown depths and distances, requiring labors which in magnitude may well be compared with those which excavated the catacombs of Rome.

The above statements conclude the results of my observations upon the architectural habits of the Fallow Ants of the Alleghenies. It remains to give some account of their general habits. The opportunity to study upon the field the internal economy of the formicaries is very limited. For this the use of an artificial nest seems necessary. But I was enabled, more through good fortune than skill, to note some characteristics which, I believe, have not yet been recorded. In order properly to present these some reference to well known habits will be required.

A general description of the insects will first be of interest. These forms are found in the nest: male, female, worker-major, worker-minor,

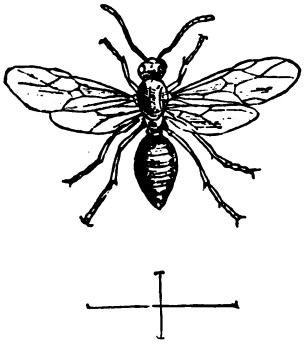


FIG. 5.—Male of *F. rufa*, magnified.

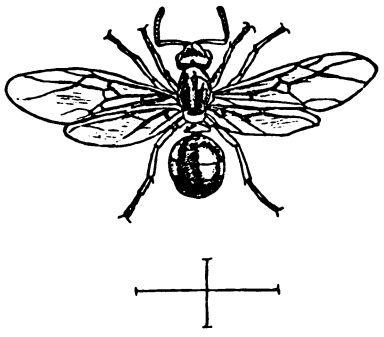


FIG. 6.—Female of *F. rufa*, magnified.

and dwarf. The length of these forms, stated approximately, is as

follows: male and female six-sixteenths of an inch, worker-major five-sixteenths, worker-minor four-sixteenths, dwarf three-sixteenths. The color of all these, except the male is the same, the head, thorax and legs varying from an orange-yellow, to a yellowish-red. The abdomen, except when distended with honey-dew, is black. The wings of the male and female are pale, smoky color. The male is wholly black, and is not so robust in form as the female, and has a smaller head. The illustrations fairly represent the general details of form in the male, Fig. 5; female, Fig. 6; and worker, Fig. 7; the lines beneath the latter figure show the natural length of the three worker forms.* A technical description of these insects will be found at the close of this paper.

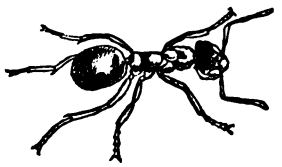


FIG. 7.—W.-major, *F. rufa.*

Food, Feeding Places, Feeding.—As the life of any one hill is substantially repeated in all the others, let us take our stand, for example, before the large mound at Pl. II. The work of construction as above described is being pressed forward upon all parts of the surface. Issuing from, and thronging into the doors that skirt the base are two columns of workers. Their fellows are hovering around the gates, hurrying backward and forward upon their several duties; but these columns keep up a steady march and countermarch, without visible diminution of numbers and (with a single exception which is recorded hereafter), without cessation day or night. One of them stretches off to the southwest, disappearing at intervals under flat stones, appearing again and crossing the top of similar stones, intersecting the lines of workers busy about the small surrounding hills, and, penetrating the jungle of grass beyond, is finally distributed among a number of young trees not far distant. The other column leads off to the southeast, up the hill a distance of eight rods, to an oak tree having a girth of twelve inches, which stands by the stone wall or fence that marks the limit of the field. This "avenue" (as we may designate the path which such a column pursues), keeps a well nigh straight course. It crosses at one point a footh-path used

*The cuts in these pages are reproduced by photo-engraving from my own rough drawings, except these three figures for which I am indebted to Dr. Edw. J. Nolan, the Secretary and Librarian of the Acad. Nat. Sciences, Phila.

by the farmers on their way over the mountain to the town. There is no marked impression upon the surface as of a worn or prepared road, but the boundaries of the avenue are constant, the ants invariably traversing the same general limits, which vary from one to three inches in width. Leaving the avenue at the foot of the young oak, the column stretches its double line along the trunk and is distributed among the principal branches. A considerable portion leads off upon one of the lower limbs which overhangs the stone fence. I mount this wall, and at once have the key to the movements of the promenaders upon the avenue beneath.

Galls.—At various points along the bough and its branches vast numbers of aphides are clustered. Many of these are fastened upon the bark in the usual manner, the head depressed, the abdomen elevated. Others are clustered about small oak galls, some white, marbled with black, some of a pink-brown color with rings, some of a brownish hue. These galls contain a quantity of minute black powder, a number of very small white oval eggs (?), and a grub three-tenths of an inch long, with twelve rings, head marked with black, a black ring on the neck, and three pairs of feet. The ants seemed to be feeding upon these galls; they at least fed upon the juices of several of the grubs which were crushed with the point of a knife, while removing the galls. These, however, are but secondary objects of attention. The aphides, black insects, with brownish thorax and head, are the centres of principal interest. Here is one whose abdomen is elevated at an angle of about 45°. Upon the apex is shining a tiny globule of transparent liquid. It is greedily lapped by the attendant ant, who all the while, with alternate strokes of the antennæ, gently embraces or pats the insect. Again and again in rapid succession the sweet secretion, (the honey-dew of popular speech) gathers in drops, and is removed by the ants, several of whom have in turn enjoyed the refection. At last the aphis, one of mature size, leaves its position and moves along the limb towards the trunk. It is passed by groups and individuals of ants all of whom greet it with the antennæ as though testing its disposition or resources, and at once allow it to

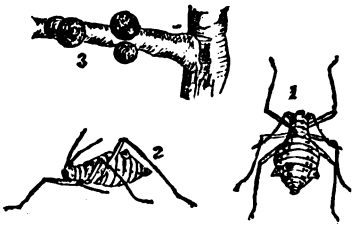


FIG. 8.—Aphis and galls. (1), aphis, back view; (2), same, side view; (3), galls. Aphis, *Lachnus Allegheniensis*.

pass on. Its abdomen appears flattened. Many of its fellows are rounded out with fullness, and must evidently be uncomfortable. The ants, however, are fast relieving them, and in the meantime, their own abdomens are undergoing a very noticeable change. They swell and elongate, until the folded bands which unite the several segments or rings are pulled out from their V shape into a straight white ribbon. The abdomens are quite translucent at last, and the burdened honey-gatherers turn toward home. Let us for convenience, call the ants in this condition, "repletes." Standing at the foot of the tree one can notice that the individuals in the ascending portion of the column have round black abdomens, while those in the descending portion are nearly all repletes.

There were two facts connected with the above observations, which for several days puzzled me. I observed that among the crowds of workers thronging the avenues radiating from the hills to various points, chiefly oak trees, the number of repletes was relatively small. It seemed out of proportion to the numbers of repletes seen descending the tree-paths from feeding grounds, with abdomens distended and translucent with honey-dew. Moreover, numbers of workers were observed returning to the hills *without* swollen abdomens. If they had not been foraging, what then? Or had they simply been more moderate in the indulgence of appetite? I was led by these reflections to follow the repletes down the tree-paths with greater care, and observed some of them disappearing at the roots. I now turned back the sod, cleared away the leaves, and observed this interesting fact: At the foot of the tree, particularly in the angle of the roots, the descending ants or repletes were stopped by workers seeking food, "pensioners" let us call them. Evidently a gallery or galleries communicating with the hill had been opened at these points, and around the openings numbers of insects were huddled together, some trying to escape down the galleries, some opposing or hindering these, and others engaged in drawing or bestowing rations of honey-dew. The process was commonly as follows: The replete reared upon her hind legs and placed her mouth to the mouth of the pensioner who assumed the same rampant position. Thus the meal passed. Of course I could not see the process of disgorgement, but could have no doubt of the fact that the builders had thus come to be fed in the same manner that queens, males and young ants are fed. I frequently saw two, sometimes three ants thus feeding at once from one replete. The repletes commonly made no objections, at least submitted quietly; but at times I noticed

what appeared anxiety to break away without parting with any of the precious treasure. The pensioners would occasionally solicit with their antennæ. Once at least the replete was seized rather vigorously. After the feeding, the repletes dashed into the galleries and disappeared through the mass of legs, heads and black abdomens of ants, all stationary and apparently engaged as above. Although the peculiar position of the fallow ants under these observations prevented me from seeing the actual process of regurgitation, yet in the case of other ants imprisoned in glass jars I have seen the passing of the honey-dew from the mouth of one insect to that of the other.

The repletes that passed down the tree without being arrested, were generally met beyond by the pensioners. Removing the flat stones around the roots, I found the insects engaged as above. The under surface of these stones seemed to be a sort of commissary stations. I covered over one cavity, made by the removal of a stone; in which I had surprised a number of ants, expecting thus to re-establish a feeding station. It happened as I had hoped. Presently lifting the stone a little, I surprised a pensioner drawing his rations, and others scrambling away as though disturbed.

The above facts were confirmed by numerous observations, at various points.

I have frequently seen the Pennsylvania Carpenter Ants, *Camponotus* (*Formica*) *Pennsylvanica*, occupied in the same manner. In one case the exchange seemed to be between occasional workers, and members of the "body guard" which constantly surrounded the fertile queen of a small colony under observation in a box. Other ants have the same habit, but the main significance of the behaviour above described is in the view which it gives of the public economy of the ant republic. It exhibits a concerted, systematic and general movement which has very much the appearance of an acknowledged division of labor. Those members of the community engaged in the work of building and protecting the formicary, really appear to leave the collecting of food to others of their fellow-citizens, not only for the helpless and dependent inmates of the nest, but also for themselves. Content with satisfying the simple wants of nature, that they may have strength to toil, they leave their work at stated periods, and visit the feeding grounds to obtain food from the super-abundance of the repletes. The stations are chosen for this purpose with admirable wisdom, for, as many of the foragers really seem to overload themselves, their progress homeward is doubtless facilitated by yielding

somewhat from their stores, and no loss is wrought to the commonwealth. Besides, it seems probable that the instinct which urges the repletes to gather store for the larvæ, nymphs and other dependents, might effectually prevent them from yielding such store to any others, after the formicary had been reached. It may be supposed, since ant nature is not unlike human nature in some respects, that the surplus honey-dew, after feeding the dependents, would be kept for individual delectation, and thus the builders and sentinels be compelled to leave their work, and forage for themselves. The general movement, therefore, to arrest the repletes at the stations near the feeding grounds is evidently for the public good.

Sentinels.—I observed on the tree-paths a movement that had the appearance of some policy of police. Workers, with the normal round black abdomen, were scattered at intervals along the trunk. They did not seem to belong to the line of ascending foragers, but rather to be stationary, as though they were sentinels or policemen. They were active in challenging with their antennæ the repletes who were on the return, and were quick to resent any interference made by intruding a finger or straw upon the path. This statement is made with reservation as I was not able fully to satisfy myself that the facts revealed a fixed habit. The point, however, is well worthy of future investigation. There is at least a probability, from analagous habits of the ant, that the individuals referred to above were indeed sentinels as their behaviour indicated. It is a well established fact, in the economy of ant hills, that sentinels are posted at or near the entrances, and common avenues of approach. I satisfied myself of this by very many observations and experiments which it is not necessary to relate in detail. It will suffice to say that on every occasion of approach of any object to a hill or entrance, workers instantly sprang upon the surface. These sentries were constantly seen lurking just inside the gallery doors, whence they issued with every mark of intense vigilance and excitement the moment a finger was intruded or the smallest object dropped near them. Frequently they patrolled the vicinity of the gates. They attacked every intruder with the utmost promptness and intrepedity. It gave subject for great wonder to note the rapidity with which an alarm was communicated throughout a large hill. Two hills in particular, whose inhabitants were for several days in a condition of high nervous excitement, attracted attention. Standing a yard or more from the base, I would agitate with my foot a stone which evidently had communication with the interior of the mound. There was scarcely

an appreciable interval of time ere the whole surface of the cone was covered with insects. The black and red masses whirled in indistinguishable mazes producing a very perceptible buzzing sound by their rapid movements. Even for several feet beyond the hill, on the opposite side, the excitement extended, and was manifest with almost equal rapidity.

Tree-paths.—The word tree-path, as used above, perhaps needs a brief explanation. It was observed that the ants ascending and descending the trees invariably kept to a beaten track, two or more inches in width. In many cases this track or tree-path was stained, the entire length of the trunk, a brownish-yellow color, caused doubtless by the formic acid which the ants secrete. The position of these tree-paths is determined by the situation of the hill to whose domain the tree belongs, for each community has its own special feeding grounds upon which intrusion is rarely if ever made. The tree-path is located habitually upon that part of the trunk which directly faces the hill. This was verified by observations upon a very great number of trees. One illustration may be given. The group of hills at Pl. III, as may be seen in the figure, was located in a considerable open space entirely surrounded by oak trees. The tree-paths were distinctly marked upon nearly all of these, showing long use, and on all of them, were columns of ascending and descending ants. Starting at any one tree, and following the circuit entirely around, it was found that the positions of the tree-paths change as one proceeds, being always inward and facing the hills. No test could be more perfect than this, the conclusion being very much to the credit of the general emmet-faculty for economizing time and labor.

An Ancient Record Confirmed.—It is worthy of note as confirming one of the most ancient records of the economy of ants, (Prov. vi. 7), that in all these movements in column, and in all building and foraging and police operations, the ants exhibited an entire independence and individuality of behaviour. Each emmet seemed to be a law unto herself, and turned freely and commonly unfailingly into the most helpful and necessary channels of duty, "having neither guide, overseer nor ruler."

Miscellaneous Food.—It will be best to introduce here further observations made upon the food consumed by these ants. No sort of attention was paid to grain and grass seeds thrown upon and near the hills. Dead beetles, hornets and other insects were found surrounded by groups of ants evidently intent upon utilizing the carcass for

commissary purposes. Ants were also found carrying the blossoms of plants and flowers. Into a little colony, settled within an artificial formicary, was introduced a large female wolf spider (*Lycosa lenta*), one of the most powerful and ferocious species. The ants attacked her with demoniacal fury, and in a moment had torn off her limbs, and were hurrying the mutilated body into the galleries. The attack showed a courage that was quite characteristic, but the method and results I was wholly unprepared for, and can only be sufficiently accounted for on the supposition of experience with such foes, and familiarity with such food. The sheriff of the county, whom I met casually, assured me that, when he was a boy, he had snared a garter snake, nearly two feet long and fastened it to one of these ant hills. The serpent was instantly attacked, and in two days the bare skeleton was found upon the hill, the flesh having been entirely removed. This was doubtless used for food, but possibly, may have been removed as a matter of cleanliness, as no offensive matter is permitted to remain upon the hills. A young gentleman, in whose statement I have confidence, informed me that he had frequently amused himself by watching these ants catch flies, which was done by a quick spring, very much after the habit of vaulting spiders. It thus appears that the fallow ants fulfill their special duty as natural scavengers, and besides the honey-dew of aphides, which is their "staff of life," are able to prey upon insects, arachnids and even reptilia. This certainly shows a range of appetite which fairly entitles them to rank as omniverous animals. I did not observe them preying upon their congeners, after the manner of some other ants. The only appearance of cannibalism was developed by dropping an ant that had been accidentally crushed upon a hill. The carcass was seized by a worker, who after apparently feeding for a while upon the juices of the crushed abdomen, bore the body away. The dead bodies of their fellows, as with all ants whose habits I have observed, are removed to some separate spot, and sometimes little heaps of carcasses are deposited together as though some rude idea of a charnel-house had entered the little creatures' heads.

Water Supply.—Water is necessary for ants as well as food. I very much wished to test the supposition that they sink their galleries through the light surface soil to the moist earth, or to the water gathered upon the underlying clay. But we were not prepared to undertake the labor required. The following pertinent observation, however, is worthy of record. One day while bending over in close examination of feeding stations at the roots of a tree, I chanced to

cough and expectorate against the trunk in the very track of the descending ants. The moisture was immediately surrounded by ants who lapped it up greedily. Following this suggestion, I procured spring-water and dampened the tree-path, placing some also at the foot of the tree in a wooden insect-box. Quite an excitement ensued. The ants eagerly took the water; some clustered over the damp bark, some surrounded the drops gathered in the crevices, some hung upon the edge and sides of the box absorbing the water from the saturated wood. One ant, whom I particularly observed, hung by the second and third pairs of legs and throwing her head far over into the box drank long. An ant coming up the tree from this trough with minute globules of moisture adhering to the maxillæ and thorax, was rudely seized and the water lapped off by one and another of her comrades. Two ants were observed imparting the water to others in the manner of repletes to pensioners. This experiment was tried at another tree, with the same results, except that the water was not taken quite so eagerly. It occurred to me that this thirst might have resulted from the long separation of the workers from the hills while foraging upon the trees. I therefore made a similar test at three separate hills. In no case was the water received with any show of thirst. Numbers of ants came up, tested, but evidently did not taste it, and turned away. This was the well nigh invariable rule, a very few exceptions being noted. These facts point, first, to the conclusion that the worker ants require water, perhaps quite constantly; and second, to the inference that the ordinary water supply is located in the vicinity of the hills.

Recognition of Fellows.—During the above investigation I was accidentally set upon the track of an interesting discovery. An ant fell into a box containing water placed at the foot of a tree. She remained in the liquid several moments and crept out. Immediately she was seized in a hostile manner, first by one, then another, then by a third. The two antennæ and one leg were thus held. A fourth ant assaulted the middle thorax and petiole. The poor little bather was thus dragged helplessly to and fro for a long time and was evidently ordained to death. Presently I took up the struggling heap. Two of the assailants kept their hold; one finally dropped, the other I could not tease loose, and so put the pair back upon the tree leaving the doomed immersionist to her hard fate.

A number of experiments were now made at the hills For example, thrusting a finger near an entrance, a sentinel instantly leaped upon and fastened herself to it. She was submerged in a cup of water,

thoroughly shaken up, and in a few moments replaced upon the mound. The moisture had scarcely dried into the sand, and the creature roused herself, ere she was attacked by a sentinel and dragged away like a culprit. This was repeated a number of times, on different insects, with the same result. Sometimes the immersed ant would be attacked by a dozen or more comrades at once. These assailants were taken with their victim, submerged and restored to the hill. So with a third series, the assailants of the assailants were themselves attacked, and invariably the same measure meted to them that they had measured to others. Like tests were made with an infusion of winter-green, and with cold coffee, with like results. In some cases the parties assailed were presently released, as though the mistake had been perceived. But for the most part there was every indication of a mortal purpose and a fatal issue. The conclusion therefore, seems warranted that the peculiar odor or condition by which the ants recognize each other, was temporarily destroyed by the bath, and the individuals thus "tainted" were held to be intruders, alien and enemy. This conclusion is certainly unfavorable to the theory that anything like an intelligent social sentiment exists among the ants. The recognition of their fellows is reduced to a mere matter of physical sensation or "smell."

The following may be set upon the opposite side. The conduct of these "tainted" ants seemed to be in curious contrast with the character of the species for pluck and ferocity. It seemed to me that they had the carriage of persons detected in some meanness, a "hang-dog" sort of air, if I may be allowed the expression. They were quite passive under the fierce assault of their fellows, and succumbed with little or no effort at resistance. Can it be that these emmets possess something like a sense of submission to the legal authority, and tacitly recognize the fact that they have become obnoxious to the communal police? One's judgment is so apt to be biased by his interest in and sympathy with these wise little creatures, that he is inclined to distrust his own observations, and fear that he may unconsciously have interpreted their behaviour after the operations of his own mind. But the facts really seemed to justify the suggestion above raised.

Amity and Confederation.—The description which Huber has given of terrible conflicts between rival communities of the fallow ant, the accounts of other writers, together with my own observations of battles between separate republics of the same species other than Formica rufa, had prepared me to expect many views of sanguinary fights among the colonists of Camp Riddle. True, I had seen nothing of the kind at previous visits; but I confidently expected some such

to occur during a week's stay upon the field. However, my anticipations were not realized; on the contrary my experiments revealed a surprising state of amity if not of confederation between the inhabitants of the several hills. The nature and results of these experiments may be gathered from the following examples. A small oak branch covered with aphides and their attendant ants was broken from a tree and placed erect upon a hill twenty rods distant. It was thought that if anything would incite to hostility it would be a meeting of members of separate communities upon the same feeding grounds. On the contrary, ants issued from the hill, mounted the branch with the usual tokens of excitement, and then mingling with the original occupants of the twig, began quietly to feed from the galls and aphides. A larger branch, having many more ants upon it, was cut, and planted upon a hill a considerable distance beyond the first. The insects were called out by tapping upon the surface. They issued with the usual whirl of excitement and anger and, as before, blended with the intruded ants without a sign of hostility. A spade full of earth was now taken from a hill, placed together with ants, cocoons and broken cells within a pail, carried to a hill some fifty rods distant and thrown upon the surface, and around the lower entrances. I could not of course distinguish between the respective members of the hills, as the masses of excited ants poured forth and began their usual movements, but I observed no sign of hostility; the imported ants melted away into the general community as if at home.

The only other test of this nature which need be mentioned was made upon three hills, say, A, B and C, which were found in such an unusually excited condition that they are down in my note book as the "hysterical hills." By the way, I visited them on the day after the shower referred to above, in order to see if they had set to work at building, like their sister cities, and if such occupation had quieted their nerves. It was as I had imagined; they were busy and greatly subdued, honest and hearty toil having quieted them very much as it does over nervous human beings. Large pieces of the cones of A and B, which are twelve feet apart, were interchanged, tossed from one to another, and although swarming with insects in the most intense state of excitement, there was no appearance of hostility. I then proceeded to C, 114 ft. distant, and called out the ants until the cone was fairly black with them. From the densest centre of life, I swiftly cut out a section about six inches square, and bore it hurriedly to B, catching the dropping ants in my hat as I ran. The contents of shovel and hat were thrown upon B, in the midst of its hosts of inhabitants. The

most complete fraternization ensued; there was the usual quick challenging with antennæ, but during the half hour that I spent intently watching every movement, there was not the slightest demonstration of hostility.

The final test was made in an artificial nest, prepared in a glass jar within which earth, sticks and surface refuse were placed. Insects taken from a number of hills situated in parts of the field most remote from each other, were introduced; cocoons from other hills were added; aphides, water and honey were given them. They united with the utmost harmony in building galleries, caring for the cocoons, and defending the nest from intruded ants of other species and spiders. From time to time ants and cocoons were added from yet different hills, but were always and at once adopted. It would thus appear that among the myriads of creatures occupying these more than 1600 hills, there is complete fraternity, if they be not indeed one mighty confederacy; a republic, which in the number of its separate states, and the multitude of its total population, far exceeds the most enthusiastic prophecy of the future of the Great Republic. If there be anything like local attachment among the inmates of the individual hills it must be very slight, or be suspended at certain periods. It would be hard to conceive of anything like local patriotism or jealousy of neighboring communities leading to war, existing among hills which were the subjects of the above experiments. And yet some other observer may record on the same ground such sanguinary battles as Huber has related. It may be that the combativeness of these ants is dependent upon some internal condition of the formicaries, and is excited only at certain seasons.

Night Work.—I may mention here another difference between the habits of our fallow ants and those of Switzerland as described by M. Huber. That naturalist records that the Swiss ants do not work at night, but shut themselves within their hills. On the contrary, the ants at Camp Riddle, when observed (as they were by me) during nearly every hour of the night from sunset to sunrise, were found to be pursuing the very same labors in the same way, and in the same fields as during the day. The avenues, tree-paths, feeding stations, feeding grounds, and hills were always thronged day and night.

Behaviour under Frost.—There was one notable exception to this. Sabbath night (Aug. 20th), was very cold. The thermometer at Hollidaysburg fell to 53° (Fahr.), a change of 30° from the temperature of the day. The next day frost was reported to have fallen at Frankstown and Newry in the vicinity. We became conscious of the

change by the uncomfortable temperature within tent. At 3.45 A. M. I visited the hills to observe the effects of the cold upon the ants. Not an ant was visible on the mounds, on the avenues or the tree-paths. Tapping the hills and stamping upon the surrounding stones, which always had brought out a multitude of insects, failed to arouse a single sentinel. I dug beneath the surface of the hill six or eight inches before coming upon ants, and these showed little activity, a sharp contrast with their usual zeal in defence of their domain. In order to be assured that the absence of the ants from avenues and tree-paths (never before noticed), was not occasioned by the torpidity or absence of the aphides, I examined one of the most largely patronized feeding grounds, the white oak beside the stone fence, already referred to as frequented by the inmates of hill Pl. II. I mounted the wall, and turned the lantern-light upon the overhanging branches. The aphides were in their places surrounded and covered by groups of ants in a semi-torpid condition. Ants in the same estate were hanging all around the intervening sections of the bough. The frost had evidently surprised them at their feast, and left them frigid upon the spot. Some of the insects had their abdomens well filled, as the honey-dew showed transparent in the lantern-light. At 8.40 A. M. a few sluggish movements were noted on the hill. On the avenues (in the shade), there were a number of ants, the great majority being homebound, and of these a large proportion repletes. At 8.50 the tree-path, then in the sunshine, was covered with ants, the majority repletes and very full. At 9.5 the ants were in their normal condition in the branches, then in full sunlight.

Winter Habits.—I was greatly desirous of knowing the condition and habits of the ants during winter. During a visit to Altoona, Oct. 26, 1876, I took occasion to drive over to Camp Riddle, some six miles distant. It was a raw, cold day, with occasional flakes of snow. The ants were confined to the mounds, only a few stragglers appearing upon the surface in a rather inactive condition. Those within the hills, however, were quite active and were able to spring upon the hand and inflict the usual wound. They all were much less affected by the cold than during the frost of the summer. The aphides were hanging upon the branches, unattended, black and with distended abdomens. Signs of work were seen on one hill; warts raised over several gallery-doors, as though a new story had been begun.

The solution of this inquiry into winter economy was referred to Mr. Kay, who on the 14th Feb., 1877, with Mr. Knox, a friend, visited the colony at Pine Hill. He had been furnished with various points

concerning which information was desired, and sent an admirable report the substance of which is given. The temperature of the day was 32° (Fahr.). Hills were first examined on the northern slope upon which lay snow five inches deep. The snow upon the mounds was of the same depth, and had not, therefore, been interfered with by the ants. A mound, about two feet in height from the vertex to the level and ten feet in circumference at the base, was opened, first on the northern and eastern sides. The frost had penetrated about four inches from the surface. At three inches small clusters of ants were found, very stupid but not torpid; the temperature here was 33°. On the south and west sides the frost had penetrated eight inches, and throughout this frozen portion, (thermometer at 33°) from a distance of three inches from the surface inward, ants were scattered, in the same condition as above. The whole top of the mound was now found to be loosened and was inverted, giving a cone whose altitude *A B* was 18 inches. The hill was found to be frozen only to the plane *C D* except on the surface as above described. The temperature of the cone at 12 inches from the vertex was 30°; the temperature of the now frustrum of a cone at six inches below the plane *C D* was 33°. There were not many ants in the cone. The greatest number was found at a distance of two feet from the vertex in temperature 33°; a few at 12 inches from the vertex in temperature 30°, sticking in the icy galleries with as much show of life as those a foot below them in a temperature 3° warmer. None of them however were very lively. The underground galleries were then examined, how far down is not stated, but no ants or other insects were found.

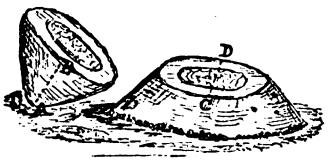


FIG. 9.—Segments of Frozen Hill.

According to instructions, mounds entirely exposed to the sun were next investigated. They lay upon the western slope from which the snow had nearly all melted away except where shaded by foliage. The hill reported below was entirely exposed to the sun, and of about the same dimensions as that just described. On the south and west sides the frost was melted out for about four inches at which point the thermometer gave 40°. Then followed two inches of frozen ground at 32°. On the east and north sides the frost was not melted out for more than an inch; the frozen portion extended inward four inches at 33°. The top of the cone was then turned over as before, and found

to be frozen to a horizontal plane 12 inches from the vertex, the melted portions named above excepted. The temperature at 18 inches from the vertex was 34°. In the frozen parts no ants or other insects were found; but on the rim of the unfrozen portion a colony of white ants (*Termes flavipes*), was found occupying a series of cells in a space about four inches square, and in a quite lively condition. Near them was a large collection of roaches, a hundred or more apparently of the most lively character. There were scarcely any ants near these; but in the centre of the piece they were very plentiful and lively. No beetles were found, and no aphides were discovered about the roots of the grass, although diligent search was made.

There are several inferences, more or less conclusive, concerning the winter economy of the fallow ant which we may draw from the above facts. First, the ants dwell within their formicaries during winter and make no attempt to modify the surface surroundings. Second, the vast majority of the community, together with the fertile queens, larvæ and cocoons occupy the underground galleries. This appears from the fact that but one young queen, and comparatively few workers of the various classes, were found in the hill galleries. Third, the composition of the mounds is such as to ensure, in the central parts, a good degree of protection against ordinarily severe winters for the few ants that occupy them. Fourth, the vitality of the ants is sufficient to keep them active within the hills during all ordinary seasons. Fifth, it is yet more evident that the occupants of the underground galleries are not torpid during ordinary winters, if ever, but exist in a state of considerable activity. Finally, it would appear that the ants are able to spend the winter in the active state without regular and ordinary supplies of food.

I do not advance this last opinion with any great degree of confidence. The mystery of the underground galleries still vails the facts that would solve the question completely. But all the known facts point to the above inference. I had thought that the tufts of grass which grow upon many hills, and which evidently grow at the ants, consent might be preserved not only to strengthen the architecture, but to furnish at their roots sustenance for aphides. Accordingly, at a visit made Oct. 26, 1876, a cold, snowy day, I carefully searched for aphides upon the roots of the grass, but found none. Mr. Kay's search was equally fruitless. The roaches found in such numbers by Mr. Kay, and also by myself, are doubtless simply squatters upon the emmet territory. However, it must be considered as still unsettled whether

our mountain mound-builders feed during winter, and if so, what are the sources of their food supply.

Beetles.—The possibility that the beetles, certain species of which are well known to frequent the nests of ants, might be in some way concerned in this interesting query, did not escape my attention. But I was never so fortunate as to take any beetles in the hills either during the summer or fall visit. This was doubtless chiefly owing to my ignorance at that time of the size and appearance of the insects, and the best mode of capturing them. I hope at another visit to remedy this deficiency. Dr. Horn informs me that the Spring is the best season to search for these domesticated beetles. Among the ants collected in midwinter by Mr. Kay, and sent to me as specimens, I found one beetle. It is a small insect, about one-tenth of an inch in length, of a dark claret-brown color, quite closely resembling in this respect the ants among whom it dwells. It is determined by Dr. Horn as *Tmesiphorus costatis* Leconte, and belongs to the Clavigeridæ. The discovery of this beetle in midwinter, together with the fact that the beetles are found in abundance with the ants in early spring, show these insects to be closely connected with the winter life of the ants, if not with their winter food supply.

Dr. John L. Leconte, so widely distinguished for his thorough knowledge of the Coleoptera, has shown me the following species collected by himself from ants' nests. Two of these, taken from formicaries of our Allegheney mountain mound-builders, I have been permitted to figure. They are drawn in order simply to give a general idea of their appearance, and not for systematic description. The most interesting of these is perhaps Fig. 10, 1, *Atemeles cava*, Leconte, which, like the Clavigeridæ, is furnished with tufts of hollow, hair-like tubes, on the sides of the abdomen. From these tufts a sweet secretion exudes, upon which the ants feed, as upon the honey-dew of the aphides. *A. cava* is a brown-colored insect, about one-fifth of an inch in length. Specimens were found with fallow ants in Columbia Co., Pa.; in Michigan, Maryland and Illinois. Those from Ill. were found in nests of F. rufa (?) in large numbers. One of the ants taken with the beetles, still holds in its mandibles, firmly clasped even in death, one of these household treasures. The other specimens figured are desti-

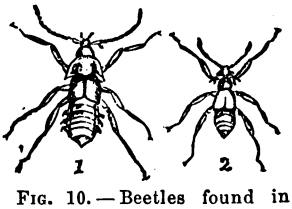


FIG. 10.—Beetles found in nests of F. rufa. No. 1, *Atemeles cava*, Leconte. No. 2, *Cedius Ziegleri*, Leconte.

tute of the hair-like tufts, and probably serve simply as scavengers, or, are permitted to remain as "squatters" in the formicary, for some purpose the economy of which is unknown. *Cedius Zieyleri*, Leconte, Fig. 10, 2, was taken in a hill of F. rufa at Bedford, Pa. It has short elytra, the color is brown, the length is one-tenth of an inch. On each of the first pair of legs are two spines, one located (apparently) at the base of the femur, the other on the trochanter. The remaining specimens were also taken at Bedford, Pa., and are an undescribed species of Homalota, and an unnamed species of Oxypoda. They are small brownish insects, with a slight pubescence.

Larvæ, Cocci and Aphides with Ants.—That the cocci may contribute quite largely, and the larvæ of some beetles more or less, to the limited supply of food required by the ants in the cold season, is probable. I have taken larvæ in the mounds, and two were sent by Mr. Kay from a frozen mound opened by him. I have never taken them in positions that justified the belief that they were attended by the ants, they having been brought out in the broken earth of the hills. Mr. Kay's specimens were probably taken in the same way. Prof. Leidy (Proc. Acad. Nat. Sci. 1877, p. 145), found, in the early spring, that a small colony of yellow ants (probably *Lasius flavus*), had three different insects in their possession, consisting of a species of aphis, a coccus, and the larva of an insect which Dr. Horn informs me is of some species of Coleoptera. The aphides were kept in two separate herds, and these were separated from a herd of cocci. The larva was in the midst of one of the former herds. In a larger colony of the same ants, there was a herd of aphides which occupied the under part of one margin of the stone under which the formicary opened, and was almost ten inches long by three-fourths of an inch in breadth.

The number of "domestic cattle" included within such a space was obviously very large. This same colony was also possessed of a herd of cocci who were closely crowded together and occupied about a square inch of space. These were kept quite separate from the aphides. In both the above colonies the aphis and coccus were the same. The aphis was of a pale yellow color with white tubercles on the dorsal surface of the abdominal segments. The coccus was of a dark-red hue. Both aphides and cocci with few exceptions adhered to the under surface of the stones, and were not attached to roots. They appeared to be carefully attended by the ants who surrounded them. I have frequently observed white aphides, apparently the same as the above, in similar

positions in early spring, attended by these yellow ants. They always seemed to be in good condition, (as Dr. Leidy says were also the aphides observed by him), were plump and active, as though having weathered the winter in robust health. It is not improbable, considering the habits of our F. rufa, that aphides are domesticated within their nests, and could be found in the early spring. The fact that aphides are thus found in nests of *Lasius flavus*, indicates that for at least the latter part of the winter they contribute to the food supply of the ants. The same conclusion would be drawn from a similar fact in the economy of F. rufa. It is to be hoped that this point will receive attention from some observer who can have access to the hills in the early months of the year.

The coleopterous larva alluded to by Dr. Leidy was almost six millimeters (about one-fourth of an inch), long, and was covered on the back with a thick white cotton-like secretion. It was also carefully attended by the ants, which were frequently observed to stroke it with their antennæ. It is a point to be investigated, whether like larvæ similarly attended, may not be found in spring-time within the nests of rufa.

Lepidoptera larvæ with Ants.—I introduce here as bearing upon the general matter of ant food, and the relation of ants to myrmecophilous insects, the following observation. During the early summer of 1877, I had frequent opportunity to note the habits of a large colony of black, shining ants, *Formica subsericea*, Say, whose formicary is established at the edge of a grove on the farm of Mr. George B. Lownes, Delaware Co., Pa., nine miles from Philadelphia. The ants were found scattered through the woods, within a circuit of many rods from the nest. June 18th, I observed a column of these ants ascending a young wild-cherry tree, near which grew several tall stalks of the black snake-root or bug-bane, *Cimicifuga racemosa*. While watching the ascending column I noticed an ant moving upon the round blossoms of this plant. Attracted by some peculiarity in its movements I fixed my attention upon it, and saw it to be in attendance upon a small green grub about one-half inch long, which proved to be the larva of a butterfly probably some species of Lycænidæ. The lower segments of the abdomen were continually gently stroked by the antennæ, in the familiar manner of ants when soliciting honey-dew from aphides. This novel behaviour was of such interest that I placed the ant under close continuous observation for more than two hours. During this time the strokes were repeatedly interrupted by short ex-

cursions up or down the plant, the ant always returning and renewing the solicitation. The ant always occupied a position below the grub, and directed her strokes toward the head, which, however, generally fell upon the lower part of the body. The larva did not remain stationary, but several times moved its position, slowly creeping around the stem. I ceased observation at noon, and returned to the grove at 4 P. M. The grub was in about the same position, and was attended by the same (or another) ant who was accompanied by a companion. The same behaviour observed in the morning was continued until 5 P. M., when I captured ants and grub and took them home. A number of the same larvæ in different stages of growth were found on the same plant in various parts of the grove. I was only able to observe that the ant continued to attend the grub under confinement just as in the woods. But preparations for a journey to Texas, compelled me to suspend observations. Although satisfied that the object of the ants was to secure some kind of refreshment from the larvæ, I was not able to note any secretion on the grub, or anything like the actual taking of food by the ant, although the mouth organs were applied to the last segments.

A casual mention of my discovery was the means of opening communication with W. H. Edwards, well known for his valuable works upon the Lepidoptera, who later in the summer (as I infer), had observed the same fact. In comparing notes it was found that the larva observed by him in West Virginia, was also of the Lycænidæ (*Lycæna Pseudargiolus*), and that it was domiciled upon the same plant, (*Cimicifuga racemosa*). Two species of ants were seen attending the larvæ. Mr. Edwards has kindly communicated to me the details of his own observations; but as he purposes to give them to the public at an early date, I will not anticipate any further than to say that under the microscope the larvæ prove to be possessed of organs upon the upper part of the last segments, apparently designed or fitted for the exudation of some fluid. Mr. Edwards also directed my attention to a paper by M. Guenèe, in the "Annales de la Sociètè Entomologique de France," Ser. iv, tome 7, 1867, pp. 665—668, which I have consulted. The paper is brief but exceedingly interesting, and gives a full description, illustrated by figures, of organs found upon the eleventh segment of the larva of the butterfly (*Lycæna bœtica*), whose protrusion from two openings near the ninth and last pair of stigmata, was observed, and the action and organ figured and described. At the summit of the tenth segment the author found another single opening, placed trans-

versely, and surrounded by a projecting border around which the granulations which cover the whole body of the larva are especially massed. Out of this sort of button-hole, and at the middle, rises, at the will of the grub, a species of hemispherical, transparent vescicle, which gives passage to a serous liquid sufficiently abundant to form a large drop, which is reproduced whenever it is removed. The larva does not secrete this liquid except when disturbed imitating in this the *Cucullia* and many other larvæ which disgorge at the mouth a colored liquid, with the intention, doubtless, of repelling those who molest them. M. Guenèe ventures no opinion as to the economy of this exceptional structure. But, his description throws great light upon the behaviour of the ants as recorded above. There can be little doubt that the gathering of a serous liquid, like that observed by M. Guenèe, upon *Lycæna bœtica*, was the object of the attendance of the ants of *Formica subsericea* upon the Lycænid larva as observed by myself. This larva (in alcohol), was placed in Dr. Leidy's hands for examination, under the microscope. He found on each side of the two (or three) last segments, on the dorsal surface, a prominent, circular, brown-colored glandular looking body, with a central depression. These glands were quite distinct from the spiracles, which are not represented in the accompanying cut. Fig. 11 shows the appearance of these glands as situated upon one side of the terminal segments. It is possible that the last three segments are here represented, the last (twelfth) being contracted. Dr. Leidy found no opening at the summit of the tenth or other segment, corresponding with the button-hole like secretory gland described by M. Guenèe. The above facts are all of very great interest, and may prove to be another important factor in solving questions concerning the food supply of ants under both ordinary and extraordinary circumstances.

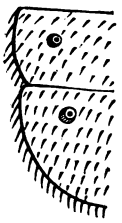


FIG. 11. Glands upon terminal segments of Lycænid larva, attended by *Formica subsericea*.

Natural Enemies.—When we consider the vast numbers of insects within a single community of the fallow ant, and their apparent immunity from the destructive effects of climate, we are not only deeply interested but much perplexed under the inquiry, what are the agents and influences that limit their increase? If the amicable relations existing under my own observations are permanent, their numbers are not held in check by civil wars. There appears to be an established feud between them and the large black Carpenter Ant, *Camponotus*

(*Formica*) *Pennsylvanicus*, but the losses inflicted during the occasional conflicts with these creatures must be quite small. Spiders of the various sub-orders destroy some. At the foot of one hill between two stalks of grass a female of *Argiope fasciata*, one of the most beautiful of our indiginous orb-weavers, had spread her snare. An ant which was fed to her was seized, rapidly swathed in the usual fine white web, and fed upon. The numerous sedentary spiders that spread their webs upon trees and bushes must ensnare a goodly number. A variety of Formica rufa which for several years has inhabited the great cliff at Rockland in Fairmount Park, finds a most formidable foe in that ferocious line-weaver *Theridium tepidariorum* (*vulgare*, Hentz), who spreads her great, strong snare in the recesses of the rock. I have seen scores of ants clinging to these webs and have gathered up half-handfulls of the dry carcasses underneath. The various genera of the wandering spiders are no doubt formidable to single ants. On the trees the abuscading Laterigrades and those swift-vaulting garroters, the Saltigrades, must cut off many a straggling forager. On the ground, perils threaten the Formicidæ from the powerful and ferocious wolf-spiders (*Lycosidæ*), and the familiar spotted tube-weaver (*Agalena nævia*), whose broad-sheeted, funneled snare is so widely spread among the weeds and grasses. But we may well exclaim, what are these among so many?

The birds may pick up a few. A gentleman who visited our camp one day informed me that as he rode along he observed a large flock of blackbirds in the woods, on the ground among the hills, a dozen or more being on a hill apparently pecking at the ants. These birds harbored in the woods several days, and although our party all watched them closely nothing of the kind was again observed. Mr. Prough, the farmer whose land and residence adjoin the wood, declares that although crows freely eat the black Pennsylvania Carpenter Ant, no sort of birds or fowl will touch these "pismires," as the fallow ants are popularly called upon the mountain. Perhaps after all the chief causes operating to limit the spread of this species are geological. But until we know more certainly the geological conditions favorable and adverse to their increase, the question must remain open.

The species is found in abundance in the sandy barrens of New Jersey. I have in my possession an artificial formicary of living specimens sent me by Mrs. Mary Treat of Vineland, who during the past summer has made many interesting observations upon ants, particularly the kidnapping *Formica sanguinea*. The New Jersey rufas

quite closely resemble those of the Allegheney mountains. I have also specimens taken during last summer by Prof. Joseph Leidy, M. D., in the Rocky mountains, near Fort Bridger, Wyoming Territory. These insects, though closely resembling the Allegheney mountain forms, are somewhat longer, and more nearly approach the ants found in Fairmount Park, Philadelphia. The latter do not raise mounds; the Rocky mountain insects are mound-makers. In all the above cases a light, sandy soil is the natural habitat of the ants.

Means of Attack and Defense.—The worker and female ants are provided each with a pair of curved mandibles (Fig. 12; 8, inside or palm; 10, outside; 9, male mandible); irregularly toothed on the inner edge, which are attached to the lower part of the head and have a horizontal articulation. The teeth are seven, the outermost one being much the longest; there are (counting inward), two large teeth, one small, one large; two small and one flat tooth on the inner edge. These organs are the implements of labor and the weapons of warfare. They are plied with terrible earnestness and vast force. The method of inflicting a wound, as observed upon my own hand, is as follows: the mandibles clasp the finger, and while the feet hold firmly to the skin, are drawn together over it, with a scraping motion. At the same time the abdomen is doubled under the body acting as a sort of lever which being pressed downward against the skin, greatly increases the power of the mandibles to tear and pull the object seized. But this is not the chief purpose of this movement; for from the lower part of the abdomen a jet of formic acid is thrown forward upon the surface on which the mandibles are working. As the teeth or "cogs" penetrate the cuticle this acid produces a sharp, stinging pain, suggesting a puncture by a red-hot needle. I could not see the jet of acid, as I have seen it when issuing from the Carpenter Ant, but the taste and odor as well as pain, showed its presence.

FIG. 12.—8, mandible of worker, inside view; 10, same, outside; 9, mandible of male.

The wound thus made, which is neither a bite nor a sting, but something like a combination of the two, is quite serious to inferior animals, and is very annoying to horses and cattle. It is sufficiently formidable to human beings to make them cautious in all their approaches to the hills. When the creatures fasten upon the neck or get under the clothing and unexpectedly bestow their "bite," the

effect is at times rather comical to all save the victim. However, I was able to protect myself sufficiently by the use of gloves, and some precautions against the entrance of the irrate creatures under the clothing. I was frequently covered with ants and often wounded, but was rarely compelled to abandon my observations. I was satisfied, therefore, that the effect of the fallow ant's "bite" has been exaggerated.

To test it fairly, I uncovered a foot and thrust it against a hill. It was soon black with ants and recalled to my mind Swift's description of the little people of Lilliput swarming upon the Man-mountain. I was quite able to endure the pain, but unfortunately for my experiment, two musquitoes lit upon and bit the foot just as the ants began to make themselves felt. There was a smarting sensation in the foot for about thirty-six hours, which I credited mainly to the musquito bites, to which my flesh is very sensitive. Several small, scarlet spots somewhat resembling a rash were the only effects of the ant poison, beyond the immediate pain. Such was my experience; the consequences, however, to other persons might have been much more serious.

Sexes, Cocoons and Larvæ.—Among the most interesting points of economy, and which I was most anxious to observe, are the relation of the sexes and the development and care of the young. But it was my misfortune to observe nothing of any importance. Neither male nor female ants were found during the whole week. The males had evidently disappeared for the season, as the pairing of the sexes occurs about the close of June. I am inclined to think that the fertile queens must occupy the galleries beneath the surface, as the most careful search in many hills failed to discover one. A young queen, however, with the stubs of wings still adhering to the body, was taken by Mr. Kay in the centre of a mound in the middle of February. About the middle of July I have taken the winged queens upon the surface of the hills, where they were being led about under the convoy of a worker. Other queens were seen conducted into the galleries. I infer that these were recently fertilized queens whom the workers had captured and were conveying home, but I made no examination to confirm the inference.

Numbers of cocoons were found, and a few small larvæ. The former are straw-colored, cylindrical, about a quarter of an inch long, a small black knot of hard, dry matter, apparently excrementitious, at the apex of the abdomen. The cocoons were found massed in cells of

various sizes, and at various distances, varying from two inches from the surface to eighteen. The cocoons under care in an artificial nest were invariably kept in the dark; as soon as the cells containing them were exposed to light they were removed. The number of shells which the workers were carrying out of the hills indicated that many of the nymphs were being released from the cocoons. For some observation made by me upon the manner in which this is done by the Carpenter Ant, I refer to a paper in Transactions of the American Entomological Society, Dec., 1876, p. 288. These antlings are at first of a pale color, and while yet callow, within a few days of their release from the shell, engage in the care of the cocoons. Such at least was the case with those confined in an artificial nest. The antlings remained in the nursery close by the cocoons, for which they showed the strong maternal anxiety of a mature worker. It is probable, as Sir John Lubbock has suggested, that they do not enter upon more exposed duties until after the thorough induration of the skin.

The following is a description of the ant whose habits are detailed in this paper:

Formica rufa.

Female.—Head, thorax, legs and scale of the petiole of abdomen ferruginous; mandibles and posterior margin of vertex dusky; flagellum of antennæ dusky, the scape ferruginous; wings with one marginal, two submarginal and one discoidal cells, pale fusco-hyaline, stigma brown; abdomen shining, blackish, varied with ferruginous at base, the apex and venter sometimes tinged with brownish and clothed with pale hairs, petiole and scale ferruginous, the latter vertical, compressed, rounded on the sides above and slightly notched on the middle. Length .35 inch.

Worker.—Ferruginous; mandibles, flagellum and legs except coxæ, trochanters and extreme base of tibiæ, fuscous; abdomen except petiole blackish, shining; scale of petiole subrotund, subsinuate above. Length .25 inch.

Male.—Blackish-fuscous, clothed with a very fine sericeous pile, more conspicuous on abdomen; antennæ brown, scape tinged with ferruginous; wings as in ♀; legs pale ferruginous, posterior coxæ dusky. Length .35 inch.

Allegheney Mts., Pennsylvania.

I add from the admirable work of Dr. Auguste Forel, "Les Fourmis de la Suisse," the following translation of his descriptions of the sub-family, genus and European species to which our F. rufa belongs. My observations were all made and the results recorded more than a year before I had access to M. Forel's work. My paper is therefore in every respect wholly independent of his. I mention this fact because it gives added value to those facts observed by myself, which will be found also in the "Swiss Ants." The same co-incidence will be observed in the results recorded in my paper on *Camponotus* (*Formica*) *Pennsylvanicus*.

Family, **FORMICARIÆ.**

Sub-family, FORMICIDÆ. First Division. *Workers.*—The abdomen seen from above, shows five segments, of which the fifth is conical and terminal; the anus is small, circular, apical, and ciliated at its edge. Spurs simple; poison vessel cushioned; nymphs nearly always enclosed in cocoons. The bowl of the gizzard spherical, or a little wanting of spherical. The chaperon is not prolonged between the frontal ridges (*arêtes frontales*), beyond their origin.

Females.—Exactly corresponding with workers. Wings with one cubital cell.

Genus, **Formica,** Linn. *Workers.*—Mandibles broad, toothed at the outer border, as with other genera. Metanotum bossed, (*bossu*), but not more elevated than the rest of the thorax. Labial palpi with four joints. The anterior part of the chaperon is advanced at the mddle and pulls out the origin of the labrum (*labre*), like the eaves of a roof, (*en avant toit*).

Frontal area triangular, very distinct; ocelli likewise very distinct, as is also the frontal furrow. The maxillary palpi with six, sometimes with five joints. The joints of the flagellum of the antennæ continue to diminish in length and thickness from the first to the tenth; the eleventh (twelfth of the antennæ), is on the other hand a little longer. Scale vertical, calix of the gizzard (*gèsier*), a little greater than the bowl.

Females.—Frontal area triangular, very distinct; characters (thorax excepted), identical with those of the worker.

Males.—External genital organs large. Exterior genital valvules cultriform. Frontal area, palpi, gizzard as with ☿. Median lobule of the last joint of the posterior tarsi having scarcely half the length of the hooks, (crochets). Scale vertical, thick. Body robust; size often equal to that of the ♀.

Species, **F. rufa.** *Workers.*—Chaperon entire at its anterior edge, size very variable, body thick-set, (*ramassé*). Head and abdomen much wider than the thorax. The notch between the mesonotum and the metanotum large. Metanotum greatly arched. Of a fallow red color quite lively, (varying in brightness), more or less mixed with brown and black, but the boundaries of the colors always quite plain, except with the very small individuals, (dwarfs). Eyes and ocelli large. Chaperon with a keel indistinct or distinct only on its anterior half. *The frontal area always smooth and shining.* This ant has the habit of ejecting its venom. Nests made of gathered materials. Nymphs almost always in cocoons.

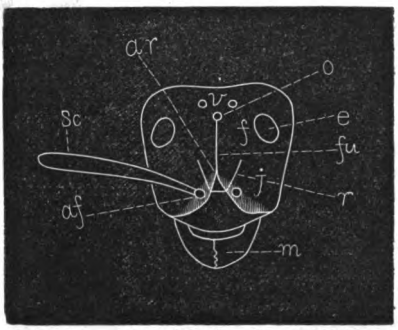
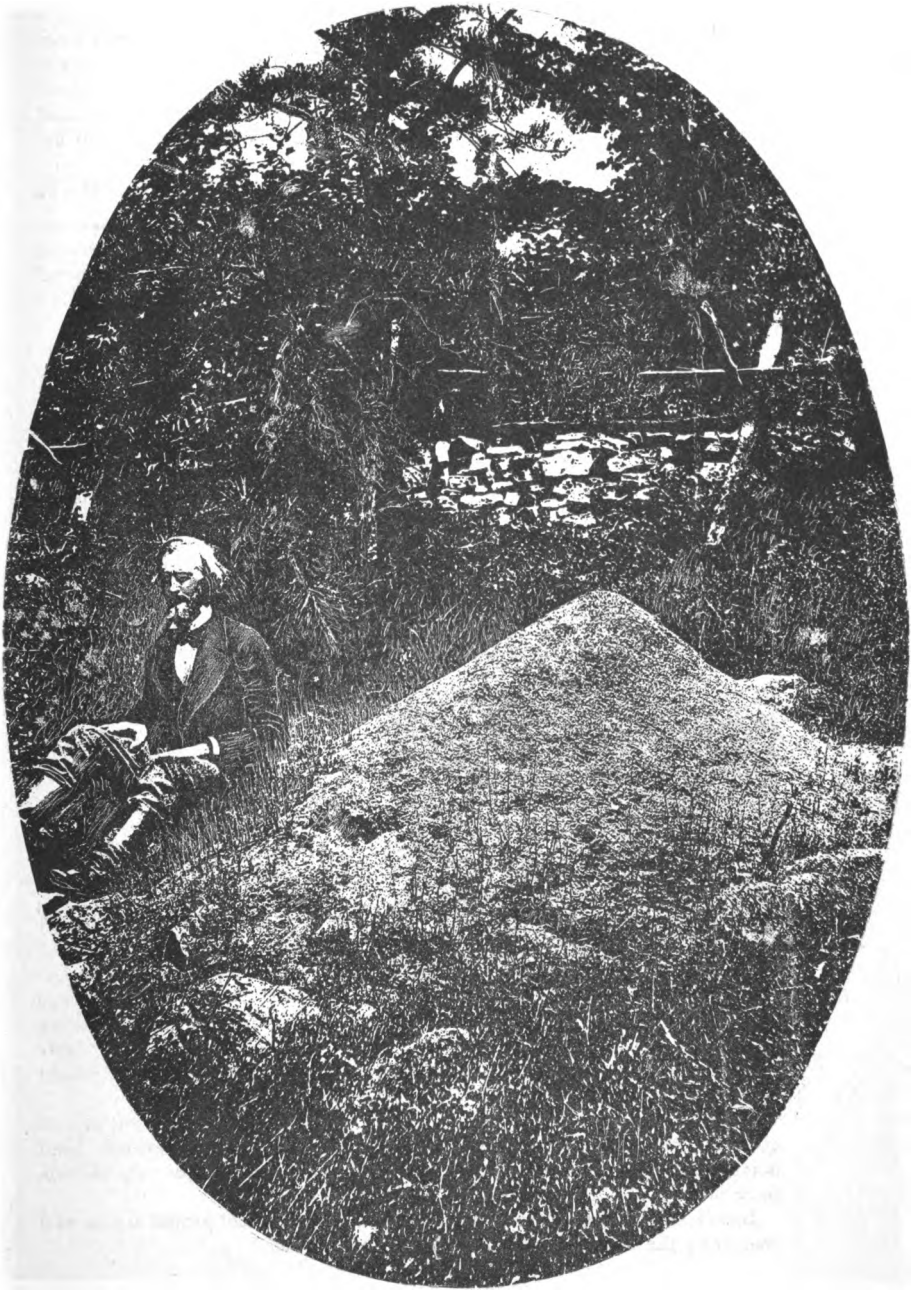


FIG. 13.—(after Forel). Head of *F. pratensis*. *m*, mandibles. *c*, chaperon. *j*, left jaw. *f*, front. *v*, vertex. *o*, ocelli. *e*, left eye. *fu*, frontal furrow. *r*, left frontal ridge. *af*, right antennal fosse. *Sc*, scape of right antennæ. *ar*, frontal area.

Females.—Abdomen short, almost spherical, body thick-set, squat (*trapu*), very robust; thorax elevated; head much larger than the thorax. *Frontal area always smooth and very shining.* Color of worker. L. 9—11 mm.

Males.—Body robust, broad, very hairy, black. External genital organs and frequently the legs of a yellowish-red. L. 9—11 mm.



T. Sinclair & Son, lith. Phila.

Hill of Fallow Ant Brush Mt. Penna.

Formica rufa, Hill-cluster or Family Group.

T. Sinclair & Son, lith. Phila.

F. rufa_section views.

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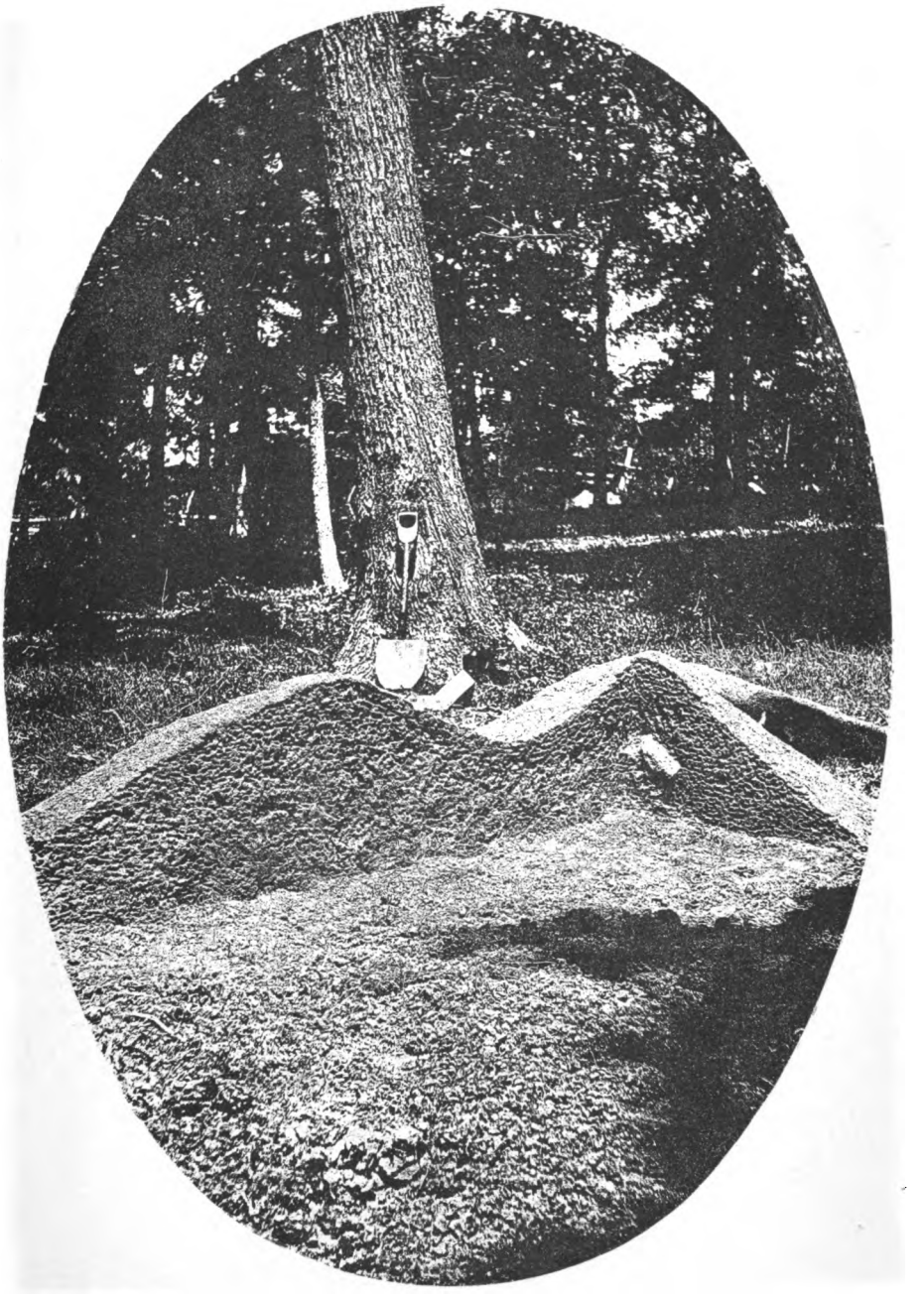
F. rufa, Twin Hills, view of galleries.



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F. rufa. Double Hill, section view.