PERIODICAL CICADAS IN BALTIMORE, MD.

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IN the northern parts of Baltimore as now extended to include fields and woods certain restricted areas long inhabited and well grown with shade and fruit trees about country and suburban residences were overrun with great numbers of the noisy and conspicuous periodical cicada, Cicada septendecim, popularly known as the seventeen-year locust, during the early summer of 1919 and the same was true in even greater force in 1902 as I have observed.

Upon digging into the earth under sod or in old plantations of shrubs and trees in 1916-'17-'18 one saw many tunnels or tubular holes smaller than one's finger, but many inches long, two feet or more under the surface and in each might be a clumsy light colored gnome-like creature with grotesquely large and powerful front legs and claws and provided with an enigmatically closed-in face and head, making it a matter of search to discover the concealed tube or sucking mouth—apparatus through which it had been many years drawing from the roots of trees and shrubs the juices that had enabled it to grow to the size and plumpness of a peanut (with some of like food value). These cicada young in the spring of 1918 pushed their tunnels up well toward the surface of the ground and led one to surmise that they might be about to emerge from the dark into the air above. In fact some few must have done so for later in the summer a very few were heard singing their unmistakable song in the trees and a few of their cast off pupal cases were collected at the foot of trees, smaller than the seldom found cases of the non-periodical cicada, or harvest fly, Cicada tibicem.

But in 1919 the holes in the ground were all extended up almost to the surface or even beyond, as described below, and finally after seventeen years of darkness each inhabitant emerged from its own tunnel into the dim light of late day to transform into the winged insect.

Excepting as below noted these tunnels present the mystery of no seeming place for discharge of the excavated soil: but Fabre has given a remarkable suggestion as to how the tunnels may be made in dense soil with no outlet for soil removal.

In April and May diggings under apple trees showed very many vertical tunnels, each straight and smooth lined, each ending very near the surface with a well made roof of earth hollowed out below as dome over the vertical burrow. In each sat one larva braced with its

legs against the smooth sides but ready upon slight disturbance to shut up its legs and drop down to the moist bottom of the tunnel if not given time to slowly crawl down into safety. When the top was dug off from the tunnel the inhabitant soon fashioned a new arched roof at the top.

Where boards lay on the ground the holes that came up under these obstacles were prolonged out of the earth against the board and then turning at right angles extended many inches horizontally along under the board as circular passages with walls made up of small pellets stuck together and all smoothed off inside. Often the board itself furnished some part of the roof of these horizontal extensions of the burrow.

Is it the light or heat that is sensed in the vertical burrow to bring about a cessation of work when near the surface, and is it the absence of this contrast between deep down and near surface which leads the larva under the board to keep on and on where possible and so to impress upon the onlooker the idea that the larva is aware of the obstacle to emergence?

Very many such restrained larvae remained under the boards after those in the open had emerged, but finally most of those under the boards found a way to the edges and escaped. When such board was raised the larvae were often in the horizontal burrows and could be more readily caught as they ran but slowly along to the vertical burrow down which they went with speed so great that rapid cut off from below with knife or spade was the only chance of intercepting their flight.

In some regions, chiefly those well shaded or not with normal exposure to light and air the vertical tunnels rose up into the air in the form of a chimney closely resembling those made by burrowing crayfish. Each chimney is built up by additions of small pellets of mud brought from below, often of the hard subsoil or clay and hence conspicuous upon the darker top soil. Each may be one and a half to two inches or more in diameter and one to five inches in height and either straight vertical or bending to one side.

In any case when not being worked at, each chimney is capped over at summit completely by pellets that make the top like the sides all one mass of irregular roughened drying or dry mud easily kicked aside as of no importance, yet each chimney upon being broken from its continuation down into the earth is seen to have in it the same vertical tunnel as large as one's finger, nicely smoothed on all its walls and arched over at the top by the smooth dome that is present at the top of all the vertical burrows which stop short of reaching the surface of the ground.

Such chimneys arose in great numbers in a small garage shed,

closed in and dark. They were found under a porch beneath which roots of Norway maple extended and where light was very dim. These little chimneys in great numbers stuck up in the tall grass close to the bases of trees, around the bottoms of cherry trees along a privet hedge, and under the hedge itself where the shadow is always deep. When knocked off they lay about like so many mud finger stalls.

The numbers of holes varied greatly but in many places there were ten in a square foot; yet all garden or flower bed soil contained none and the same was true of roads and paths even though the roots of the trees extended under them and the gravel might have permitted egress.

Observations upon such cicada pupae kept in jars of earth in 1902 showed that the peculiar face of the insect was used as a hod to bring up to the surface of the ground the small pellets of mud collected below and laboriously carried to the surface. As the tunnel making involves no transport of material, it is the more enigmatical that the chimneys and horizontal tubes under the boards are made by hard work of a kind not, apparently, known during the 17 years of underground life.

The earliest date recorded for the coming of these cicadas forth from the ground in Baltimore was the finding May 16 by Mr. Ibara of one male with expanded wings in Druid Hill Park and one male in Wyman Park. While at the same date I observed the wings of one individual on a flower bed in my garden, apparently an early pioneer that had been sacrificed to the eager birds.

On the 21st of May a pint or more of winged forms were recorded as collected on the south side of Professor Mast's house in Roland Park. On the following day I saw the first pupae emerging and going toward the trees in my lawn while many persons reported them as appearing in numbers in Govans and Mt. Washington. On May 23 there was a second emergence from eight to nine p. m. when there was still good daylight. Many reports stated that the cicadas were emerging at Embla Park and on Charles Street north of Homewood, in great numbers. On May 24 the cicadas emerged again before 8 p. m. and walked straight toward the trees.

From then on cicadas came out of the ground every evening from eight to ten p. m. and some few later in the evening but the numbers emerging in any one region fell off till very few indeed came out after the first of June. May 26 many emerged as early as 7:30. In general the emergence began earliest in the season in localities that had the warmer soil and later in cold clay or in regions on north of buildings. Localities a few hundred feet apart differed by 7 days in date of first emergence. But even in the latest region, under trees north of house the few last cicadas were coming out June 7th and no more came out June 8th. Thus the entire outburst from the ground life of seventeen years was concentrated within a maximum of three weeks time while

in any one spot the emergence was restricted to a period of less than two weeks.

Having lived some seventeen years below ground, the first advent into the air is followed by a remarkable migration before the actual hatching out of the larva-like pupa into the imago or perfected winged insect.

Upon breaking slowly through the arched dome that ends its vertical burrow, the pupa thrusts its head into the air above while there is still daylight of rapidly diminishing intensity and seems to face in various directions before actually coming out of the burrow. But once upon the earth the pupa begins a most persistent rectilinear journey toward some neighboring object, tree, wall, grass or flower stalk, or building. Standing under an isolated tree, it is a remarkable sight that presents itself when from north, south, east and west and all intermediate radii the emerging pupae, as if all of one mind march steadily toward the tree trunk at the center of their entire area of emergence.

Arrived at the tree or other upright they do not hesitate to climb up it with slow but steady progress often for many feet of vertical toil, but when a horizontal outlying part, as a branch, is reached, the pupae turn aside from the vertical which they had so long persisted to maintain underground and again resort to the horizontal journey they had recently quitted when ascending from the earth to the tree trunk. Out toward the ends of the branch they climb upon the twigs and the leaves and there finally come to their journey's end. Here they stretch out their legs, so that the hooks on their ends firmly hold them and as darkness comes on the transformation is completed; each back splitting open to allow of the slow emergence of a conspicuous white and very soft creature which will hang head down in apparent danger of falling to the ground till strong enough to mount upon its shell, gain a firm footing, and slowly pump up its wing pads with air while allowing of the fermentative processes in its soft skin to fashion a dark and stiff encasing layer that will make it henceforth so well able to use its muscles and be protected from minor injuries. As the eyes color red and two squarish areas above the wing muscles early turn black, the generally yellow white of the hatching adult is the more striking.

The next morning few indeed remain in such undefended softness since with the coming of day most all of the night's product vibrate their wings and fly away with great speed and strength of flight, well able to elude many birds on the wing and as well able to dodge about the limb or take again to wing when in danger of attack.

The three stages of the first journey in the above-ground were strikingly shown in the case of many cicadas arising from the earth near clothes poles which they found after a horizontal walk of many feet

and mounted vertically five feet then to crawl out horizontally along the slightly sagging line only $\frac{1}{16}$ of an inch thick to settle down and transform all along the line up to a maximum distance from the pole of forty-eight feet.

Concerning the first part of the journey above ground, the walk to the trees, two sets of observations suggest problems to be solved, as to orientation with reference to vertical objects. The first observations relate to the numbers going to one isolated tree; the others relate to the distances traversed as if impelled by the sight of that tree.

Having in advance of the emergence protected most trees by bands of tin about the trunk it was found that the cicadas could not climb up this smooth surface, unless some crack allowed of use of the front leg nippers, and thus as fast as they arrived at base of a tree they tended to accumulate there and were not rapidly dispersed up over the whole tree where they could not be counted, while by collecting the cicadas arrested by the tin barrier a fair estimate of the entire number arriving at any particular tree could be readily had.

The tree most observed was a very large pear, probably Doyenne Boussock, thirty feet high by actual measurement and with a spread of twenty-one feet; its branches were nine feet above ground at origin but sagged somewhat and were very dense so that the tree was a very dark object; the overhang of the limbs toward the south was about eleven as opposed to ten feet toward the north. This tree stood isolated on a cut lawn, fourteen feet from a privet hedge running East and West, five feet high and six wide and was 36 feet from a silver maple toward the southwest, twenty-five feet from a very feeble old pear tree of 12 feet height and 10 feet spread to the north and 22 feet from a cherry tree in hedge to North East having spread of 10 feet and height of 17 but like the old pear tree casting little shade. The trunk of the big pear tree was 3 feet 9 inches in circumference at base.

The cicadas which emerged from the ground under this big pear tree, went toward the trunk as if drawn by a powerful magnet, both from near the hedge and from all other radial directions, but meanwhile some few cicadas under the hedge and under the other trees above mentioned remained in their own areas of attraction and climbed up the hedge plants or strove to ascend the tree trunks. However, it was evident that the big pear tree drew the great majority of all cicadas emerging within a circle much greater than its branches overhung and absolutely controlled all cicadas emerging under its branches.

The following figures show the run of cicadas collected at the base of this big pear tree daily, evening and morning May 22 to June 3. Those collected in the evening represented most of those of the day but as a few came out late these were collected in the morning and added to the previous evenings count for the total of that day. Thus on

the 26th, 550 were taken at 8:30 and 250 more at 11 p. m. and 110 were waiting at the tin the next morning at 9.

Numbers showing daily emerging of 4,983 cicada pupae from area 15 feet radius around one tree during thirteen days, May 22 to June 3 inclusive; 65, 240, 400, 338, 910, 784, 551, 738, 561, 234, 118, 39, 5.

That is, the first day saw only 65 emerge, but the second day 240 and so on till after a maximum of 910 on the fifth day, there was a slow falling off and then rapid decline on the last three days from 118 to only 5.

In like manner, other trees yielded daily crops of cicadas from their roots and these newly emerged parasites strove to attain the trunks and branches near at hand. Very large numbers were involved in small areas. In two weeks one hundred quarts of cicadas were gathered by hand from about one acre of ground while in addition probably as many more were consumed by Indian Runner ducks let loose morning and evening for the purpose of eating up the emerging cicadas, which they accomplished to the limit of capacity of each individual crop and with the greatest enthusiasm and persistence.

As it was found that one quart of winged cicadas contained from 270 to 330 individuals and weighed 10½ to 12½ ounces and that a quart of the emerging pupae contained 435 crawling individuals with weight of 17 ounces, it is evident that the entire number emerging from an acre of such suburban land runs up toward one hundred thousand with a combined weight of near one-tenth of a ton.

Turning to the second set of observations that relate to the possible modes by which the emerging pupae are able to find a tree to climb.

At the Northeast corner of a large lawn bounded North and East by hedges at right angles stood a black locust tree fifty or sixty feet in height at the end of a row of like trees running East.

It was found that the root system of this tree extended under the sod to a distance of at least seventy feet. Over this area the cicadas emerged in numbers and crawled toward the tree trunk along radii all over the quadrant represented by the area between the above hedges.

One cicada was watched from a point 61 feet from the locust tree as it went straight toward the locust tree although behind it on the same radius stood a smaller pear tree twenty-four feet away with height of some 18 feet. The large locust tree had few branches till toward the top and appeared as distinct area of but light foliage against the sky at the time of evening when the cicadas were emerging. Another cicada started from a point nearly in the center of the entire area, 36 feet from the locust tree. And a third from 27 feet though behind it was a small pear tree only four feet away. Standing on the lawn it was astonishing to see so many cicadas walking along all possible

radii from such distances as if drawn to the trunk; while many moved along parallel to the hedges and turned not aside others went along all the radii between these two hedge radii that were at right angles to one another.

A great many cicadas emerged every evening, as May 22 and 23, and all marching toward the exact middle of the tree they became concentrated more and more as they drew near the tree. However, it happened that scarcely one of this host ever reached the tree, for while but five or six out of hundreds turned aside to mount up the privet hedge some six feet in height and width, the great majority after the long walk met with an obstacle in the shape of a chicken-net wire and tall flowering orchard grass some seven or eight feet in extent and one and a half wide lying across the line of march and but five feet from the trunk of the tree. Coming to these upright but slender grass stalks the cicadas all mounted up and there stretched out to transform. Some successfully transformed though most were collected when so easy of access.

The impression made by so many individuals on different days all centered toward the same object was of forced movements impelled by the tree's presence, but whether the cicadas moved thus radially on account of their life underground having been often radial along the root system or whether for the first time the tree appealed to them as being in some sense seen against the sky was not evident. When such crawling cicadas were interrupted they returned again to their radial course.

As bearing upon the use of the eyes in this orientation may be cited a few experiments made in the midst of the lawn: a kitchen table was placed radially and cicadas placed upon it with the result that the cicadas continued along the radius toward the tree till coming to the end of the table they fell off and resumed progress in the same direction on the grass. When reversed on the table they generally soon turned back into the direction toward the tree. When both eyes were blackened with asphaltum the cicadas wandered about on the table or on the grass not showing any distinct orientation. A few with but one eye blackened seemed to walk toward the tree without much hesitation, but these experiments were made too late in the evening to be well observed.

In general one was left wondering if the cicadas did not actually see the tree in some way and be influenced by it as if it were to them a conspicuous elevated area.

For a few days after emergence no noise came from the winged cicadas but on May 26th they were very plainly heard along Charles street road and on Cold Spring lane and on the 28th along Bellona Avenue and in the woods of Homewood.

From then on all day their peculiar cries resounded in and near all other regions of emergence while very many silent areas showed their absence. While at first heard only in the heat of the day, by May 31st when the temperature had risen to 89° and the air was dry their unwelcome noise lasted on late into the night and on the leaves of trees some were found pairing.

They continued noisy day and even at night, June 6, but then more and more showed the destructive fungus in their bodies. One last noisy one was heard June 28 after a week of near silence.

It was not this species of Cicada of which the poet sung:

Du kluges Kind der Erden,
Du Freundin schoener Lieder,
Wirst nie from Alter traurig.
Dich plagen keine Schmertzen,
Du hast, so wie die Goetter,
Kein Fleisch und kein Gebleute,
Bist du nicht ihres Gleichen?

During the period of mating the cicadas collected in great numbers upon trees and bushes often at considerable heights and too frequently upon trees remote from those under which they had emerged so that despite decimation from collecting, fresh flying insects from neighbors' trees again populated the partially cleaned area; but there was no evidence of any wide migration so that concerted action could readily have rid infected areas of a large part of the accumulations of seventeen years' growth. Not only was the tin placed about trees good protection when combined with collecting by hand or by duck aid, since it arrested the crawlers and held them restricted till the daylight made collecting easy; but later on when the trees were full of flying insects the tins still had useful features. Thus June 7th after a thunder storm many flying insects were beaten to the ground and under the above pear tree 150 were found struggling to climb up the trunk and held back by the tin since they preferred the old way of crawling and climbing to get to an elevation from which to take wing. In this connection may be noted that when a tree was shaken, while most flew away many pairing or separate fell to the ground and thus could be caught: June 4th at 8 p. m. 282 were thus gathered under the pear tree.

Upon the trees the cicadas tended to congregate upon the warm sunny aspects and to crowd upon certain outstanding branches or twigs, flying constantly from twig to twig as if in search of something and gradually aggregating upon certain favored trees though neglecting completely very few indeed.

By June 3 the females were rapidly laying eggs in the twigs of ash-leaved maple, apple, plum, peach, apricot, pear, etc.

By June 8 no more were emerging. June 17, many were dying, and before the end of that month practically all adults had ceased to exist.

Meantime the new generation was progressing. As is well known the fecundated female chooses top and outlying twigs for deposit of her eggs and walking along saws into the wood deep gashes in regular series within which the same efficient ovispositor that rips open the wood deposits nicely placed packets of elongated eggs.

So deep are these injuries to the twigs and so extensive the areas affected that many twigs fail to carry their usual sap and hence the leaves shrivel. By June 17th many trees showed so many terminal twigs with brown and shrivelled leaves that it seem as if they had been scorched by fire. By June 29th the rain and wind had broken off many of these too deeply injured twigs and strewn them on the ground. Such twigs taken into the dry laboratory showed after a week only dried and shrivelled eggs, so that it may well be that very many eggs perish when the twigs in which they are placed are so severely injured that the twigs fall off. On the other hand, the great majority of twigs were not so severely injured as to loose vitality, and these remaining upon the tree finally liberated the young. Such twigs cut off and placed in a jar of water and thus kept from too great drying yielded large numbers of the young.

From August 8 to 23 such stems taken indoors yielded large crops of small white larvae which coming out of the wood crawled along and soon fell off. When the water jar was placed in a large bowl the young falling off were unable to escape up the smooth sides and gradually collected in large numbers and could be removed before they dried up.

Unlike the pupae, which emerging into the light leave a darker for a lighter region, these newly hatched larvae go from the light towards the darker areas and so collect underneath overhanging objects. Unlike the pupae which strongly strive to crawl upward the newly hatched larvae tend to crawl downward.

When placed upon earth these little larvae soon managed to dig in and disappeared from the light downward into the dark earth.

Mr. Ibara found that such young in receptacles with grass attached themselves to the roots of the grass and apparently began thus to feed from the juices of these plants.

Amongst so many cicadas coming under observation there were notable diversities. Not only the well-known dwarf cicadas, but certain exceptional varieties were observed. The dwarfs often emerged in large numbers largely by themselves with few of the larger forms at the same time and place and were especially common under a very old russet apple tree.

Amongst 9½ quarts of the flying cicadas gathered June and chiefly perfected the night previous, there were two with white eyes, one with black eyes and one with chestnut brown face. The white-

eyed cicadas have also lighter colored costal edges to the front wings and this might be considered a failure to completely darken the wing which at first was white and normally turns darker soon after hatching out from the pupa case. The white eye, however, is of fundamental nature since the normal red eye is one of the earliest areas of the body which stands out against the general whiteness as fiery red and in these two white-eyed individuals the absence of color in the eye dated back beyond the time of transformation.

Thus amidst about five thousand seven hundred cicadas two had white, one black and one chestnut colored eyes. Other collections showed that white-eyed and brown-eyed forms occurred now and then both in this same region and in Roland Park and thus from diverse groups that had been separated a couple of miles for seventeen years at least.

In the assumedly rather uniform and simple conditions of seventeen years of growth under ground there would seem little opportunity for light or other external conditions to exert any such modifying influence as might lead to white in place of red eye. Regarding the two periods of life, the short one as active larva getting into the ground and the concealed egg in the wood, as opposed to the germ life in the active adult, we seem safe in assuming that here as elsewhere the initiative to change in eye color came in the germinal material.

The injury done to trees and shrubs by the adult females in laying is not only the immediate death of important twigs when too severely cut by the ovispositor but in the leaving of wounds that may later cause injury. While the severely injured twigs may fall off soon and thus often lead to the failure of the cicada eggs from drying, the partly injured twig remains and begins to heal over, but this overgrowth rarely overtakes the young before it comes out of the wound. The following summer, 1920, many of the injured twigs were healed over more or less completely. Nevertheless the wood had been so deeply injured that a great many twigs bearing green leaves and such fruits as those of the Norway Maple were wrenched off by storms owing to the internal weakening caused by the previous season by the cicadas.

While the extensive pruning may not cause serious results in many shade trees, the dying off of twigs, the remaining of dead tips and the presence of innumerable wounds is of moment in some fruit trees and in the dogwood the pruning back by the cicadas tended to make considerable changes in fruiting, flowering and proportions of growth, while in some chestnut shoots recovering from dying down after the blight the wounds made by cicadas were placed with reference to new infestations of the blight so as to suggest that the blight had entered through these wounds in the firm young bark.

How serious the loss of sap of roots through long years of cicada sucking may be, remains to be found out.

The almost absolute completeness of the emergence in 1919 is seen in the fact that in 1920 search for these seventeen year locust yielded not one. Even in the region along Charles Street north of University Parkway where in 1919 the cicadas were swept up from the sidewalk in great numbers no cast off shells could be found in 1920 and but one solitary song in this region indicated that there had been an emergence of one of the race this season; all the others having come out in 1919 with practically no lag.

It is the phenomenal uniformity with which all these creatures in a given region run through their long period of growth to emerge within so few days after seventeen years and with so few exceptional hurried or lagging individuals that presents a problem in rhythmic growth of great interest as is also the question as to how far these insects may be guided by sight in the first use of their eyes upon coming from seventeen years of apparent darkness. These and other questions may be approached experimentally if attention is called to this field in time; and fortunately some broods of these insects come out at predictable dates in various parts of the country in different years so that observation can be spread over much of the long interval otherwise lost in any one locality.