C. V. Riley, del. L. Sullivan, pinx.

TRANSFORMATION OF PERIODICAL CICADA (TIBICEN SEPTENDECIM).

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 71.

L. O. HOWARD, Entomologist and Chief of Bureau.

THE PERIODICAL CICADA.

BY

C. L. MARLATT, M. S.,

Entomologist and Acting Chief in Absence of Chief.

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U. S. DEPARTMENT OF AGRICULTURE,
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Washington, D. C., April 16, 1907.

SIR: The subject of the periodical or 17-year Cicada has been treated in two publications of this Bureau, namely, Bulletin No. 8 (old series), published in 1885, and Bulletin No. 14 (new series), published in 1898. Both of these publications are now out of print, and the accumulation of a large amount of new records of distribution and the increase of information on the habits of this insect call for a new publication. Mr. C. L. Marlatt, who was the author of Bulletin No. 14, has thoroughly revised that publication, incorporating all new records and information, and the manuscript is submitted for publication as Bulletin No. 71 of this Bureau.

In this publication the new numbering of the broods suggested by Mr. Marlatt in Bulletin No. 18 (new series), of this Bureau, is followed, so that now the designation of the broods indicates directly their relationship to each other in time and distribution.

The writings on this species are voluminous, and the bibliography published in Bulletin No. 14 has been extended to include the important additions to the literature which have appeared since 1898.

A good deal of the matter from Bulletin No. 14 has been used without change, but the brood records have been thoroughly revised and a distribution map has been made for each of the known broods. Some new photographs have been introduced to illustrate particular features of the life history of the Cicada.

The periodical Cicada covers in its range nearly all of the United States from the Mississippi Valley eastward, and has a very considerable economic importance. The curious features of its regular periodic appearances and its long subterranean life give it perhaps the greatest popular interest which attaches to any insect whatever, and lead to many inquiries with every recurrence of an important brood.

The present year will witness the recurrence in the Southern States of the largest of the 13-year broods of this insect, and the prompt publication of this Bulletin is therefore advised to meet inquiries for information and to assist in the collection of accurate records of this and subsequent broods.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE PERIODICAL CICADA.

SUMMARY OF THE HABITS AND CHARACTERISTICS OF THE CICADA.

The periodical Cicada, often erroneously called the "17-year locust," or merely the "locust"—a term which should apply only to grasshoppers [a]—is, in the curious features of its life history, undoubtedly the most anomalous and interesting of all the insects peculiar to the American Continent. This Cicada is especially remarkable in its adolescent period, the features of particular divergence from other insects being its long subterranean life of 13 or 17 years, during all of which time its existence is unsuspected and unindicated by any superficial sign, and the perfect regularity with which at the end of these periods every generation, though numbering millions of individuals, attains maturity at almost the same moment. To the naturalist, familiar in a general way with the peculiar habits of this Cicada, its regular periodic recurrence always arouses the keenest interest on account of the anomalous life problems presented. To those unfamiliar with its habits, these sudden recurrences not only startle but often excite the gravest fears for the safety of trees and shrubs or even of annual plants.

In view of the damage often occasioned by unusual insect outbreaks, such fears are not unreasonable, when, without warning, this Cicada suddenly emerges over greater or smaller areas, filling the ground from which it issues with innumerable exit holes, swarming over trees and shrubs, and making the air vibrate with its shrill, discordant notes. During its short aerial life it leaves very decided marks of its presence in the egg slits which thickly fill all the smaller twigs and branches, the killing or injury of which causes some temporary harm and a sort of general twig pruning not especially injurious to forest trees, but more so to fruit trees, and very undesirable and disastrous to young trees and nursery stock. (See Pl. I.)

[a] The confusion of the Cicada with the true locust or grasshopper was a natural one and appeared in the earliest published notice of the Cicada (1666), and the name locust has ever since remained the popular designation of this insect. The sudden appearance of the Cicada in vast numbers very naturally recalled to the first observers the hordes of migratory locusts or grasshoppers of the Old World, as Say and Fitch early pointed out.

Following briefly the history of the insect, the young ant-like larva, hatching from the egg a few weeks after the latter has been laid, escapes from the wounded limb, falls lightly to the ground, and quickly burrows out of sight, forming for itself a little subterranean chamber or cell over some rootlet, where it remains through winter and summer, buried from light, air, and sun and protected in a manner from cold and frost. It lives in absolute solitude, separated from its fellows, in its moist earthen chamber, rarely changing its position save as some accident to the nourishing rootlet may necessitate its seeking another. In this manner it passes the seventeen or thirteen years of its hypogeal existence in a dark cell in slow growth and preparation for a few weeks only of the society of its fellows and the enjoyment of the warmth and brightness of the sun and the fragrant air of early summer. During this brief period of aerial life it attends actively to the needs of continuing its species, is sluggish in movement, rarely taking wing, and seldom takes food. For four or five weeks the male sings his song of love and courtship, and the female busies herself for a little longer period, perhaps, with the placing of the eggs which are to produce the subsequent generation thirteen or seventeen years later. At the close of its short adult existence the Cicada falls to the ground again, perhaps within a few feet of the point from which it issued, to be there dismembered and scattered about, carpeting the surface of the ground with its wings and the fragments of its body. Such in brief is the life round of this anomalous insect.

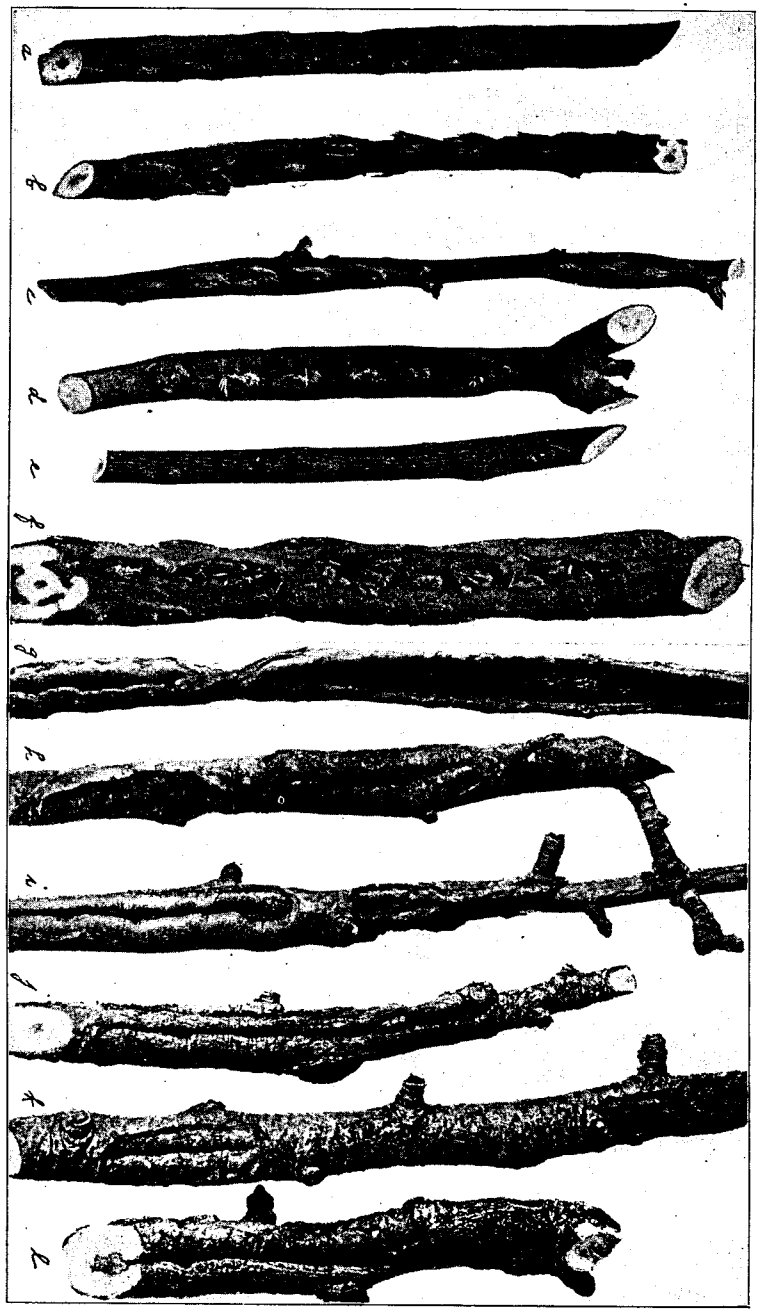
So far as is known, other cicadas appear every year, usually in comparatively small numbers, and this yearly recurrence has led to the belief that the larval existence of these species is much shorter, if not limited to a single year. In the absence of direct experimental proof, however, it may be true that all cicadas have a long larval existence, and the absence of well-marked broods in other species or the complete breaking up or scattering of these broods, so that individuals emerge practically every year, have erroneously been taken to indicate a much shorter term of underground life.[a]

If we can not satisfactorily explain the reason for the long larval life of the periodical Cicada or the conditions which led to the origin

[a] The writer recalls that in the summer of 1885 a very large species of Cicada (*C. marginata* Say) appeared in considerable numbers among the scrubby white oaks bordering a stream near Manhattan, Kans., and filled the air with its very loud and discordant vibrations; yet, although familiar with and a frequent visitor of these woods in earlier and later years, no other experience with this particular species was had. It may be, therefore, that this species, which is more than twice the size of the periodical Cicada, has an even longer life period.

There are other western or Rocky Mountain species which give evidence of paralleling very closely in periodicity and number the eastern periodical Cicada. (See p. 36.)

WORK OF THE PERIODICAL CICADA.



a, Fresh wounds in maple; *b*, *d*, *e*, and *f*, Condition four months later in maple; *c*, Wounds healed in one season; *c*, Three months' old scars in wild cherry, showing that the punctures may extend both forward the top and base of the twig; *g*, *h*, *i*, *j*, *k*, *l*, Cicada scars seventeen years old on terminal branches from old trees; *g*, *h*, *i*, Apple; *j*, *k*, *l*, Pear. (After Hopkins.)

of this peculiarity, assuming it to be abnormal, we can at least see certain advantages coming to the species therefrom. Among these are the protection from attacks of parasitic enemies, since we can hardly conceive of a parasite limited to this Cicada which could possibly extend its existence over an equal term of years. Its occurrence, also, in overwhelming numbers at almost the same moment everywhere within the range of the brood prevents its being very often seriously checked in its adult stage by the attacks of birds and other vertebrate enemies, which fatten on it in enormous numbers. For this species this is a most important consideration, for it is naturally sluggish and helpless and seems to lack almost completely the instinct of fear common to most other insects, and this leaves it an easy prey to insectivorous animals. The almost entire absence of fear and consequent effort to save itself from danger by flight or concealment is apparently a consequence of the long intervals between its aerial appearances.

The greatest check on the species has been in the advent of Europeans on this continent and the accompanying clearing of woodlands and increase of settlement. The vast areas in the more densely populated East, which were once thickly inhabited by one or the other of the broods of the periodical Cicada, are rapidly losing this characteristic, and the Cicada will doubtless appear in fewer and fewer numbers in all settled districts. A recent important factor which is assisting in this particular is the English sparrow, and it has been shown by Professor Riley and later observers that in and about cities nearly all of the few cicadas which still emerge under these more or less unfavorable conditions are devoured by this voracious bird. On the other hand, as stated (p. 58), the first brood of these insects to be noted by the early New England colonists, namely, the swarm recorded for Plymouth for 1634, was just as abundant in 1906, the year when it last recurred, as ever. This is, however, not the normal condition, the wooded areas having been considerably maintained in Plymouth and Barnstable counties, whereas ordinarily such wooded areas have been greatly reduced or obliterated, and the Cicada in consequence slowly exterminated.

The rapid disappearance of the Cicada, as a result of the clearing of forest areas and the conditions which accompany settlement, is notably shown in the case of Brood XI, which formerly occupied a compact territory in the valley of the Connecticut River in the States of Massachusetts and Connecticut. In a letter to the writer, Mr. George Dimmock, who has made a special study of this brood in the northern part of the town of Suffield, Conn., says: "When I saw them in 1869 the cicadas were so abundant that small bushes and undergrowth in the rather sparse woods in which they occurred were weighted down with them." In 1886 he was unable to visit the region, but was

informed that very few of the insects appeared that year. In explanation of this he writes: "The woodland in the vicinity has been steadily reduced and the cicadas, of which there are records going back about a century, seem to be dying out. The owner of the land where the cicadas appeared (a man born in 1815, died in 1892) informed me that the rate of reduction was so rapid that he doubted if any of them would appear in 1903."

To the lover of nature there is something regrettable in this slow extermination of an insect which presents, as does the periodical Cicada, so much that is interesting and anomalous in its habits and life history. During the long periods of past time the species has recurred with absolute regularity except as influenced by notable changes in the natural topographical conditions and the despoliation of forests which has followed the path of settlement by the white man. It is interesting, therefore, in thought to trace the history of this species backward, taking, as time measures, its periodic recurrences, until in retrospect it is possible to fancy its shrill notes jarring on the ears of the early colonists or listened to in the woodlands bordering the ocean by the still earlier discoverers and explorers. Still more remotely one can picture its song causing wonderment to the savage Indians who attributed to it baleful influences, and yet, less dainty than their white followers, used the soft, newly emerged cicadas as food; or further back in time, when it had only wild animals as auditors. With these long-time measures our brief periods of days, weeks, months, and years seem trivial enough.

THE RACES, BROODS, AND VARIETIES OF THE CICADA.

Much obscurity must always attach to the past history of this insect and the origin of its peculiar habits, and notably the causes and conditions which have led to the establishment of the long underground existence and the equally extraordinary regularity in time of emergence at the end of this period. Explanations may, however, be suggested for some of its peculiarities as presented in its life at the present time—as, for example, the origin of the two distinct races, one with a 17-year period and the other with a 13-year period, with both of which a small variety occurs, and the existence of a multitude of distinct broods occupying the same or different territory and appearing in different years but with absolute regularity of periods.

A SEVENTEEN-YEAR RACE AND A THIRTEEN-YEAR RACE.

One of the greatest difficulties in solving the problem of the broods of this insect and their geographical limits was removed by the discovery of the existence of two distinct races—namely, one requiring seventeen years for its development and limited geographically, in a general way, to the northern half of the range of the species, and the other requiring but thirteen years for its development and covering the southern half of the range of the species.

This interesting and very important fact was first discovered, it seems, by Dr. D. L. Phares, then of Woodville, Miss., who announced the 13-year period for the southern broods in a local paper—the Woodville (Miss.) Republican, May 17, 1845. As this paper had only a local circulation the significance of this discovery was lost sight of and probably never came to the attention of naturalists; and it was not until 1868, when Dr. B. D. Walsh and Prof. C. V. Riley arrived at the same conclusion and published, in a joint article in the American Entomologist,[a] a mass of accumulated observations bearing thereon, that the 13-year period for the southern broods came to be generally accepted.

In Professor Riley's first report on the insects of Missouri, published the following year (1869), the joint article just referred to was reproduced substantially without change, except for a revision of the classification of the broods, based on data obtained chiefly from a very valuable unpublished monograph entitled "The American locust," etc., by Dr. Gideon B. Smith, of Baltimore, Md.

This manuscript paper, on the authority of Professor Riley, was communicated to him by Dr. J. G. Morris, of Baltimore, some four months after the publication of the existence of the 13-year race by Walsh and Riley, but in time for use in the preparation of the article for the First Missouri Report. In it the existence of the 13-year Southern race, occurring in several broods, is fully recorded by Doctor Smith in connection with the use of the specific name "*tredecim*." (See Appendix.)

After the existence of the 13-year Southern race was again brought into prominence by Walsh and Riley, Doctor Phares published an article in the Southern Field and Factory, Jackson, Miss., April, 1873, in which he called attention to his earlier publication, cited above, where he seems to have controverted the belief that there is no 13-year brood, evidently entertained up to that time by Doctor Smith, with whom Doctor Phares was in correspondence, and also to an article published May 5, 1858, in the Republican, where he used the title "Cicada tredecim." Doctor Smith later evidently accepted the conclusions of Doctor Phares and introduced them in his last revision of his manuscript memoir, which Professor Riley saw and used. To Doctor Phares, therefore, belongs the honor of having made the discovery of the 13-year period for the Southern broods. Nevertheless, but for the independent work of Walsh and Riley, the knowledge of the 13-year broods might have been long lacking, and, in the

[a] Vol. 1, pp. 63–72, December, 1868.

nonpublication of Doctor Smith's monograph,[a] these broods would have failed of the abundant proof on which they now rest. The race name of *tredecim* for the 13-year broods was suggested by Walsh and Riley without knowledge of its earlier use by Doctor Phares. The latter's early articles in the Republican are lost altogether, the author himself not being able to recover them in later years, and the credit for the name *tredecim* for the 13-year race, following the customary rules, should go to Walsh and Riley.

The discovery of the 13-year Southern race was of vast assistance in clearing up the confusion which had attended the study of the different broods of this insect and enabled Walsh and Riley to separate some sixteen distinct broods, three of which belong to the *tredecim* race, and later enabled Professor Riley, with the aid of Doctor Smith's paper, to increase the number of *tredecim* broods to seven and the total of the broods to twenty-two, twenty-one of which the records of subsequent appearances have proved to be valid.

Doctor Smith's remarks in his manuscript chapter on geographical tribes and districts present the status of the 17-year and 13-year races very clearly. He says:

> There are two divisions or tribes, differing from each other only in the periods of their lives; the one and much the larger division living 17 years, and the other 13; hence the impropriety of the specific name *septendecim*. * * * The anatomy of the insects of both divisions is precisely the same, but *septendecim* does not of course apply to the Southern division, whose lives are but 13 years. Shall we call the latter *Cicada tredecim?* Why there is this difference in the periods of lives of the two tribes we can not explain. It is not the climate that causes it, as a moment's reflection will prove. If that were the cause the difference would be more gradual. For example, in northern New York they would have been, say, 17 years; in Pennsylvania, 16; in Maryland and Virginia, 15; in North Carolina and Tennessee, 14, and in South Carolina, etc., 13 years in completing their existence. But that is not the case. The difference of years takes place abruptly on and about the line of 34° and 35° of north latitude, on the north side of which the period is 17 years and on the south 13 years.

While Doctor Smith is hardly justified in the last statement, it is nevertheless true that the 17-year race is northern and the 13-year race is southern. The territory of the two races is graphically shown in figures 2 and 3, and is described in detail and mapped for all the broods in a later section.

In this bulletin the two forms of the periodical Cicada have been designated as "races," adopting the position taken by Professor Riley and the majority of the writers on this insect, rather than considering them to be distinct species, as is held by some specialists. Professor Riley and others opposed the idea of their being specifically distinct, not only because of their practical identity in general characteristics and habits, but also on the ground of external structure, no material difference in this respect having been noted between the two races, although it was known that the individuals did not cross when they appeared together. Doctor Walsh was very firmly of the opinion, on the other hand, that they represent two distinct species, yet in a letter to Mr. Darwin he described the 13-year race as an incipient species, to which, for convenience, it is desirable to give a distinctive name.[a] His published views on the subject, given in a posthumous paper, are quoted below.[b] Referring to the impossibility of distinguishing species in certain genera by a mere comparison of the perfect specimens, he says:

> Upon the same principle I strongly incline to believe that the 17-year form of the periodical Cicada (*C. septendecim* Linn.) is a distinct species from the 13-year form (*C. tredecim* (Walsh and Riley[c]) Riley), although it has been impossible for me, on the closest examination of very numerous specimens, to detect any specific difference between these two forms. It is very true that the 13-year form is confined to the more southerly regions of the United States, while the 17-year form is generally, but not universally, peculiar to the Northern States; whence it has been, with some show of plausibility, inferred that the 13-year form is nothing but the 17-year form accelerated in its metamorphosis by the influence of a hot southern climate. But, as these two forms interlock and overlap each other in various localities, and as it frequently happens that particular broods of the two forms come out in the same year, we should certainly expect that if the forms belonged to the same species they would occasionally intercross, whence would arise an intermediate variety having a periodic time of 14, 15, or 16 years. As this does not appear to have taken place, but, on the contrary, there is a pretty sharp dividing line between the habits of the two forms, without any intermediate grades of any consequence, I infer that the internal organization of the two forms must be distinct, although externally, when placed side by side, they are exactly alike. Otherwise, what possible reason could there be for one and the same species to lie under ground in the larva state for nearly 17 years in one county and in the next adjoining county to lie under ground in the larva state for scarcely 13 years? I presume that even the most bigoted believer in the old theory of species would allow that, if it can once be proved to his satisfaction that two apparently identical forms are always structurally distinct, whether in their external or their internal organization, they must necessarily be distinct species.

The reasons urged by Doctor Walsh give a strong basis of probability to the theory of the specific distinctness of the two races, and particularly the fact that where the broods overlap there seems to be no interbreeding. Doctor Walsh's position has been upheld by Dr. Wm. H. Ashmead, who states that in a very careful examination

[a] A summary, with extracts, of this manuscript made by Professor Riley is the writer's source of information on this valuable paper, which, while containing much error and wrong inference, yet indicates careful study and accurate observation.

[a] See Index to Missouri Entomological Reports, Bul. 6, U. S. Ent. Comm., p. 58.

[b] American Entomologist, Vol. II, p. 335.

[c] Taking the ground that Doctor Phares can not be credited with the race name "tredecim" on account of the ephemeral character of the journal in which he employed it, the credit should go to Walsh-Riley, since the article in the American Entomologist of December, 1868, where it was next suggested, was a joint or editorial one. Professor Riley himself sanctions this course in the Bibliography of Economic Entomology, Part II, p. 61, No. 474.

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of the material in the National Museum he has observed small but constant differences between the two races in the shape of the last ventral segment of both the male and the female.

For the present purpose, however, it seems wiser to consider the 13-year broods as representing a race merely, or an incipient species, as suggested by Walsh, because of the absolute resemblance in practically every feature of structure, coloration, and habit, in the two forms, which exhibit the single important point of difference represented by the four years' variation in the length of their subterranean lives.

While in the matter of interbreeding they may be distinct, as the records seem to prove conclusively, the two races represent one species for all practical purposes and differ in a very striking manner from all other species of the family Cicadidæ. One race is unquestionably the offshoot of the other, the original differentiation being probably caused by some variation in climatic conditions.

It is, perhaps, a hopeless task, and at best only a matter of conjecture, to attempt to explain the phenomenon of what is practically the same insect requiring in one part of the country seventeen years for its underground development through its preliminary stages and in another section thirteen years, in the face of the fact that while, in the main, the two sections are, respectively, northern and southern, yet at the point of juncture the broods of the two races overlap. That the 17-year period does not depend so much on the greater severity of the northern winters is evident, protected as the insect is by the depth of its burrows, and the natural explanation is that the longer period of warmth in the South hastens the development of the insect, or, in other words, that the difference in the length of the warm growing period during which the insect can thrive and increase in size in the southern half of its range enables it to go through its development in four years less time than in the North, where shorter summers and consequently shorter periods of growth occur. The chief objections to this theory, but not necessarily controverting it, are those made by Doctors Smith and Walsh in the quotations given. The problem is, however, a very interesting one, and some light may be thrown upon it by further experiments similar to those described under the head following.

RELATION OF CLIMATE TO THE RACES.

The anomaly presented of two distinct periods for the completion of the adolescent stages of the periodical Cicada, exhibited by the 13-year and 17-year races, and its apparent basis in climate led Professor Riley to institute some careful experiments in transferring the eggs of the 13-year race, collected in various Southern States, to different localities in the North, and conversely, eggs of the 17-year race collected in the North to localities in the South, to determine the actual influence

of temperature or whether the 13-year race would maintain its normal period in the North and the 17-year race in the South. The object of the experiment, in other words, was to determine whether the difference in time of development between the two races is really one of climate and temperature only or whether a fixed characteristic has been acquired, not subject to much, if any, modification with changing temperature conditions. That the separation was originally caused by differences in climate in different parts of the range of the species can not be doubted, but the fact that the two races often overlap in the adjoining territory of their respective ranges would seem to indicate that this time period has become in the course of ages a rather permanent feature.

Doctor Riley's early experiments in this direction were in 1881 with the 13-year Brood XIX, but the eggs distributed were in such condition that it is doubtful if they hatched, and the effort failed.

A much more elaborate test was instituted in the summer of 1885, in connection with the joint appearance that year of the 13-year Brood XXIII, which returned in 1898, and the 17-year Brood X, which returned in 1902. All possible precautions were observed not only to collect the egg-bearing twigs at the right moment and to distribute them in fresh, healthy condition, but to see also that they were properly placed under suitable trees and that a record was made in each instance of the exact locality. Furthermore, most of the transfers were kept under observation for a time to see that the eggs actually hatched and the larvæ entered the soil in their new situations. The record of these transfers is given in detail in the report of the Entomologist, Report of the Department of Agriculture for 1885, pages 254–257, and was reproduced in Bulletin 14 as Appendix A. The eggs of the 13-year brood were collected in Mississippi between July 6 and 17, and distributed to entomologists in New York, Iowa, Massachusetts, and Maine in eleven lots. The eggs of the 17-year Brood X were collected in Indiana, Pennsylvania, and Michigan, chiefly in the latter State, between July 6 and 21, and distributed in seventeen different lots to correspondents or entomologists in Georgia, Mississippi, Alabama, and Missouri. The preliminary report on the condition of this material is given in the appendix cited of Bulletin 14. The only positive record received was from Prof. Eugene A. Smith, University of Alabama, who found in 1898 one pupal shell and noticed several holes in the ground which answered to the description of exit openings made by the Cicada. The pupal shell was sent to me and proved to belong to the periodical species. That it comes from the eggs planted in 1885 seems probable, from the fact that no brood was due in this locality in 1898, and this would seem to indicate that the 17-year brood may be greatly abbreviated or reduced to the 13-year term in a warmer latitude. Part of the eggs sent to Professor

Smith came from Indiana and the rest from Michigan. Too much importance, however, can not be given to this isolated experience. Correspondence was kept up with as many of the points as could be reached during the next four years, but no further records were obtainable.

Nothing whatever came of the 13-year material sent to northern localities.

The difficulty in an experiment of this kind lies in the long term over which it extends, and the inevitable changes of local conditions and the removal or death of observers intrusted with the experiment. It is necessary, as demonstrated by a later test (see pp. 114–116) of egg transfers, to have an enormous quantity of eggs to insure the insects going through the entire term undestroyed by natural enemies or accidents.

THE DWARF PERIODICAL CICADA.

In connection with the discussion of the 13-year and 17-year races of the Cicada, it is interesting to note also that in both races the insect occurs in two distinct types, viz, a large form and a small form, the former comprising the bulk of the individuals of the brood and the latter more rare and often unobserved. The existence of these two types was commented upon as early as 1830 by Doctor Hildreth, of Marietta, Ohio,[a] and was especially remarked in the great Cicada year 1868. The typical larger Cicada (fig. 1, *A*) measures on an average 1½ inches from the head to the tip of the closed wings and expands over 3 inches. The underside of the abdomen is of a dull orange-brown color and in the male four or five segments are of the same color on the back. The smaller form is rarely more than two-thirds the size of the larger, and usually lacks altogether the light abdominal markings, although they are sometimes represented on the edge of the segments beneath.

The small form (fig. 1, *B*) was described in 1851 as a distinct species, *Cicada cassinii*, by Dr. J. C. Fisher.[b] The contention that it represents a distinct species was urged particularly on the ground that there exists a variation in the genitalia, but this variation has since been shown by Professor Riley not to be constant, and specimens are to be found in both sizes which present the same structure in these parts.

In view of the close anatomical correspondence, except in size, of the two forms and the fact that they always occur together in the same broods and have the same anomalous subterranean period of larval and pupal life, the specific importance of the smaller Cicada has been naturally open to question, and in Bulletin 14 the writer was inclined

[a] Silliman's Journal, XVIII, p. 47.

[b] Proc. Acad. Nat. Sc. Phila., Vol. V., p. 272.

to consider this small form as a mere variety or, more properly, a dimorphic variety of the larger form.

On the authority of various observers certain divergences in habits between the two forms were commented upon. It seemed to be the general belief that the larger one appears somewhat earlier, from eight to ten days, and correspondingly, also, the smaller form disappears somewhat later in the season than the larger. The smaller cicadas were also reported by various observers as being more or less gregarious in habit, not always intermingling with the larger ones but collecting in small companies in orchards or in thickets along streams and moist places. Further, the song note of the small form was somewhat different, but this last variation was not fully confirmed.

This small Cicada was particularly noted in the case of Brood X at the time it was studied by Walsh and Riley in 1868 and, judging from the records obtained of this brood of 1885 and 1902, Brood X seems to be its particular stronghold, although it occurs with other broods, often very scatteringly.

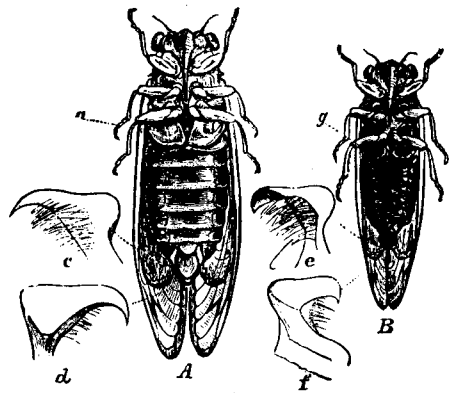

FIG. 1.—The periodical Cicada: *A*, male of typical form, natural size; *c*, *d*, genital hooks enlarged; *g*, singing apparatus, natural size: *B*, male of the small form (*cassinii*), natural size; *e*, *f*, genital hooks, enlarged. (After Riley and Hagen.)

In 1902 the writer observed this small form in great abundance in and near the District of Columbia, but, contrary to the former belief, it appeared in large percentage during the first week or ten days of the emergence of the Cicada, probably representing 50 per cent of the specimens, and soon disappeared. Both sexes were represented, and mating and oviposition seemed to go on normally as with the large form. The song notes of the dwarf Cicada were distinctly different from the common note of the large Cicada, namely, a broken and chirping note, very shrill and loud. The abundance of the small form in 1902 and the difference in its song notes were observed by various persons throughout the range of the brood.

A careful statistical study of the variation in size and characteristics of the large and small forms was made in connection with the 1902 appearance of this brood in Ohio by Prof. Herbert Osborn.[a] Professor Osborn examined and made careful measurements of some 800 specimens taken at random from various localities. The results

[a] Ohio Naturalist, III, pp. 323–326, December, 1902.

of these measurements indicated a decided constancy for each variety and for each sex of each variety in wing lengths and widths and body lengths. The color variation was also very constant. The abdomen of the *cassinii* form is normally entirely black beneath, only rare specimens showing a narrow hind border of yellowish or orange yellow. The cross veins also on the wing forming the W mark are commonly less black, and the W therefore shortened. This point, however, as in the normal form, seems subject to wider variation than the other features.

There is a difference in genitalia, but apparently not enough to exclude the idea of crossing, and, according to Riley, this difference is not constant. In the mating, out of seventy pairs observed there was no instance of *cassinii* pairing with the normal large form, evidencing an apparently complete isolation by sexual selection. Professor Osborn shows, therefore, that there is no ground for considering the small form as a dimorphic or seasonal stage of the large.

Professor Osborn infers that the *cassinii* is a derived form, since it appears less commonly than the other and probably has a more restricted range, and suggests that it may be possibly a "depauperate variety" which has become in the course of ages fully established, especially with Brood X, being very rare with Broods III and XIII, which he had also studied. He concludes: "Whether this form be called a variety, subspecies, or species, is, it seems to me, of less importance than a recognition of its distinctness, and the determination, if possible, of its phylogenetic relationship."

The nomenclature of the species, variety, and races of the periodical Cicada adopted by the writer is the same as that followed in Bulletin 14, namely, the Linnaean species *Tibicen* (*Cicada*) *septendecim*, with the *tredecim* race of Walsh and Riley, and the variety *cassinii* of Fisher.

THE BROODS OF THE PERIODICAL CICADA.

The subject of the broods of the periodical Cicada presents a number of interesting fields of inquiry, such as the consideration of the origin of the broods, their chronological history and classification, and their exact geographical limits or distribution. These topics will be taken up somewhat in detail, with the exception of the chronological history of the appearances during the last two hundred years and accompanying voluminous historical records, which, for reasons to be later noted, have been largely omitted.

The Origin of the Broods.

It is not necessarily true, but it is a reasonable inference, that in the early period of the existence of the periodical Cicada on this continent it was represented by a single brood. Assuming this to have been the

case, the Cicada would have appeared everywhere over its range in the same year and probably at about the same time. In the long course of ages, with the consequent important changes—geographic, climatic, and topographic—this original brood became gradually broken up into many broods, with constantly increasing divergence in the dates of appearance, so that at the present time nearly every year has its brood, or broods, each of which is limited, as a rule, to well-defined districts, and each reappearing at the proper intervals with absolute regularity. Of the upward of twenty broods which have been differentiated, most of them have been carefully studied, chronological records collected, and the limits of distribution fairly well determined. For convenience of reference, these broods have been designated by Roman numerals, as Brood VI, Brood XXVI, etc.

The origin of distinct broods in an insect possessing as long a developing period as the one under discussion is not difficult of explanation. It is a well-known phenomenon in connection with insect life that, whatever may be the period of development of a species, certain individuals will often, for some reason or other, such as insufficient or unsuitable food, unfavorable temperature, or other conditions, be delayed or retarded, while others, for reasons the converse of the last, namely, conditions exceptionally favorable, will develop more rapidly or will be accelerated and appear earlier. Therefore, under the former conditions we have a longer and under the latter conditions a shorter life period.

This is true to a slight degree at the present time of the periodical Cicada, and especially with the larger broods has it been noticed that scattering individuals appear the year before and others the year after the great brood year. It is not difficult to imagine, therefore, that under exceptional conditions some of the earlier appearing individuals or the later ones may occur in sufficient numbers to establish a well-marked peculiarity in this direction and form a new brood appearing a year earlier or a year later than the original one. If in the long course of years some accident should happen to the parent brood in that portion of its range the derivative brood might be left to hold the territory alone or to become the predominant swarm.

This explanation is supported also by the fact that it often happens that the broods of two successive years occupy contiguous territory, as, for example, the 13-year Brood XXII, which last appeared in 1897, is distributed between Vicksburg and New Orleans, or just south of the 13-year brood which appeared in 1898. It is reasonable to infer, therefore, that Brood XXII is simply a strong, well-established colony of accelerated individuals from the southern end of Brood XXIII, with a 13-year period terminating one year earlier than that of the parent brood. The conditions which led to the emergence of the insect below Vicksburg in twelve years some time in the remote past

being temporary, this portion of the old brood resumed the normal 13-year period.

Another marked instance of the same kind is shown in the relations between Brood XI and Brood X, the former being merely an appendix or a continuation in a northeasterly direction of the territory occupied by the eastern branch of Brood X, which always precedes Brood XI by one year. The interrelations of these and all the other broods are indicated in the discussion of the distribution of the Cicada.

Local or temporary conditions which have caused a moderate change in the time of emergence of the Cicada are on record, one notable instance resulting from an artificial heating of the soil by hot pipes (see p. 90).

A similar instance of acceleration of Brood XIII, due in 1905, but amounting to a full year, occurred in 1904 in a greenhouse at Belvidere, Ill. The owner, Mr. B. Eldredge, writes that in 1888 he moved from Chicago to Belvidere, and found everything covered with locusts, and an enormous amount of damage to all kinds of shrubs and trees was done. At the time he bought the place it was covered with an old apple orchard, and the locusts worked very abundantly in these trees. Some seven years afterwards these trees were grubbed out and the ground covered with greenhouses, and the ground so protected had been kept warm winter and summer ever since. Mr. Eldredge is convinced, and he is undoubtedly right in this belief, that this continual heat and absence of frost accounts for the appearance of the locusts in his greenhouses a year ahead of time.

He states that the locusts appeared in quantity. Before the matter was brought to the writer's attention they had largely disappeared, but two adult locusts were submitted and a lot of shed skins, which fully confirmed the identification of the insect. It would be rather interesting to know more about the local conditions to determine how the cicadas were able to survive in soil from which the vegetation must have been entirely removed.

An instance of a few weeks acceleration under outdoor conditions is given by Mr. Schwarz.[a] Commenting on the slightly earlier emergence of individuals of Brood XIV near Harpers Ferry, W. Va., in 1889, in a small clearing surrounded by woods, Mr. Schwarz urges that a clearing made in the midst of a dense forest forms a natural hothouse, the soil receiving in such places much more warmth than in the shady woods. That the cicadas should appear a little earlier in such situations is not remarkable, and he suggests also that under favorable circumstances the Cicada might develop on such cleared places one or more years in advance of the normal time, and that these precursors, if numerous enough, would be able to form a new brood.

[a] Proc. Ent. Soc. Wash., I, p. 230.

It is possible to conceive also of conditions which would result in the acceleration or retardation in the development of an entire brood or broods of the Cicada, such as variation in climatic conditions, geological changes, or changed conditions of the topography of the country, including the character of the vegetation.

In this or other ways, at any rate, the Cicada has become broken up into a large number of distinct broods, often covering different territory, but not necessarily so doing, each, however, maintaining its regular time of appearance.

The slight but constant tendency to variation which has brought into existence the broods now so well marked, continued indefinitely, would so break up and scatter the present broods as to ultimately obscure them altogether, and the overlapping of districts and the variation in time of appearance would lead to a rather general occurrence every year of the periodical Cicada throughout its range, the long period for development, however, still persisting. Anticipating such an outcome from the intermixture and overlapping merely of different broods, Doctor Smith (Smith MS.) rather mournfully says: "In those times, if these sayings of mine should be thought of, they will be ridiculed as a superstitious legend of the olden times."

The Classification of the Broods.

In the first edition of this bulletin the numerical designation of the broods of the two races suggested by Professor Riley was followed. This numbering has, however, objectionable features and obscures the relations of the broods of each race to each other. To overcome these objections a new system of numbering was proposed by the writer,[a] which has since been generally adopted. The reasons for making this change and the numerical designations proposed are here reproduced with little change from the publication cited.

The earlier writers, viz, Prof. Nat. Potter, Dr. William T. Harris, and Dr. G. B. Smith, classified the broods solely according to the years of their appearance. The unpublished register left by Doctor Smith includes every important brood now known classified according to race, and gives the localities for one additional brood, the existence of which seems not to have been confirmed. Though lacking any special designation for the broods, Doctor Smith's classification is as complete and accurate as that published by Doctor Riley and since followed by all later writers.[b] Dr. Asa Fitch was the first to introduce a numbering system for the different broods, enumerating nine altogether, but his data were very limited and he was not aware of the thirteen-year southern period, and there necessarily resulted no little confusion of the broods of the two races. The

[a] Bull. 18, n. s., Div. Ent., U. S. Dept. Agric., pp. 52–58, 1898.
[b] See Appendix.

Walsh-Riley enumeration of 1878 gave the records for sixteen broods, which were designated by Roman numerals from I to XVI, the enumeration being based on the sequence of the different broods after 1868. In 1869, in his First Missouri Report, Professor Riley, having in the meantime secured the manuscript paper of Doctor Smith, added the six broods from this paper not represented in the Walsh-Riley enumeration, increasing the number of the broods to XXII, and renumbered them again in accordance with their sequence, beginning with 1869. These broods vary enormously in their extent, some of them being represented by scattered colonies, which perhaps have no real relationship in point of origin, and others covering nearly uniformly vast stretches of territory extending over several States together. Several are rather unimportant, or lack confirmation, and one of them, Brood III, was founded on an erroneous record and has been dropped.

In the enumeration of the broods by Walsh-Riley, and later by Riley, the two races are mixed together and a sequence of numbers given which, after the first thirteen years, lost all significance as a record of the order of the broods in time of appearance, and from the first obscured the true kinship of the broods in each race. If, on the other hand, each race be considered separately and its broods be arranged in a series in accordance with their sequence in time, an important natural relationship in point of origin and distribution is plainly indicated.

Taking first the broods of the 17-year race, as Riley numbered them, it will be seen from the subjoined table that if the enumeration begin with Brood XI, the 17-year broods follow each other in regular succession for eleven consecutive years, then after a break of one year follow Broods V and VIII, and after another break of one year Brood IX. Another break of one year precedes the next recurrence of Brood XI, with which the series starts.

Chronological order of the Riley broods of the Cicada from 1893 to 1910.

Year.	17-year race.	13-year race.	Year.	17-year race.	13-year race.
1893	XI	XVI	1902	XXII	.....
1894	XII	XVIII	1903	I	.....
1895	XIII	II	1904	.....	.....
1896	XIV	IV	1905	V	.....
1897	XV	VI	1906	VIII	XVI
1898	XVII	VII	1907	.....	XVIII
1899	XIX	.....	1908	IX	II
1900	XX	.....	1909	.....	IV
1901	XXI	X	1910	XI	VI

Taking up the 13-year broods in the same way, it will be seen that if the enumeration start with Brood XVI, a 13-year brood follows in regular succession for six years. With the exception of the very doubtful Brood X, which is separated from the last 13-year brood by

three years, there follow seven successive years in which no 13-year broods occur.

Under the supposition that the different broods of the 17-year and 13-year races sprang in the remote past from an original brood of each, it would naturally follow that the broods most closely related in time would also present a closer relationship in their range, and this, in fact, proves to be generally true.

To show this relationship and to indicate the natural order of their occurrence, I have suggested a new enumeration of the broods in which the two races are separated—the 17-year broods coming first, followed, for convenience merely, by the 13-year broods. Thus Brood XI of the 17-year race becomes Brood I, and the others are numbered in the regular order of their occurrence, except that I have assigned a brood number to each of the seventeen years. This leaves Broods XII, XV, and XVII, as newly numbered, without any definite colonies, so far accepted, as representatives of established broods. As will be shown later, however, there are records which indicate the existence of small or scattering broods filling the three gaps mentioned in the 17-year series.

In renumbering the broods of the 13-year race I have continued for convenience from the end of the series of the 17-year race, the first 13-year brood becoming Brood XVIII, and I have assigned brood numbers to each year of the 13-year period, making a total enumeration of the broods of both races of XXX. As already indicated, six of the numbers given to the 13-year race have had no brood assigned to them, although records have been secured which seem to indicate the existence of scattering broods filling some of the gaps, as will be noted in the records given further on.

It does not necessarily follow, in fact it is quite unlikely, that Brood I, as here designated, is the original or oldest brood of the 17-year race. Undoubtedly some of the 17-year broods, perhaps half or more of them, originated by retardation of individuals, and perhaps half by acceleration of individuals; so that the original brood, if it still exists, is more likely to be one of the intermediate ones. Brood X, being the largest of the 17-year broods, perhaps has best claim to this distinction.

For the same reasons an intermediate brood in the 13-year series is doubtless the original brood of the 13-year race, and this title may possibly belong to Brood XIX, which has the widest range of all the broods of the 13-year race. The fewer number of broods in this race would seem to indicate that it is of later origin than the 17-year race, and this belief is further justified by the fact of its occupying, in the main, a territory of later geological formation.

The following table, beginning with 1893, when the initial broods of both the 17-year and the 13-year series appeared in conjunction,

illustrates the new nomenclature suggested, and in parallel columns also are given the corresponding nomenclatures proposed by Professor Riley, by Fitch, and the year records in Doctor Smith's register:

Nomenclature of the broods of the periodical Cicada.

Year.	Broods of the 17-year race.				Broods of the 13-year race.			
	Proposed enumeration.	Riley numbers.	Fitch numbers.	Smith register.	Proposed enumeration.	Riley numbers.	Fitch numbers.	Smith register.
1893	I	XI	.....	1842	XVIII	XVI	.....	1854
1894	II	XII	1	1843	XIX	XVIII	3	1842–1855
1895	III	XIII	.....	1844	XX	II	.....	1843
1896	IV	XIV	.....	1845	XXI	IV	.....	1844
1897	V	XV	5	1846	XXII	VI	.....	1845
1898	VI	XVII	7	1847	XXIII	VII	5	1846–1859
1899	VII	XIX	.....	1848	XXIV	.....	.....	.....
1900	VIII	XX	2–8	1849	XXV	.....	.....	.....
1901	IX	XXI	.....	1850	XXVI	X	.....	1859
1902	X	XXII	4	1851	XXVII	.....	.....	.....
1903	XI	I	9	1852	XXVIII	.....	.....	.....
1904	XII	.....	.....	1853	XXIX	.....	.....	.....
1905	XIII	V	6	1854	XXX	.....	.....	.....
1906	XIV	VIII	3	1855	XVIII	XVI	.....	1854
1907	XV	.....	.....	.....	XIX	XVIII	3	1842–1855
1908	XVI	IX	.....	.....	XX	II	.....	1843
1909	XVII	.....	.....	.....	XXI	IV	.....	1844

The Relationship of the Different Broods.

As a rule, the relationship of the broods in point of distribution agrees with their kinship as indicated by their sequence in time of appearance. The relationship indicated by the latter, viz, their sequence in time, is doubtless untrustworthy as indicating origin, in some instances on account of the uncertainty arising from the action of the principle of retardation on the one hand and acceleration on the other in the forming of new broods.

In the case of a widely scattered brood, like Brood VI, it is quite possible that certain swarms originated from a later-appearing brood by retardation of individuals, and other swarms from an earlier brood by acceleration in time of appearance of individuals.[a]

This same condition may be true of other of the more scattered broods, but with the broods presenting a compact range a singleness of origin is evident.

Examination of the distribution of the broods in connection with their sequence in time of appearance indicates, however, a certain

[a] Prof. W. E. Castle, Museum of Comparative Zoology, Cambridge, Mass., in a letter to the writer July 20, 1898, suggested a plausible theory for Brood VI. The isolation and wide distribution of this brood leads him to infer that it may be a relatively old or "played out" brood, and if this be true it may be considered the parent of Broods V and VII, the former an offshoot by acceleration and the latter by retardation of development. He suggests, however, that the Pennsylvania portion of Brood VII may have originated independently of the New York part, since it lies in the mountainous country, where the broods would naturally be mixed up more than in any other part of the range of the 17-year race. In Ohio he notes that the distinct areas

relationship between the different broods in point of origin, which may be indicated as follows:

The Relationship of the Seventeen-year Broods.

From the standpoint of distribution the broods of the 17-year race may be grouped as follows: (1) Broods I and II; (2) Broods III and IV; (3) Brood V; (4) Brood VI; (5) Broods VII, VIII, IX, X, and XI; (6) Broods XII, XIII, XIV, and XV; (7) Broods XVI and XVII, the last connecting again with Brood I.

Taking up these broods in regular order:

The main body of Brood I occupies territory immediately west of the more important and perhaps parent Brood II, and also presents a number of colonies extending westward to Kansas. Broods I and II seem, therefore, closely allied in point of origin.

Brood III presents little, if any, relationship to Brood II in point of location and distribution, but is closely allied to the following brood, IV, and the latter is evidently a retarded western and southern extension of III.

Brood V presents little relationship with Brood IV in point of distribution and covers a very compact territory.

Brood VI, being a widely scattered one, and occurring usually in small numbers, does not seem to present any particular relationship with any of the preceding or following broods unless the explanation suggested by Professor Castle be accepted.

Brood VII is local in distribution and not very important, and is divided into two sections by the territory occupied by the following brood, VIII, with which it thus seems to be closely allied. Brood IX is very distinctly a southern extension of Broods VII and VIII. These three broods seem, therefore, to be closely allied in their origin, and, curiously enough, occupy territory which divides the two main sections of the great 17-year Brood X, which next follows in regular succession, and is perhaps the oldest or parent brood of the 17-year race. Brood XI, following X, is evidently an extreme northeastern extension of the latter.

Brood XII is represented by a series of very doubtful records, which, if validated in future return periods, will connect the western

covered by Brood VI lie for the most part just outside the area covered by Brood V and on opposite sides of the latter.

This interpretation by Professor Castle may be in part correct; but in view of the wide range of this brood and the very scattering nature and separation of the individual swarms, it seems to me more probable to account for it as a development of scattering broods originating for the most part independently by means of retardation or acceleration from other broods, and none of the colonies developing enough to fill and hold any very large definite territory. In other words, most of the colonies are probably of late origin rather than the remnants of an old, extensive, worn-out brood.

Brood XIII with group 5. Brood XIII is the principal western representative of group 6, which, through the three broods XIII, XIV, and XV, extends from the extreme western to the eastern limits of the Cicada. Brood XIV has a very wide range to the eastward of XIII, and connects with the latter through the colonies in northern Illinois and Indiana. Brood XV is limited to the Atlantic seaboard and connects directly with the eastern colonies of XIV.

Brood XVI is based on somewhat doubtful records and is unimportant. Brood XVII is intermediate between Brood XVI and Brood I, its western colonies connected with the former and the eastern colonies with the latter.

THE RELATIONSHIP OF THE THIRTEEN-YEAR BROODS.

The broods of the 13-year race break up into the following natural groups: (1) Related closely to Brood XIX, and comprising Broods XVIII, XIX, and XX; and (2) related to Brood XXIII, and comprising Broods XXI, XXII, XXIII, and our new Brood XXIV.

The first of these broods, Brood XVIII, is a rather insignificant one and is undoubtedly an eastern extension or offshoot of the great 13-year Brood XIX, which succeeds it. Brood XX, is undoubtedly a section of Brood XIX retarded one year, just as Brood XVIII consists of accelerated swarms of the same.

Brood XXI, separated from Brood XIX by two years, seems to bear little relationship to the latter, and a more logical arrangement consists in connecting it with Brood XXIII through Brood XXII, of which last it may be considered as an eastern and northern extension. Brood XXII is a very marked instance of the formation of a new brood by an acceleration in time of the appearance of a portion of a larger and older brood. Its relationship with Brood XXIII is very marked and can not be questioned. Brood XXIII, the main representative of this group, is followed by the new Brood XXIV, which is evidently a retarded swarm of the preceding brood.

Of Broods XXVI and the new Broods XXIX and XXX, both of which need verification, no significant relationship can be pointed out. Brood XXIX is very doubtful, and the records are possibly based on a confusion with the 17-year race.

SOURCES OF ERROR IN THE OLD RECORDS.

In examining the records of the distribution of the broods of the periodical Cicada, it is seen that considerable uncertainty attaches to the data of certain broods, not only from the fact of their covering, in greater or less degree, territory occupied by both races, but more particularly because the records are frequently based on years in which broods so overlapping have appeared in conjunction.

In the case of the broods of the 17-year race, the following extend on their southern boundaries into the territory of the 13-year race, and hence the records of the southern localities are open to some question: Broods VI, X, XIV, XVI, I, IV, to a slight extent also in the case of Broods II and III, and doubtfully in the case of Brood IX, the possibility of confusion in this last brood depending on the accuracy of the extreme northeastern extension of the 13-year Brood XIX.

The following broods of the 13-year race extend northward into the territory occupied by the 17-year race, and hence are open to some question: Broods XXIII, XVIII, XIX, and XX.

The records can not be questioned on this ground of the 17-year Broods VII, VIII, XI, XIII, and V, and of the 13-year Broods XXIV, XXI, and XXII, because these broods are limited in distribution to the territory of a single race.

The most notable instance of the overlapping and consequent probable confusion of the records is seen in the case of Brood X of the 17-year race with Broods XXIII and XIX of the 13-year race. The remarkable feature in the distribution of the broods named is the notable extension northward in Illinois and Missouri of the 13-year Broods XXIII and XIX, which fills almost exactly a district which would naturally be supposed to belong to the 17-year race and probably to Brood X. As pointed out in Bulletin 14, page 26, this circumstance had special significance in view of the fact that the northward extension of the 13-year race is based on Broods XIX and XXIII, and that the records prior to 1898 of the former were collected for the most part in 1868, when this brood was in conjunction with Brood X, and of the latter in 1885, when Brood XXIII was also in conjunction with Brood X, the limits of which, curiously enough, stop rather suddenly at or near the eastern State line of Illinois. The possibility was immediately suggested that the northern localities assigned to Broods XIX and XXIII properly belong to Brood X.

The occasion of the reappearance of the 13-year Brood XXIII in 1898 without any important 17-year brood to confuse the records and of the 17-year Brood X in 1902, also without a joint occurrence of any important 13-year brood, gave the opportunity wished for to determine the validity of old records and to fix more accurately the distribution of the three broods concerned.

A very thorough canvass was made in 1898 of the territory covered by Brood XXIII, and especially the territory in doubt, by calling into requisition the very numerous county correspondents of the Statistical Division of the Department of Agriculture and also of the Weather Service in addition to the regular correspondents of the Division of Entomology. Several thousand replies were received,

negative and positive. Reports were also kindly submitted by Professor Forbes, of Illinois, which added four or five counties to the records obtained for that State, and other reports were received from entomologists of other States covered by this brood. A preliminary report was published in Bulletin 14, and a full report in Bulletin 18, of this Bureau. The records obtained confirmed the general accuracy of the old belief of the distribution of Brood XXIII. The occurrence of scattering colonies of the 17-year Brood VI over some of the territory adds a slight element of doubt; but in the main the records given for Brood XXIII, taken in connection with older records, are probably correctly assigned.

The data obtained of the 17-year Brood X in 1902 is even more satisfactory, inasmuch as in this case there was no 13-year brood to throw doubt on any of the records. The same means was taken to get full reports as were used in 1898; and, rather to our surprise, the substantial correctness of the old records is strikingly demonstrated, as seen on the map published in connection with the detailed discussion of this brood. Thirteen-year Brood XXIII covers southern Illinois, with a scattering outpost through southern Indiana. Brood X stops, as hitherto believed, near the eastern line of Illinois, with a few scattering outposts. There is overlapping, but, in the main, south-central and western Illinois and eastern and central Missouri seem to belong to the 13-year race, as hitherto believed.

The recurrence this year of the great 13-year Brood XIX without any 17-year brood to confuse the records will give an opportunity to complete the data relative to the distribution of these three overlapping broods, but the records already obtained of Broods X and XXIII indicate very strongly the probable correctness of the old records of Brood XIX.

Many of the other scattering records of 13-year broods northward, or of 17-year broods southward, may possibly be based on similar confusions, arising from the overlapping of broods of the two races.

The only way to accurately define the range of the different broods is to undertake with each recurrence a thorough and systematic investigation of all the territory open to the least doubt. Such work has been repeatedly instituted, and particularly since 1868, and many of the more strictly limited broods have been very carefully recorded, and their distribution has been satisfactorily defined. Work of this kind has been done for Brood III in Iowa by Professor Bessey, and for Brood V in Ohio and West Virginia by Professors Webster and Hopkins. Similar work has been done for Brood II in New York and New Jersey by Doctors Lintner and Smith, and for X and XXIII by Riley in 1885, and for Brood XIX by Walsh and Riley in 1868.

The value of a thorough and systematic canvass of the territory supposed to be covered by any brood is exhibited in much of the work referred to above, and notably in the case of Brood V studied by Professors Webster and Hopkins in Ohio and West Virginia. In the case of this brood, however, there was no difficulty from an association with any 13-year brood.

Broods of 14, 15, or 16 Year Periods.

The most notable thing about the periodical Cicada is the regularity with which it has reappeared during more than 200 years of records at the stated intervals of 13 years for the Southern race and 17 years for the Northern race. If all the cicadas belonged to a 13-year or a 17-year period—in other words, if there were but one period—this regularity would be less surprising. But the records are so complete and full that there can be no doubt whatever of the absolute uniformity of periods for the two races for the vast majority of the individuals. That unusual conditions will, however, hasten the development or retard it a year or more has been already indicated on page 24, together with notable examples of artificial acceleration. In view of these last instances there can be no doubt that this regularity of appearance is governed more by the uniformity of temperature conditions over a long period of years than from any inherent qualities in the insect itself. If these conditions are interfered with, however, the Cicada becomes, as it did in the greenhouse at Belvidere, Ill., accelerated one year; and if such conditions occurred in nature over a large area, as already indicated, a new brood would be established, but not a 16-year brood, because the climatic conditions over the long period of seventeen years would, and evidently have in practically every instance, carried these accelerated or, conversely, retarded individuals forward or back to the normal period. There are, however, a few records which seem to indicate, and particularly in the overlapping territory of the two broods, a variation in the length of the subterranean period. These reports of 14-year, 15-year, or 16-year broods have been so very scanty that it has not been possible to trace them out with any accuracy, but there seems to be no reason whatever for doubting the possibility of swarms which have actually developed and maintained for a time these intermediate periods. In the course of years we may get enough of these records to definitely map some of these variant broods.

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Future Appearances.

During the next seventeen years broods of the 17-year and 13-year races of the periodical Cicada will occur as follows:

Table of future appearances.

Year.	17-year race.		13-year race.		Year.	17-year race.		13-year race.	
1907....	XV	New?....	XIX	Major.....	1916...	VII	Minor...	XXVIII	No record.
1908....	XVI	Minor....	XX	Minor.....	1917...	VIII	....do...	XXIX	New?
1909....	XVII	New?....	XXI	.....do.....	1918...	IX	....do...	XXX	Do.
1910....	I	Minor....	XXII	.....do.....	1919...	X	Major...	XVIII	Minor.
1911....	II	Major....	XXIII	Major.....	1920...	XI	Minor...	XIX	Major.
1912....	III	....do....	XXIV	New?.....	1921...	XII	New?...	XX	Minor.
1913....	IV	....do....	XXV	No record..	1922...	XIII	Major..	XXI	Do.
1914....	V	....do....	XXVI	Minor.....	1923...	XIV	....do...	XXII	Do.
1915....	VI	Minor....	XXVII	New?.....	1924...	XV	New?...	XXIII	Major.

In this table the large or important broods are designated as major; the small or scattering broods as minor. In the latter class the new and often doubtful broods suggested by the writer also fall. In the case of a few numbers assigned to the 13-year race no records of occurrence have been reported, but such may be forthcoming at any time, although it is evident that the breaking up of the 13-year race into broods has not proceeded to anything like the extent that it has in the 17-year race.

It will be noticed that as a rule a 17-year and 13-year race are associated in the same year. This is purely accidental, and in point of fact the same two broods could only come together once in 221 years. The greatest Cicada year of recent times was 1868, when Brood X, the largest of the 17-year race, appeared in conjunction with Brood XIX, the largest of the 13-year race. These two broods will have their next joint occurrence in the year 2089, when perhaps the increase of settlement and the changed character of vegetation and superficial conditions over their respective ranges may have entirely eliminated them except for stragglers.

THE DISTRIBUTION OF THE PERIODICAL CICADA.

SOURCES OF INFORMATION.

The records on which are based the present information of the distribution of the several broods of the periodical Cicada have been the accumulation of more than two hundred years, and particularly during the last fifty years they have assumed a most voluminous character, and any effort to discuss the subject at all minutely would expand this publication beyond reasonable limits. It is impossible, therefore, to detail the evidence which has been used in determining brood limits or even to summarize the voluminous historical and chronological records on which this distribution rests. All that is possible is to continue the plan followed in Bulletin 14 of limiting

the record to a brief description of the different broods and merely noting the distribution by States and counties. The data for these summaries is the rather full account given in Bulletin 8, old series, of the Division of Entomology, supplemented, however, by the local studies made by entomologists and others in various States, and particularly the voluminous records obtained by this Bureau, collated and classified up to 1898 by Mr. E. A. Schwarz, who had long assisted Professor Riley in collecting such data. Since 1898 this field of inquiry has been under the charge of the writer, and a very thoroughgoing effort has been made to get full and accurate data of the broods which have appeared from year to year. The records for the important 13-year Brood XXIII, which appeared in 1898, in conjunction with the 17-year Brood VI, and of Brood X, the largest of all the 17-year broods, which appeared in 1902, were especially complete and satisfactory, and are summarized under the accounts of these broods. Particularly in later years, much exact information as to local distribution has come from the active cooperation of State entomologists, who have often been able to get more detailed and accurate reports than was possible through the correspondents of this office. The scant records, indicating perhaps scattering or incipient broods, covering some of the blanks in the 13 and 17 year series, are introduced in their proper order for future confirmation or rejection.

The records obtained by the Department of Agriculture, covering nearly thirty years, have become very voluminous, and during the last few years an effort has been made to go over all of these records and transfer the important information to index cards, and all the later records are being kept on such cards. It is expected also, as time offers, to incorporate in this record all the data from experiment station bulletins and other printed records. Ultimately, therefore, we shall have a classified card record which will be easily available for examination and study and which will assist greatly in establishing brood limits and determining the status of new reports.

THE GENERAL RANGE OF THE SPECIES AND OF THE TWO RACES.

Taking all the different broods together, this Cicada is known to occur pretty generally within the United States east of the one hundredth meridian and northward of latitude 30°—in other words, east of central Kansas and north of northern Florida. No broods have been found in northern New England except a doubtful record in Vermont, nor west of the Mississippi above Iowa. The State of Rhode Island, in which the Cicada was long believed to be absent, proved to harbor a small brood, as discovered in 1903 (Brood XI). The most eastward occurrences are the swarms occurring in Barnstable County, Cape Cod, Massachusetts, and on the island of Marthas Vineyard. No colonies have been found on the peninsula of Florida,

although the Cicada occurs in the northwestern portion of the State. The western records reported in Bulletin 14 in Colorado, and doubtful occurrences along the northern slope of the Big Horn Mountains of western Wyoming and Montana, have been shown, with very little doubt, to belong to another species of Cicada (*Tibicen cruentifera* Uhl. and allies), very possibly also similarly periodic in reappearance.

The territory covered by the periodical Cicada is graphically illustrated by the two maps showing the range of the 13-year and the 17-year races, respectively (figs. 2 and 3). A brief examination of these maps develops the very interesting and suggestive fact that if superimposed the areas occupied by the two races would, in a gen-

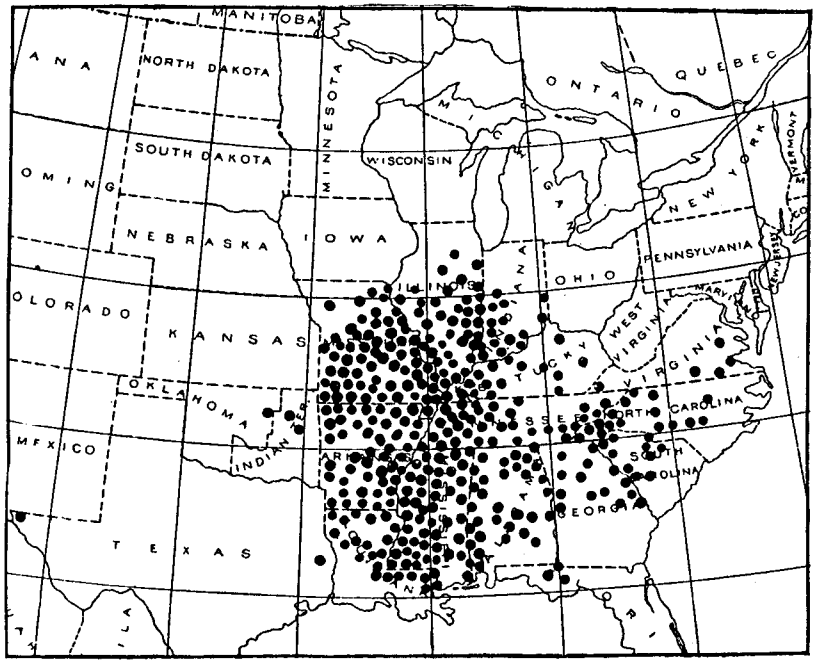

FIG. 2.—Map showing distribution of the broods of the 13-year race.

eral way, fit together along their adjoining sides. This was to have been expected, but one would hardly have predicted the notable northern extension of the 13-year race in Missouri and Illinois in the Mississippi Valley, following, however, in an exaggerated way, the isothermal lines of this region. The extension northward of the 13-year race very greatly exceeds the limits of the Lower Austral zone, as marked on Merriam's map, and if this insect were taken as a basis this zone would have to be very greatly extended northward in the two States named. With this important exception, the 13-year race is confined pretty closely to the Lower Austral and the 17-year race covers the Upper Austral, with large extensions northward into the

Transition zone. The overlapping of the two races, discussed elsewhere, is well illustrated by these two maps.

The range of the individual broods is undoubtedly much greater than the limits now assigned, since the records until recent years have been largely based on notable and dense swarms and have rarely taken into account the scattering individuals, which undoubtedly extend over a much greater territory and usually pass unnoticed. The very careful records secured of the broods, including and subsequent to 1898, have shown much of this scattering occurrence beyond the denser brood limits, as will be seen in the maps illustrating these broods. This indicates that the breaking up of the

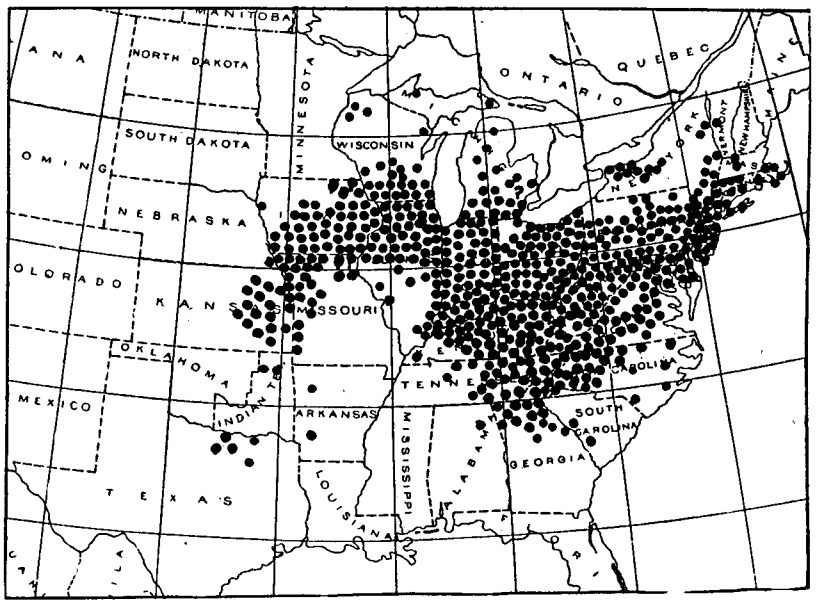

FIG. 3.—Map showing distribution of the broods of the 17-year race.

Cicada has already gone much farther than was hitherto supposed, and points to the ultimate disappearance of great broods as such and their replacement as scattering individuals every year. The disappearance of the great broods, however, is not to be anticipated in the very near future, and may not come about for a thousand or even several thousand years. This is shown by the fact that the broods first seen by the early colonists in New England on Cape Cod, at Plymouth, and on Marthas Vineyard are, as elsewhere noted, still practically unreduced in numbers and make just as startling an impression as ever. This is due to the fact that much woodland remains undisturbed in these localities. In other places, where the woods have been largely removed as the result of settlement, the Cicada has correspondingly disappeared.

THE RANGE OF THE WELL-ESTABLISHED BROODS, TAKEN IN NUMERICAL ORDER.

In the following description of the broods they are taken up in their numerical order—first, the 17-year broods, I to XVII, and then the 13-year broods, XVIII to XXX; that is, as many of the latter as have definite records. The chronological order of the broods, showing the broods of the two races which occur jointly in the same year, is indicated in the table on page 34. This arrangement, rather than a chronological one, is adopted for the reason that any chronological arrangement in the course of a few years becomes obsolete, and for the same reason individual maps of the broods have been made, rather than joining in one map the two broods that may happen to occur together on each of the next thirteen or seventeen years. The maps of important broods which have been recently more carefully studied have been entirely revised, and the importance of the records has been indicated by the size of the dots, the large dots representing counties in which the brood occurred in one or more dense characteristic swarms and the small dots, records of scattering occurrence or of doubtful validity. These same conditions are more accurately shown in the State and county records, as described under each brood. Such indications will be secured for all the broods in course of time, and will give a much more accurate picture of actual conditions than the old system of uniform dots for all records. The maps of broods which have not been recently studied have also been reengraved because of the discovery of new records—in some cases few in number, in other cases of considerable amount.

Broods of the Seventeen-Year Race.

BROOD I—*Septendecim*—1910. (Fig. 4.)

Brood I is the first of the series of well-authenticated broods of the 17-year race, and its main swarms occupy the territory immediately west of the more important Brood II, which follows the year after. It includes also widely separated swarms extending west into Kansas. It was established originally on data given by Dr. Gideon B. Smith, but its distribution is now more definitely recorded as a result of the study given it in 1893 by Professor Riley and of records which have come to this Bureau in connection with the study of other broods since that time. Several new counties for West Virginia were added by Doctor Hopkins in Bulletin 68, West Virginia Experiment Station (1900).

The doubtful records prior to 1893 were those relating to the occurrence of this brood in Kansas and Colorado. The localities in Kansas received doubtful confirmation in 1893. The Colorado localities remained unverified, although the district mentioned was visited

and special search was made for evidence of the insect. Undoubtedly the Colorado occurrence relates to some other and probably also a periodic species, such as that reported for another brood at Boulder, Colo. (XVI), and for Brood VI in Montana.

The distribution, by States and counties, follows:

DISTRICT OF COLUMBIA.—North of Washington.
ILLINOIS.—Madison(?).
INDIANA.—Knox, Posey, Sullivan.
KANSAS.—Dickinson, Leavenworth.
KENTUCKY.—Trimble.
MARYLAND.—Prince George, south half of St. Mary.

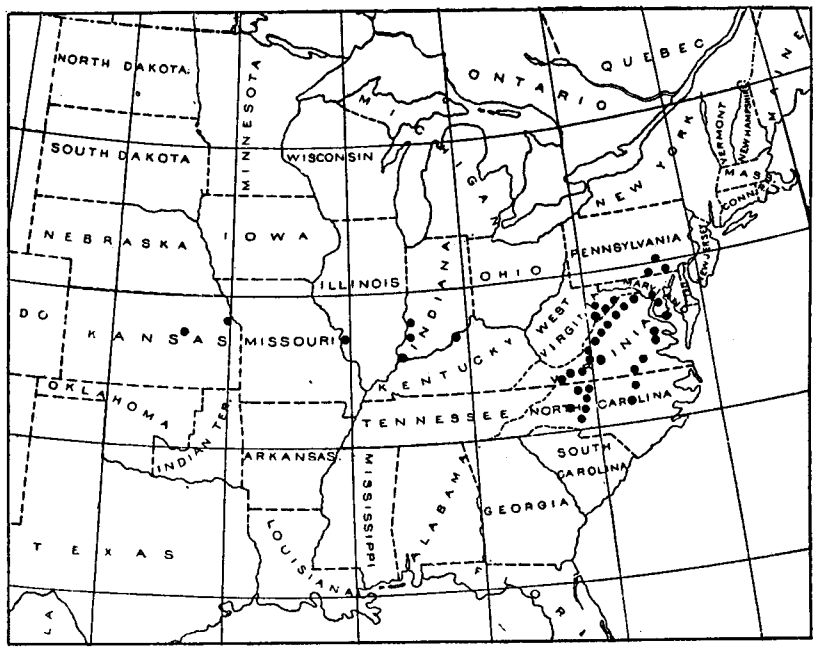

FIG. 4.—Map showing distribution of Brood I, 1910.

NORTH CAROLINA.—From Raleigh, Wake County, to northern line of State; Cabarrus, Davie, Iredell, Rowan, Surry, Yadkin.
PENNSYLVANIA.—Adams, Cumberland, Franklin.
VIRGINIA.—From Petersburg, Dinwiddie County, to southern line of State; Bedford, King William, New Kent, Rockbridge; valley from Potomac to Tennessee and North Carolina boundary.
WEST VIRGINIA.—Grant, Hardy, Pendleton, Randolph.

BROOD II—*Septendecim*—1911. (Fig. 5.)

This brood occupies, for the most part, territory immediately east of Brood I, and is one of the best recorded of the broods, since its almost exclusively eastern range brings it in the immediate vicinity

of the large towns and more densely populated districts of the Atlantic seaboard.

Fitch described its limits as his Brood No. 2, Walsh-Riley as Brood VIII, and Riley as his Brood XII. It has been reported in Connecticut regularly every seventeen years since 1724, and in New Jersey since 1775, if not earlier, and almost equally long records of it in other States have been made.

On the occasion of its last appearance, in 1894, its distribution in New Jersey was very carefully studied by Prof. J. B. Smith, confirming its occurrence in every county in that State, and in New York

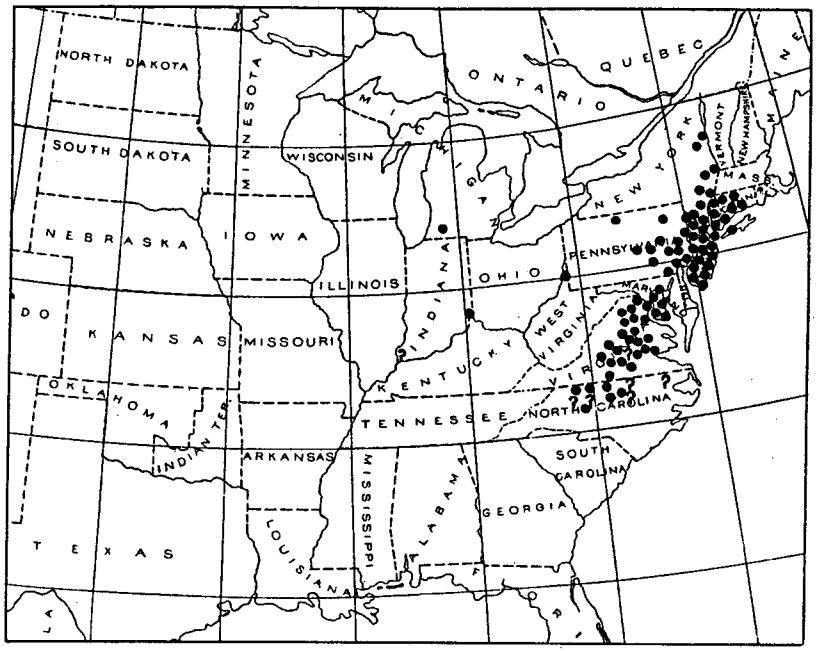

FIG. 5.—Map showing distribution of Brood II, 1911.

similar studies were made by Dr. J. A. Lintner. The Bureau also received a vast number of reports from these and other States in answer to a circular prepared by Professor Riley and mailed in May, 1894. Some of the southern records obtained in 1894 are doubtful, and this applies especially to the localities in North Carolina, because of the occurrence that year also of Brood XIX of the 13-year race.

The distribution as listed below is based on the old records given in the circular cited, with such additions and corrections as the reports of appearance in 1894 made necessary.

The distribution, by States and counties, is as follows:

CONNECTICUT.—Fairfield, Hartford, Litchfield, Middlesex, New Haven.
DISTRICT OF COLUMBIA.—Throughout.

INDIANA.—Dearborn, Posey(?).
MARYLAND.—Anne Arundel, Calvert, Charles, Prince George, St. Mary.
MICHIGAN.—Kalamazoo.
NEW JERSEY.—Entire State.
NEW YORK.—Albany, Columbia, Dutchess, Greene, Orange, Putnam, Rensselaer, Rockland, Saratoga, Ulster, Washington, Westchester, and on Staten Island and Long Island.
NORTH CAROLINA.—Bertie(?), Davie(?), Forsyth(?), Guilford, Orange, Rockingham, Rowan, Stokes, Surry, Wake(?), Warren(?), Yadkin(?).
PENNSYLVANIA.—Berks, Bucks, Chester, Dauphin, Delaware, Lancaster, Lebanon, Lehigh, Montgomery, Northampton, Philadelphia, Pike, Potter, Schuylkill, Wyoming.
VIRGINIA.—Albemarle, Alexandria, Amherst, Appomattox, Bedford, Buckingham,

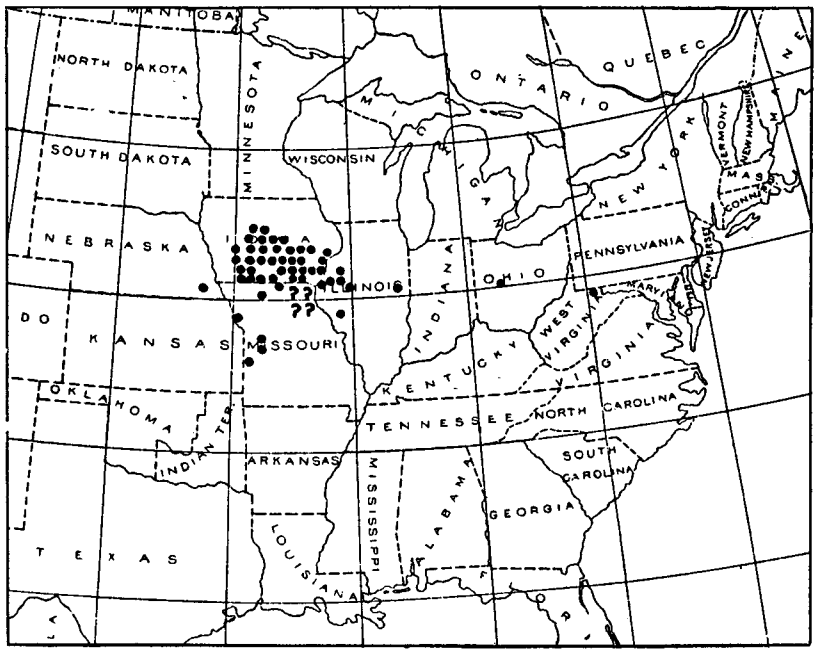

FIG. 6.—Map showing distribution of Brood III, 1912.

Campbell, Caroline, Charlotte, Culpeper, Fairfax, Fauquier, Fluvanna, Goochland, Hanover, Henrico, James City, Loudoun, Louisa, Lunenburg, Madison, Page, Pittsylvania, Powhatan, Prince Edward, Rappahannock, Spottsylvania, Stafford.
WEST VIRGINIA.—Brooke(?).

BROOD III—*Septendecim*—1912. (Fig. 6.)

This brood, described by Walsh-Riley as Brood IX (XIII of Riley) is one of the more important of the Western 17-year broods, its most compact body lying in the States of Iowa and Missouri. It is closely allied in distribution to Brood IV, but shows little relationship with Brood II. Records are given by Dr. G. B. Smith in both Iowa and Illinois in 1844, and it has been regularly recorded since,

over at least a portion of its range. The Iowa distribution of the brood was carefully studied by Professor Bessey in 1878.

The range of the brood as given below is based on the published records, together with a number of additional localities collected from the correspondence of the Bureau.

The distribution, by States and counties, is as follows:

ILLINOIS.—Champaign, Fulton, Hancock, McDonough, Mason, Warren.

IOWA.—Adair, Adams, Audubon, Boone, Cass, Dallas, Davis, Decatur, Des Moines, Greene, Hamilton, Henry, Iowa, Jasper, Jefferson, Johnson, Keokuk, Louisa, Madison, Mahaska, Marion, Marshall, Monroe, Muscatine, Polk, Poweshiek, Ringgold, Scott, Story, Taylor, Union, Van Buren, Wapello, Warren, Wayne, Webster.

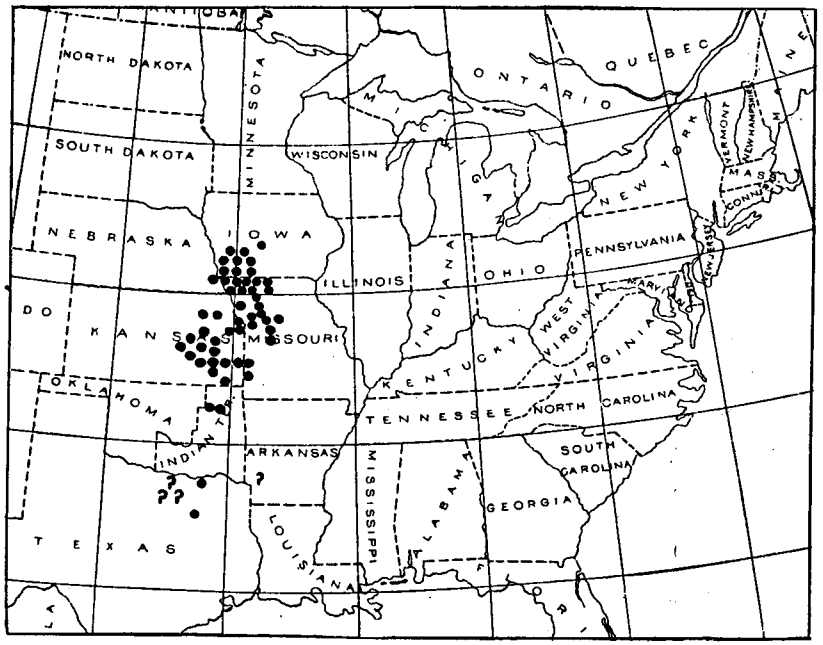

FIG. 7.—Map showing distribution of Brood IV, 1913.

MISSOURI.—Bates, Buchanan, Clark (?), Grundy, Henry, Johnson, Knox (?), Lewis (?), Macon (?), Marion (?), Monroe (?), Putnam, Ralls (?), Randolph (?), Schuyler (?), Scotland (?), Shelby.

NEBRASKA.—Johnson.

OHIO.—Champaign.

WEST VIRGINIA.—Monongalia.

BROOD IV—*Septendecim*—1913. (Fig. 7.)

This brood, described by Walsh-Riley as Brood X (Riley XIV) succeeds Brood III by one year, and in the main appears to be a southwestern extension of the latter, covering a portion of southwestern Iowa, eastern Kansas, and Indian Territory, with detached localities in Missouri and other States. Its original connection with

Brood III is apparently well shown by the adjoining or overlapping territory occupied by the two broods, together with the fact of their separation by a single year.

This brood was well recorded in 1879, the data being published by Professor Riley in Bulletin 8, old series, of the Division of Entomology. A number of additional records were obtained at its last appearance in 1896, and reports have been received since the publication of Bulletin 14 adding five new counties in northwestern Missouri.

The distribution of the brood as now determined is as follows:

ARKANSAS.—Hempstead (?).

INDIAN TERRITORY.—Muscogee, Tulsa.

IOWA.—Adams, Cass, Dallas, Fremont, Mills, Montgomery, Page, Pottawattamie, Taylor.

KANSAS.—Allen, Bourbon, Chase, Coffey, Douglas, Greenwood, Jackson, Johnson, Labette, Lyon, Marion, Morris, Osage, Pottawatomie, Wabaunsee, Wilson, Woodson, Wyandotte.

MISSOURI.—Barton, Buchanan, Caldwell, Dekalb, Grundy, Henry, Holt, Jackson, Johnson, Lafayette, Mercer, Ray, Saline, Vernon.

NEBRASKA.—Otoe.

TEXAS.—Cooke, Denton, Fannin, Kaufman, Wise.

BROOD V—*Septendecim*—1914. (Fig. 8.)

Brood V covers in the main a rather compact territory and does not connect directly with preceding broods, except possibly through Brood VI, joining the following important series of broods of the Alleghany region. Brood V was reported from Ohio as early as 1795. Fitch described it as Brood 5, Walsh-Riley as Brood XI, and Riley as Brood XV.

The limits of this brood as known prior to 1897, the date of its last appearance, were given by Mr. Schwarz in Circular No. 22 of this Bureau. In 1897 its distribution in Ohio was very carefully studied and mapped by Professor Webster and in West Virginia by Professor Hopkins. The distribution as listed below is based on the above information, together with numerous records which have since been obtained by this Bureau in the investigation of this and other broods.

The distribution, by State and counties, of this brood as now known is as follows:

OHIO.—Ashland, Athens, Belmont, Carroll, Columbiana, Coshocton, Crawford, Cuyahoga, Delaware, Erie, Fairfield, Franklin, Gallia, Geauga, Guernsey, Harrison, Hocking, Holmes, Huron, Jackson, Jefferson, Knox, Lake, Licking, Lorain, Mahoning, Medina, Meigs, Monroe, Morgan, Muskingum, Noble, Perry, Pickaway, Pike, Portage, Richland, Ross, Sandusky, Scioto, Seneca, Stark, Summit, Tuscarawas, Vinton, Washington, Wayne.

PENNSYLVANIA.—Fayette, Greene, Washington.

VIRGINIA.—Augusta, Caroline, Highland(?), Shenandoah.

WEST VIRGINIA.—Barbour, Boone, Braxton, Brooke, Calhoun, Clay, Doddridge, Fayette, Gilmer, Grant, Greenbrier(?), Hancock, Hardy, Harrison, Jackson, Kana-

wha, Lewis, Marion, Marshall, Mason, Mineral, Monongalia, Nicholas, Ohio, Pleasants, Pocahontas, Preston, Putnam, Randolph, Ritchie, Roane, Summers(?), Taylor, Tucker, Tyler, Upshur, Wayne, Webster, Wetzel, Wirt, Wood.

Brood VI—*Septendecim*—1915. (Fig. 9.)

This is an unimportant scattering brood designated as No. 7 by Fitch, XII by Walsh-Riley, and XVII by Riley. It is difficult to assign any very pointed relationship for this brood, either with preceding or following broods, unless one adopts the suggestion made by Prof. W. E. Castle that it represents a relatively old or played-out brood, and may thus be considered the parent of Broods V and VII,

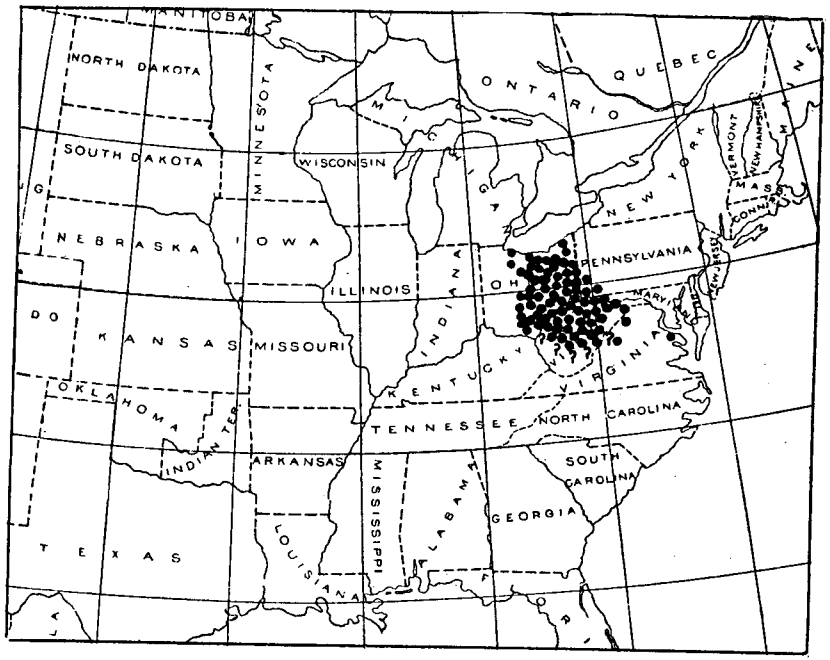

FIG. 8.—Map showing distribution of Brood V, 1914.

the former the offshoot by acceleration and the latter by retardation of development. (See pp. 28–29.) As stated elsewhere, however, it is more likely to be an assemblage of swarms of diverse origin.

This brood, while not an important one, covers a much wider territory than any of the other 17-year broods. With the exception, however, of the two extremes of its distribution in the Northwest and the Southeast, respectively, the records are of scattering individuals, in many localities only a few specimens being observed. To illustrate this graphically on the accompanying map (fig. 9), the small dots indicate localities where only a few specimens were observed or captured or a doubtful record and the large dots localities

represented by one or more dense swarms, such as are ordinarily characteristic of the species. Some of these records of scattering occurrence may be based on stragglers from preceding broods or accelerated individuals from following broods and therefore may not mean more than incipient swarms. Many of the records were secured in 1898, when a very careful canvass of the whole Cicada region was made by this Bureau with the assistance of the State entomologists.

The reports obtained in 1898, if they may be relied upon, extend the range of the periodical Cicada in Wisconsin and Michigan much farther north than any of the old records. The localities assigned to this brood in North Carolina, South Carolina, and Georgia, and in

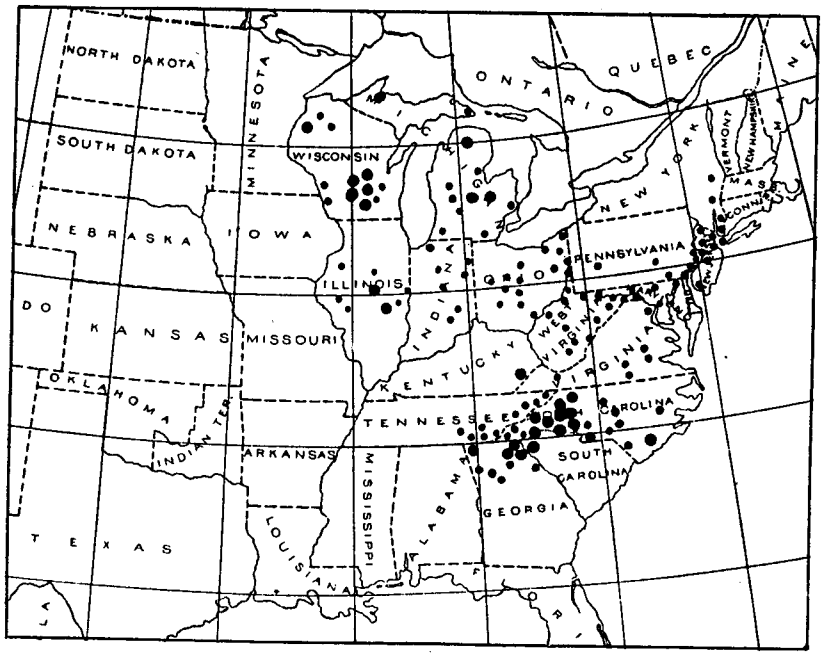

FIG. 9.—Map showing distribution of Brood VI, 1915.

eastern Kentucky and Tennessee are, in the main, in counties in the elevated mountainous district, and the correctness of the reference to this brood is established by earlier records as well as indicated by the elevation.

Reports of the occurrence of this brood in Montana were sent in by Mr. E. V. Wilcox, with the statement that the insect occurred in small numbers in the counties of Chouteau, Flathead, Gallatin, and Missoula, and that in the latter county some damage was done to young apple trees. This report was published in Bulletin 18 of this Bureau, but doubts arose afterwards in the mind of the writer as to the correctness of the determination of the Cicada, as the more

recently acquired knowledge of the existence of another periodical species in the northwestern United States threw some doubt on this reference, and an examination of collected material from that region indicates that the species referred to is *Tibicen cruentifera* Uhl., which apparently is also periodic and has other habits closely resembling *septendecim*.

The records of distribution given below are as published in Bulletin 18 of this Bureau, with the exception of West Virginia, where a good many counties have been added from Doctor Hopkins's Bulletin 68 and from later records secured by him. The starred counties indicate the occurrence of the Cicada in one or more characteristic dense swarms; the italicized counties are confirmations of old records, and the counties inclosed in parentheses are old records not reported in 1898. The distribution, by States and counties, follows:

DELAWARE.—Newcastle.
DISTRICT OF COLUMBIA.—Several localities.
GEORGIA.—Dade,* Elbert, Floyd, Habersham,* Hall,* Paulding, Rabun,* Spalding, White.
ILLINOIS.—Dewitt,* *Douglas*, Knox, McLean, Montgomery, Scott, Shelby,* Vermilion.
INDIANA.—Boone, Brown, Carroll, Grant, Johnson, Laporte, Wells.
KENTUCKY.—Letcher.*
MARYLAND.—Carroll, Cecil, Montgomery, Prince George, Washington.
MICHIGAN.—Barry, (Cass?), Chippewa, Genesee,* Houghton,* Kent(?), Macomb(?), Newaygo(?), Ogemaw(?), Otsego,* Shiawassee,* Washtenaw.
NEW JERSEY.—Bergen, Cumberland, *Essex*, Hudson, Hunterdon, Mercer, Middlesex, Morris, Passaic, Somerset, Union.
NEW YORK.—Greene, New York, *Richmond*, Schenectady, (Westchester).
NORTH CAROLINA.—Alexander,* Bladen, Buncombe, Burke,* Cabarrus, Caldwell,* Catawba,* Henderson,* Iredell, Lincoln,* McDowell,* Macon,* Montgomery, Moore, Pender,* Polk,* Randolph(?), Rutherford, Swain,* Transylvania,* Union,* Washington (?), Wilkes.*
OHIO.—(Ashtabula), Carroll, Champaign, Columbiana, Delaware, Madison, Mahoning, Montgomery, Morrow, Pickaway, Shelby, (Summit?), Union, (Vinton?).
PENNSYLVANIA.—Bucks, (Dauphin), (Lancaster), Montgomery, (Northampton and adjoining counties), (Philadelphia), *Westmoreland.*
SOUTH CAROLINA.—Oconee.*
TENNESSEE.—Bradley, Greene, Hamilton, Jefferson, Knox, Meigs, Polk, Sullivan.
VIRGINIA.—Charlotte, Chesterfield, Fairfax, Powhatan, Prince Edward, (Smyth).
WEST VIRGINIA.—Berkeley, Brooke, Clay, Fayette, Grant, Hampshire, Hancock, Hardy, Jefferson, Marshall, Mineral, Monongalia, Monroe, Morgan, *Ohio*, Pendleton, Pocahontas, Preston, Raleigh, Tucker, Tyler, Webster.
WISCONSIN.—Burnett,* *Columbia*, Crawford, Dane,* Fond du Lac, *Green Lake*,* (La Crosse), *Marquette*,* *Sauk*,* Sawyer, Washburn, Waushara.*

BROOD VII—*Septendecim*—1916. (Fig. 10.)

This brood was founded by Professor Riley in 1869 on Doctor Smith's register, in which it is recorded from 1797 to 1848 as occurring in certain counties in western New York. As indicated elsewhere,

this brood is not very important and is divided into two sections by the following brood, VIII.

The confirmations of the occurrence of this brood in New York in later years are reported in Bulletin No. 8, old series, Division of Entomology. The localities in Pennsylvania and West Virginia are based on later Divisional records.

The distribution, by States and counties, is as follows:

NEW YORK.—Cayuga, Livingston, Madison, Monroe, Onondaga, Ontario, Wyoming, Yates.
PENNSYLVANIA.—Allegheny, Washington.
WEST VIRGINIA.—Summers?.

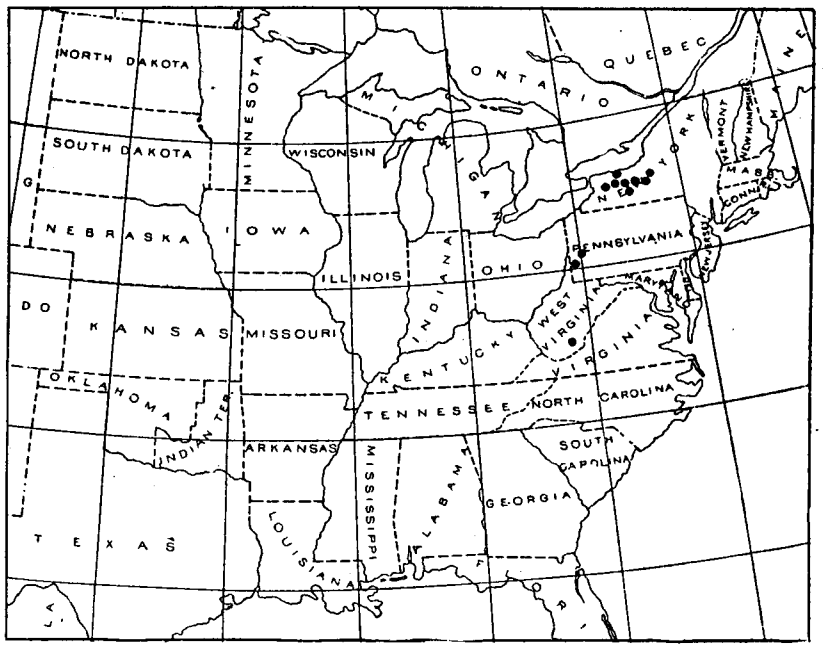

FIG. 10.—Map showing distribution of Brood VII, 1916.

BROOD VIII—*Septendecim*—1917. (Fig. 11.)

This is Fitch's second brood which he described as occurring in western New York, western Pennsylvania, and eastern Ohio, and is Brood XIV of Walsh-Riley, and XX of Riley. Dr. G. B. Smith also gives valuable data relative to its appearance and distribution.

It is one of the smaller broods and did not attract much attention on its appearance in 1883, but records of a number of additional swarms were obtained on the occasion of its appearance in 1900. The main territory covered by it is a rather compact one, lying in western Pennsylvania, eastern Ohio, and the panhandle of West Virginia. The swarms in the area thus included probably originated

by retardation from Brood VII, owing to mountain conditions as affecting temperature.

The widely separated swarm occurring on Marthas Vineyard has exceptional interest on account of the abundance of the insect and its extreme eastern location. This swarm has been well recorded since the time of Harris, and in 1900, when it last appeared, was reported by Prof. H. T. Fernald as being as abundant as ever.

Of the other scattering swarms the ones in western New York and in northern Illinois and in South Carolina are old records but extremely doubtful, and possibly based on confusion of some annual species of Cicada with the periodical species. No confirmations of

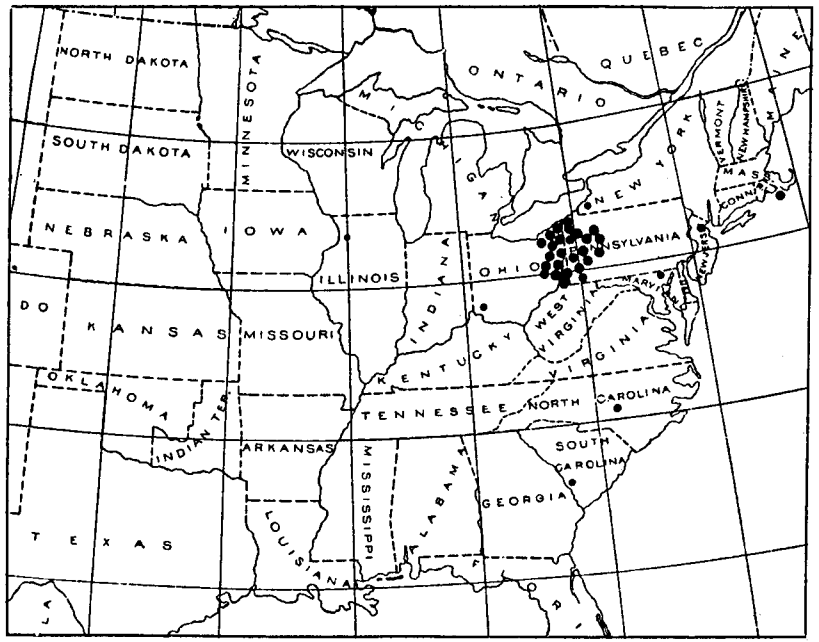

FIG. 11.—Map showing distribution of Brood VIII, 1917.

these records were obtained in 1900. New records were, however, obtained for New Jersey, Maryland, and North Carolina considerably away from the main body of the brood and very possibly having a different origin. None of the records in these three States represents important swarms, but merely scattering individuals. Some new records were obtained also in Ohio, Pennsylvania, and West Virginia, which, however, fall in with the general range of the main body of the brood.

The county indications in the list below are as with other recently studied broods, i. e., the star (*) means occurrence in swarms; *italics*, confirmation of old records; and parentheses (), failure to secure such

confirmation. The large dots on the map indicate starred counties and the small ones doubtful records or scattered presence.

The distribution, by States and counties, is as follows:

ILLINOIS.—(Whiteside) (?).
MARYLAND.—Harford.
MASSACHUSETTS.—*Dukes** (*Marthas Vineyard*).
NEW JERSEY.—Essex.
NEW YORK.—(Chautauqua) (?).
NORTH CAROLINA.—Moore (?).
OHIO.—Belmont, *Carroll*,* *Columbiana*,* Hamilton, *Jefferson*,* *Mahoning*,* Portage,* Stark,* *Trumbull*.*
PENNSYLVANIA.—Allegheny, *Armstrong*,* *Beaver*,* *Butler*,* *Cambria*,* *Clarion*,*

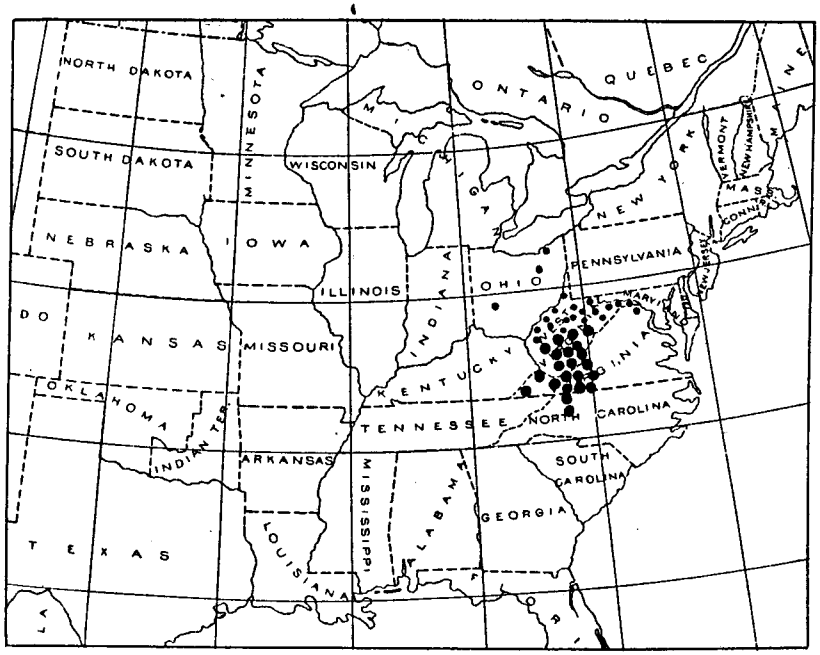

FIG. 12.—Map showing distribution of Brood IX, 1918.

Crawford, Fayette, (Forest), *Huntingdon*, *Indiana*,* (Jefferson), Lawrence,* *Mercer*,* (Snyder), *Venango*,* *Washington*,* Westmoreland.
SOUTH CAROLINA.—Barnwell (?).
WEST VIRGINIA.—Brooke,* Hancock,* (Marshall), *Ohio*.

BROOD IX—*Septendecim*—1918. (Fig. 12.)

In the main this brood (XV Walsh-Riley, XXI Riley) covers a rather compact territory, extending from the southern part of West Virginia across Virginia into North Carolina, and is the southern extension of Brood VIII one year retarded. Some widely separated swarms have been reported from Ohio and one from northern Vir-

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ginia, and one or two in northern West Virginia, but in the main these are doubtful records or unimportant, and may possibly not be connected in origin with the swarms occurring in the main territory of the brood. Since the publication of Bulletin 14 several additional counties have been reported for Virginia and West Virginia, the new records for the latter State being chiefly from a very careful survey made by Doctor Hopkins in 1901. Equally careful search would doubtless show for adjoining States the wide scattering occurrence which Doctor Hopkins has found in West Virginia. The unimportant records are indicated on the map by the small dots.

The occurrence of a swarm on Marthas Vineyard in 1833 is recorded by Doctor Harris, but the records of subsequent appearances of this swarm have shown the date mentioned to be unquestionably an error for 1832, which refers this swarm to Brood VIII.

The distribution, by States and counties, is as follows:[a]

North Carolina.—*Alleghany*,* (Wilkes*).

Ohio.—Cuyahoga, Madison?, (Medina?).

Virginia.[b]—*Bland*,* Buchanan,* Carroll,* (Craig),* Floyd,* *Franklin*,* (Giles),* (Grayson),* (Henry),* Lee,* (Loudoun), (Montgomery),* Patrick,* (Pulaski),* (Roanoke),* *Smyth*,* Wythe.*

West Virginia.—Barbour, Berkeley, Boone,* Braxton,* Clay,* Fayette,* *Greenbrier*,* Hampshire, Hardy, Harrison, Jackson, Jefferson, Kanawha, Logan, Marshall, Mason, Mercer,* Monongalia, *Monroe*,* Nicholas,* Pleasants, Pocahontas,* Preston,* Putnam, *Raleigh*,* Randolph,* Roane, *Summers*,* Tucker, Tyler, Upshur, Webster, Wetzel, Wood, Wyoming.*

Brood X—*Septendecim*—1919. (Fig. 13.)

This is the great 17-year brood occurring over the main areas covered by it in numerous dense swarms and equaling, if not exceeding in importance the largest of the 13-year broods, namely, Brood XIX. It is Brood No. 4 of Fitch, XVI of Walsh-Riley, and XXII of Riley. It has been well recorded, particularly in the East, from 1715 to 1902, the date of its last appearance. It so happened, however, that on each of the years (1868 and 1885) when it was especially studied prior to 1902 it appeared in conjunction with an important 13-year brood, and as the territories of the two races overlap, there has always been some doubt as to the correctness of the references of swarms in such overlapping regions. In 1868, when it was studied carefully by Walsh and Riley, it was in conjunction with the largest of the 13-year broods, namely, Brood XIX. In 1885 it was in conjunction with the second largest of the 13-year broods, namely, Brood XXIII. The

[a] County names in italics are confirmations of old records, names in parentheses are old records unconfirmed, and starred names indicate occurrence in swarms.

[b] The old records for Virginia not confirmed specifically in 1901 are in the midst of counties with large swarms and were confirmed in a general report covering the southwestern part of the State.

year 1902 was not marked by the recurrence of any 13-year brood, and hence the records for that year, for the first time, could practically all be assigned without question to Brood X. It had been anticipated by the writer and others that many of the records in middle and southern Illinois, for example, and northern Missouri, which had been referred to the two large 13-year broods, might possibly belong to Brood X of the 17-year race. Rather to our surprise, however, the old limits of distribution for the three broods in question seem to be pretty definitely confirmed.

Very thorough plans were made early in 1902 to have the entire territory over which the brood was expected fully and adequately

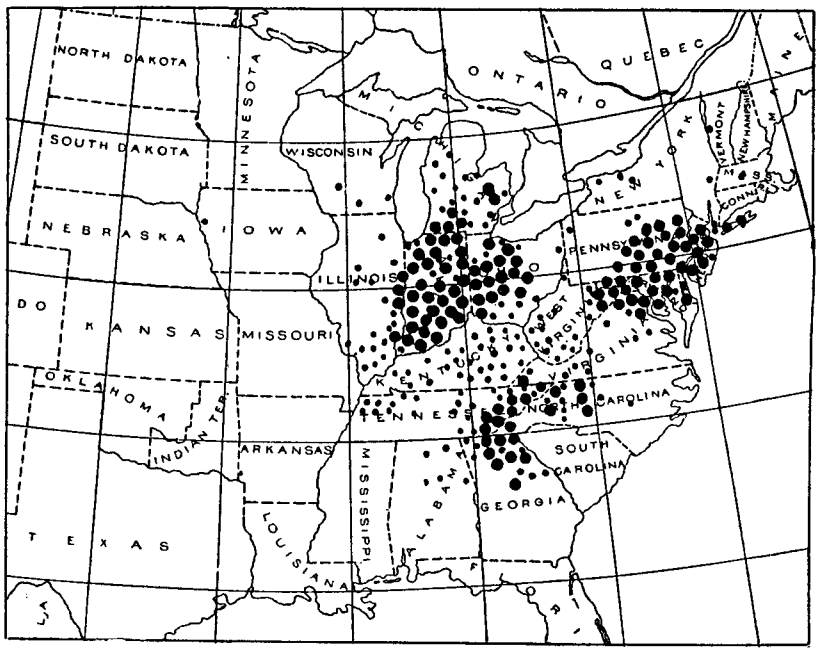

FIG. 13.—Map showing distribution of Brood X, 1919.

reported, and the responses received by this Bureau were numerous and satisfactory for practically the whole area covered by the brood. In addition to this several of the entomologists of the different States within the range of the brood carried on independent investigations, and the records obtained by them, most of which have been published since, have been incorporated with the reports received by this Bureau. All of the records agree in showing the substantial accuracy of the limits of this brood as hitherto platted. The State records available and used in the following list of States and counties, so far as they represent counties new to our records, are those reported by Pettit for Michigan, Smith for New Jersey, Sanderson for Delaware,

Garman for Kentucky, Quaintance for Maryland, Felt for New York, and Hopkins for West Virginia.

Leaving out the numerous scattering colonies the brood occupies three important regions: (1) An eastern region, covering Long Island, New Jersey, southeastern Pennsylvania, northern West Virginia and Virginia, and most of Delaware and Maryland; (2) a southern region, covering the Lower Alleghanies in northern Georgia, Tennessee, and North Carolina; and (3) a middle western region, covering western Ohio, southern Michigan, all of Indiana, except the lake shore (Webster), and the eastern line of Illinois. Many reports of scattering occurrence or of chance individuals connect these three regions and also extend the range westward as far as the Missouri River (Iowa) and northward into New York and Vermont and possibly Massachusetts. But in the main the three regions designated include the abundant appearance of the brood in dense swarms.

Where conditions had remained at all favorable there was very little falling off in abundance of the Cicada at the time of its last appearance in 1902. In the District of Columbia, where the writer personally observed the insect, emergence began with the second week in May and was a fairly prolonged one, extending over three or four weeks.[a] In this brood the small variety, *cassinii*, is perhaps better represented than in any other, and this small variety appeared very generally in 1902, and in great numbers. The deposition of eggs began about June 1 and continued with considerable activity until the middle of this month and was of sufficient amount to kill the terminal branches of trees, in some cases almost all the outer branches dying.

A big transplanting of eggs was made from the surrounding forests of the District to the grounds of the Department, where very few Cicadas had appeared, and all of them had been destroyed by birds before any egg laying had been done. This planting was made in the oak grove on the west side of the grounds, where similar experiments had formerly been in progress, so as to afford material for study of the development of the larvæ.

The records of distribution given below include all available data. The starred counties are those in which the Cicada appeared in 1902 in one or more dense swarms. The italicized counties confirm older records, and the counties in parentheses are old records which failed of confirmation in 1902. This last does not necessarily mean that the Cicada was absent from these counties, but simply the failure to receive reports of occurrence. A great many negative reports were received, and, as platted on a large study map, confirmed the accuracy of the range of this brood as now given.

[a] See Proceedings Entomological Society, Washington, Vol. V, 1902, pp. 124–126.

The distribution, by States and counties, follows:

ALABAMA.—Cleburne, Jackson, Jefferson, Morgan, (St. Clair) (?).

DISTRICT OF COLUMBIA.*

DELAWARE.—(Kent), *Newcastle,** *Sussex.**

GEORGIA.—*Banks,** Chattooga, Dade, *Dawson*, *Fannin,** *Forsyth,** (Franklin), *Gilmer,** Gordon,* Greene, *Habersham,** *Hall,** Jackson,* Lincoln, *Lumpkin,** Murray,* Newton,* Oglethorpe, *Pickens,** *Rabun,** *Union,** Walker, Walton, *White,** Whitfield, Wilkes.

ILLINOIS.—Alexander, *Clark,** *Crawford,** Cumberland, (Dewitt), *Edgar,** *Edwards*, (Gallatin), Hamilton, Hardin, (Iroquois), Jackson, (Kane), *Lawrence*, Logan, (Pope), Saline, Tazewell, Union, *Vermilion,** *Wabash*, *White,** *Williamson.*

INDIANA.—*Adams,** *Allen*, *Bartholomew,** *Benton*, *Blackford,** *Boone,** *Brown,** *Carroll,** *Cass,** *Clark,** *Clay,** *Clinton,** *Daviess,** *Dearborn,** *Decatur,** *Dekalb,** *Delaware,** *Dubois,** *Elkhart,** *Fayette,** *Floyd,** *Fountain,** *Franklin,** *Fulton,** *Gibson,** *Grant,** *Greene,** *Hamilton,** *Hancock,** *Harrison,** *Hendricks,** *Henry,** Howard,* *Huntington,** *Jackson,** *Jay*, *Jefferson,** *Jennings,** *Johnson,** *Knox,** *Kosciusko,** *Lake*, *Laporte,** *Lawrence,** *Madison,** *Marion,** Marshall,* *Martin,** *Miami,** *Monroe,** *Montgomery,** *Morgan,** *Noble,** Ohio,* *Orange,** *Owen,** *Parke,** *Perry,** *Pike,** Porter,* *Posey*, Pulaski,* *Putnam,** *Randolph,** *Ripley,** *Rush,** *St. Joseph,** *Scott,** *Shelby,** *Spencer,** Starke,* *Steuben,** *Sullivan,** *Switzerland,** *Tippecanoe,** *Tipton*, *Union,** *Vanderburg,** *Vermilion,** *Vigo,** *Warren,** *Warrick,** *Washington,** *Wayne,** *Wells,** *White.**

IOWA.—Woodbury.

KENTUCKY.—Allen, Anderson, *Barren*, Bath, Bell, Boone,* Boyd, *Breckinridge,** Butler, Caldwell, Campbell,* *Carroll,** Carter, *Casey*, Christian, Clay, Clinton, Crittenden, Cumberland, *Daviess,** Edmonson, *Fayette*, Fleming, *Franklin*, Gallatin,* Garrard, Grant,* Grayson,* Green, Greenup, Hancock,* Hardin, Harrison,* (Hart), *Henderson*, Hickman, Hopkins, *Jefferson,** Johnson, *Kenton,** Knox, Larue, Laurel, *Lawrence*, Lee, Leslie, Letcher, Lewis, Lincoln, Livingston, *McLean,** Madison, Magoffin, Martin, *Meade,** (Mercer), Monroe, Nelson, Nicholas, *Ohio,** *Oldham,** Owen,* Owsley, Pendleton,* Pike, Scott, Shelby,* Trigg, *Trimble,** Union, Warren, Washington, Wayne, Webster, Whitley, Wolfe.

MARYLAND.—*Allegany,** *Anne Arundel,** *Baltimore,** Calvert, *Caroline*, *Carroll,** *Cecil,** *Frederick,** *Garrett,** *Harford,** *Howard,** *Kent,** *Montgomery,** *Prince George,** *Queen Anne*, *Talbot,** *Washington,** Wicomico.

MASSACHUSETTS.—(Bristol) (?), Worcester(?).

MICHIGAN.—(Barry), *Branch,** *Calhoun,** Cass,* (Eaton), *Genesee,** (Gratiot), Hillsdale, Ionia, (Jackson), *Kalamazoo,** Lake, *Lenawee*, (Livingston), Missaukee, (Monroe), Muskegon, Newaygo, Oakland,* Saginaw, *St. Clair*, *St. Joseph,** Van Buren, *Washtenaw,** (Wayne).

NEW JERSEY.—*Burlington,** *Camden,** Cumberland,* Gloucester,* *Hunterdon,** *Mercer,** *Middlesex,** *Monmouth,** *Morris,** Ocean, (Passaic), Salem,* *Somerset,** Warren.*

NEW YORK.—Columbia, *Kings*, (Monroe), Nassau, (Niagara), Ontario, Queens,* *Richmond*, Suffolk.*

NORTH CAROLINA.—Alexander, Alleghany, Burke,* (Caldwell) (?), Catawba, *Cherokee,** Davidson, *Davie,** *Lincoln*, Stokes, *Surry,** (Wake) (?), *Wilkes,** *Yadkin.**

OHIO.—(Adams), Allen,* Auglaize, *Butler,** *Champaign,** *Clark,** (Clermont), Clinton, (Columbiana), Crawford,* Darke,* *Delaware,** *Fairfield,** *Franklin,** Gallia, *Greene,** *Hamilton,** Hancock, Huron, Jackson,* Logan,* *Lucas,** Madison,* Marion,* Mercer,* *Miami,** *Montgomery,** Morrow,* *Pickaway,** (Pike), Preble,* Putnam,* (Sandusky), *Seneca,** Shelby,* Union,* Van Wert, *Warren,** *Wyandot.**

PENNSYLVANIA.—*Adams,** *Bedford,** *Berks,** *Blair,** *Bucks,** *Carbon,** *Chester,** Clinton, Columbia,* *Cumberland,** *Dauphin,** *Delaware,** *Franklin,** *Fulton,** *Huntingdon,* **Juniata,** Lackawanna,* *Lancaster,** *Lebanon,** *Lehigh,** Luzerne,* Lycoming,

Mercer, *Mifflin*,* *Monroe*,* *Montgomery*,* Montour,* *Northampton*,* *Perry*,* *Philadelphia*,* *Schuylkill*,* *Snyder*,* *Somerset*,* *Union*,* *York*.*

TENNESSEE.—Benton, Bledsoe, *Blount*,* Bradley, Carroll, *Carter*, Claiborne, Cumberland, Dyer, Gibson, Grainger, Greene,* *Hamblen*,* *Hamilton*,* Hancock, Hawkins,* (James(?)), Jefferson,* *Johnson*,* *Knox*,* *Loudon*,* *McMinn*,* Montgomery, Obion, *Polk*,* Rhea, Roane, Robertson, (Scott), Sevier,* Smith,* (Sullivan), *Washington*,* Weakley, White, Williamson.

VERMONT.—(Rutland.)

VIRGINIA.—*Alexandria*,* *Augusta*, (*Carroll*), *Clarke*,* *Fairfax*,* Fauquier, *Frederick*,* Grayson, Lee,* *Loudoun*,* Orange, Prince William,* Roanoke, (Spottsylvania), *Warren*,* Wise, *Wythe*.

WEST VIRGINIA.—Barbour, *Berkeley*,* Boone, Cabell, *Grant*,* Greenbrier, *Hampshare*,* *Hardy*,* Harrison,* *Jefferson*,* Lincoln, Logan, McDowell, Mason, *Mineral*,* Mingo, Monroe, *Morgan*, Ohio, Pocahontas, Preston,* *Putnam*, Raleigh, Roane, Tucker,* Wayne.

WISCONSIN.—Dane, (Sauk).

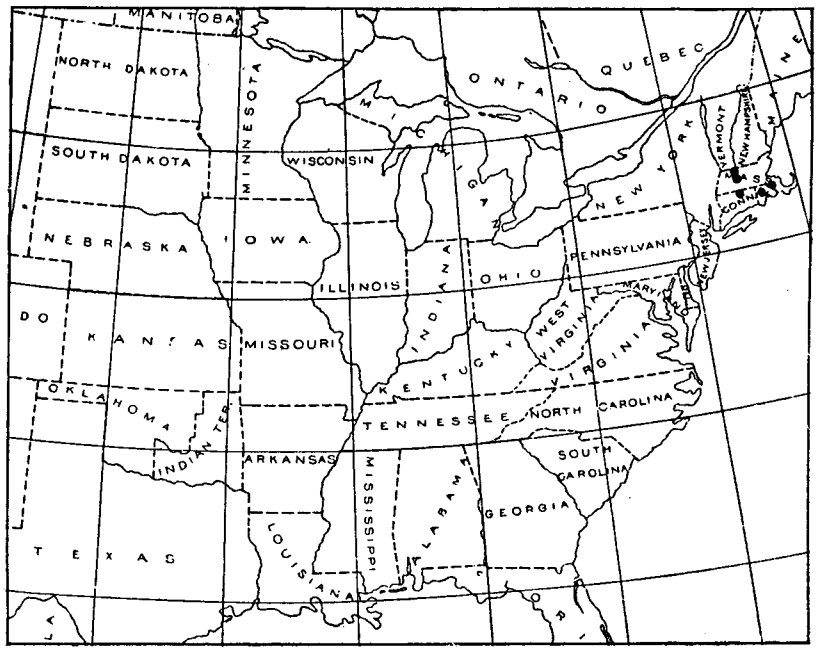

FIG. 14.—Map showing distribution of Brood XI, 1920.

BROOD XI—*Septendecim*—1920. (Fig. 14.)

This is a small brood limited, for the most part, to the valley of the Connecticut River in the States of Massachusetts and Connecticut, with one colony in the vicinity of Fall River separated from the main swarm. It is Brood I of Walsh-Riley and Brood 9 of Fitch, who reports it as having occurred in 1818 and 1835. It was recorded also by Dr. Gideon B. Smith from 1767 to 1852, and the genuineness of the brood was fully established in 1869. Like most small broods in settled regions, it is being greatly reduced in numbers, and in 1903

Mr. Britton reports[a] that he was not able to secure any records for Connecticut, although special effort was made to do so through correspondence. A personal examination of the area was, however, not made by the entomologist, and a clipping from the Hartford Courant of June 6 reports them present.

In this year (1903), however, the first record of the periodical Cicada from Rhode Island was obtained, no brood having previously been reported from this State. The late James M. Southwick, curator of the Museum of Natural History, Roger Williams Park, reported under date of May 23 that a living specimen of the Cicada was brought to him that day taken near the southwest corner of Tiogue Reservoir, about a mile north of the New London turnpike, an unsettled region with plenty of woods. The specimen was secured by Mr. C. E. Ford, of Providence, who reported that the cicadas were making so much noise that he thought they must be frogs or toads having a late spring concert. Mr. Ford says, on the authority of his mother, that some were collected there thirty-four years before. This is a very interesting as well as unexpected record.

The distribution by States and counties is as follows:

CONNECTICUT.—Hartford.
MASSACHUSETTS.—Bristol, Franklin, Hampshire.
RHODE ISLAND.—Providence.

BROOD XII—*Septendecim*—1921. (Fig. 15.)

The records on which this very doubtful new brood was based are given in Bulletin 18, new series, of this Bureau, pages 56, 57. The oldest record is that of Dr. Gideon B. Smith, who in his manuscript reports the Cicada as occurring in 1853 in Vinton County, Ohio, and Jo Daviess County, Ill. Neither one of these localities was confirmed, either in 1870, 1887, or 1904. In the latter year the writer made special effort to have records secured if possible, but without result, Professor Forbes particularly making inquiries for Jo Daviess County, Ill.

The other two records published in Bulletin 18 for this brood are as follows:

Mr. J. R. Burke, Milton, Cabell County, W. Va., writing under date of May 22, 1897, says: "The Cicada is not due here until 1904; its last visit was in 1887."

Mr. W. S. Herrick, Thurman, Allen County, Ind., writes under date of June 10, 1898, that "We had the 17-year locust in 1887, if I remember correctly." This is also a doubtful record, and it is possible that he referred either to Brood XXII, occurring in 1885, or Brood V, occurring in 1888.

No report whatever was received from Mr. Burke. Mr. Herrick, under date of September 1, 1904, reported that he went through the neighborhood where the locusts appeared in 1887, and failed to see

[a] Report Conn. Exp. Sta. 1903, Part III, p. 214.

any evidence of the occurrence of the brood. He states, however, that they were quite numerous when they appeared before. The possibility here, however, is pretty strong that there is a mistake in the date.

Some unimportant new records were obtained in 1904. Mr. S. D. Nixon found living cicadas, May 28, on a horse-chestnut tree in Mount Olivet Cemetery, Baltimore, Md. Mr. Robert A. Kemp reports that while collecting Lepidoptera in the woods at Catoctin Mountain, near Braddock, Md., his attention was arrested by the unmistakable cry of *Tibicen septendecim*. He was unable to secure the specimen, which was safely hidden in a dense grove of young chestnuts. He says:

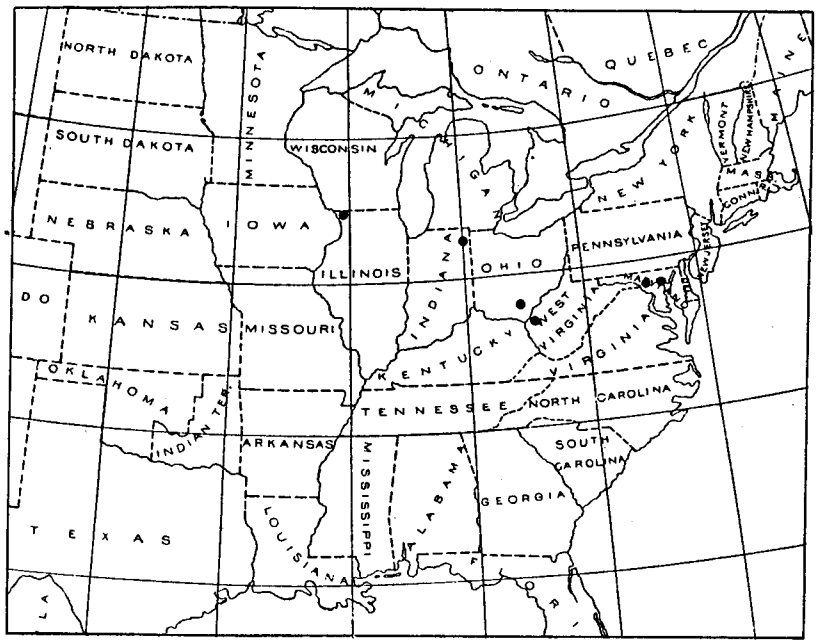

FIG. 15.—Map showing distribution of Brood XII, 1921.

I was loath to leave him inasmuch as he gave me a parting "Pharaoh" when I left him alone in his glory. I have heard during the past week in this same woods several specimens, and have not yet given up hope of securing one.

Both of these records may relate to belated specimens belonging to Brood X of 1902. Mr. C. H. Bobbit, of Baltimore, Md., reports that he heard twenty or thirty in a little piece of woods, and one captured specimen was seen by Doctor Howard.

The records of this brood therefore are as follows, all very doubtful or unimportant:

ILLINOIS.—Jo Daviess County.
INDIANA.—Allen County.

MARYLAND.—Frederick County and Baltimore.
OHIO.—Vinton County.
WEST VIRGINIA.—Cabell County.

BROOD XIII—*Septendecim*—1922. (Fig. 16.)

This very compact brood, described by Fitch as Brood No. 6, by Walsh-Riley as Brood III, and by Riley as Brood V, covers in large part a prairie or sparsely wooded region extending over portions of several States in the upper Mississippi Valley.

A detached brood was formerly known in Pennsylvania, but seems not to have been seen in later years. A few individuals were reported

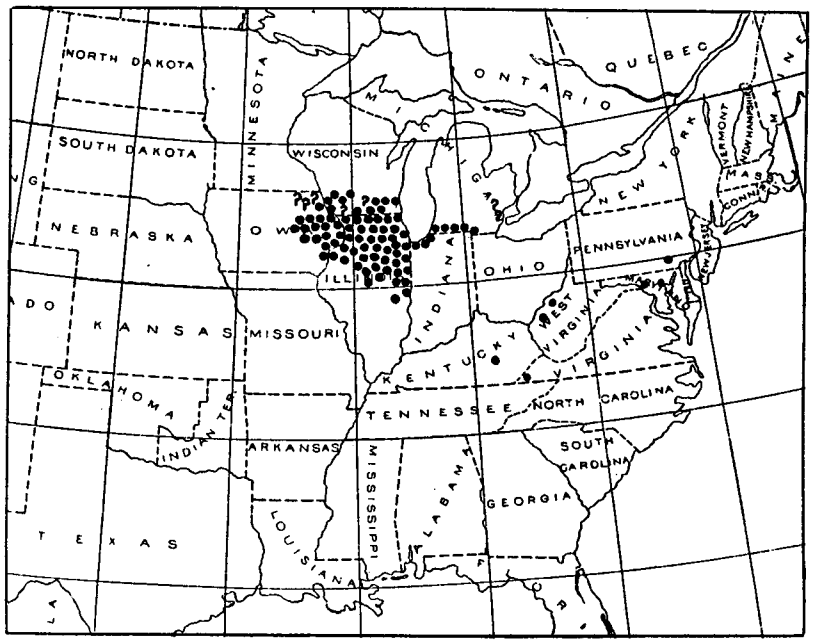

FIG. 16.—Map showing distribution of Brood XIII, 1922.

from two counties in Maryland in 1905, and two very doubtful records (1888) have been found for Kentucky and Virginia. Mr. Hopkins in his Bulletin 68 gives records indicating possible swarms in Putnam and Lincoln counties, W. Va. None of these eastern records can have other than chance time relation with the main area covered by this brood.

As the periodical Cicada is limited to forested areas, the broods occurring in prairie districts of northern Illinois and adjoining States are necessarily much broken and scattered, and Brood XIII occurs, therefore, for the most part in small colonies in woods bordering streams. No special effort was made to get records in 1905, and this

brood therefore rests practically on the data secured in earlier years. Reports came from eleven counties in Illinois—all, however, included in the region designated below—and from several of the counties in other States, where they were expected. The italicized counties are confirmations of old records.

The distribution by States and counties follows:

ILLINOIS.—All northern counties from Mercer southeast to Peoria, to Logan, Shelby, Edgar, including *Lee*, Dekalb, Dupage, Kane, McLean, Rock Island, etc.

INDIANA.—Lake, Laporte, Porter.

IOWA.—Allamakee, *Benton*, Blackhawk, Bremer, Buchanan, Cedar, Chickasaw, Clayton, Clinton, Delaware, Dubuque, Fayette, Howard, Iowa, Jackson, Johnson, Jones, Linn, Louisa, Mitchell(?), Muscatine, Scott, Tama, Winneshiek(?).

KENTUCKY.—Lincoln.

MARYLAND.—Baltimore, Frederick.

MICHIGAN.—Berrien, Branch, Cass, Hillsdale, Oakland(?), St. Joseph, Wayne(?).

PENNSYLVANIA.—Lancaster.

VIRGINIA.—Lee.

WEST VIRGINIA.—*Lincoln, Putnam.*

WISCONSIN.—Crawford, Dane, Grant, Green, Iowa, Jefferson, Lafayette(?), Milwaukee, *Richland, Rock*, Sauk, *Walworth*, Waukesha.

BROOD XIV—*Septendecim*—1923. (Fig. 17.)

This brood, so far as our records go, is the one which was first observed by the early European colonists on this continent. Two important areas occur in eastern Massachusetts, one about Plymouth and the other covering Cape Cod. The Plymouth swarm of 1634, the first after European settlement, was noted by the early Puritans and is referred to in the two earliest published notices of this curious insect. (See Bibliography.) One of these records gives the definite date of 1633, but, as shown by the subsequent appearances of the swarm, this date is probably an error for 1634. No published records have been found of the later appearances prior to 1789, but definite records have been made of each return since that year. An interesting account of the last appearance (1906) of the Cicada in Plymouth County is given in a report received from Martha W. Whitmore, Chiltonville, Plymouth, Mass. The near-by Barnstable colony was also most abundant last year (1906) all along Cape Cod. As reported by Miss Grace Avery, of Washington, D. C., the ground along the coast was covered with the dead bodies and the trees in the forests were all fired and brown from the egg-laying of the females.

Prof. H. T. Fernald reports (letter September 26, 1906) the distribution in Plymouth and Barnstable counties as in the following towns: Plymouth, Wareham, Bourne, Falmouth, Sandwich, Mashpee, Barnstable, Yarmouth, and Dennis, being most abundant in the three first named.

This brood, like Brood VI, covers a very wide range, extending from Massachusetts westward to Illinois, with important groups of

swarms extending from Pennsylvania southward into northern Virginia and in the Lower Alleghenies, covering portions of North Carolina, Tennessee, Georgia, etc., and in the Ohio Valley region, covering especially southern Ohio, Indiana, central Kentucky, and western West Virginia.

Brood XIV has been carefully studied, notably so on the occasion of its appearance in 1906, when a great many new records were obtained by this Bureau and by the entomologists of the several States included within its range.

Important new records were secured and kindly submitted to this

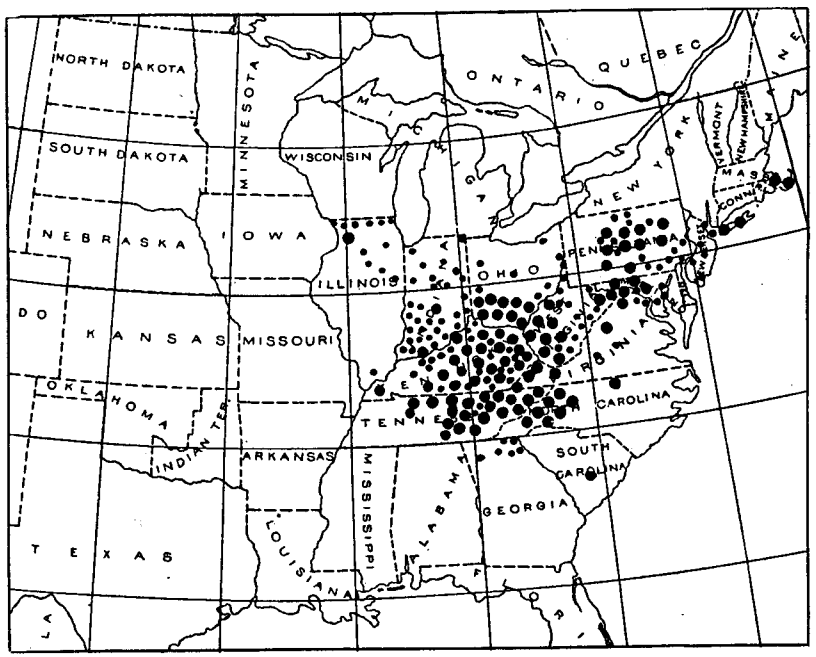

FIG. 17.—Map showing distribution of Brood XIV, 1923.

office by Messrs. Garman, Fernald, Felt, Sherman, Howser, Bentley, and Ramsay, for, respectively, Kentucky, Massachusetts, New York, North Carolina, Ohio, Tennessee, and West Virginia.

The occurrence jointly with this brood in 1906 of the small and rather unimportant 13-year Brood XVIII leaves some doubt as to the correct assignment of certain swarms in southern Illinois, western Kentucky, and Tennessee.

The starred counties indicate the occurrence of the Cicada in one or more characteristic dense swarms; the italicized counties are confirmations of old records, and the counties inclosed in parentheses are old records not reported in 1898. The large dots on the map (fig. 17)

indicate the starred counties and the small dots the unimportant or doubtful occurrences.

The distribution, by States and counties, is as follows:

DISTRICT OF COLUMBIA.—Throughout.

GEORGIA.—(Gordon), (Habersham), (Rabun), (Towns), (Union), (White).

ILLINOIS.—(Boone), Grundy(?), *Jo Daviess;* Johnson(?), (Lake), (McHenry) (McLean), (Putnam), (Stephenson), Vermilion, Whiteside,* (Winnebago), Woodford(?).

INDIANA.—Boone(?), Brown,* Carroll(?), (Clark), (Clay), (Crawford), (Daviess), Dearborn, Dubois(?), Floyd, Fountain, (Gibson), Grant, (Greene), Harrison, Jackson(?), Johnson, *Knox,* (Lake), (Lawrence), Monroe, Morgan, Orange, Perry,* (Pike), (Posey), Putnam, Ripley, Scott, Steuben(?), *Sullivan,* Tippecanoe, (Vanderburg), (Vigo), *Warrick,* Washington, Wayne.

KENTUCKY.—*Adair,** *Allen,** Anderson,* Barren, *Bath,* (Bourbon), *Boyd,** Boyle,* (Breckinridge), Bullitt,* (Carter), *Casey,** (Clark), (Clinton), *Cumberland,** Edmonson,* *Estill,** (Fayette), (Fleming), Floyd,* (Franklin), Garrard,* Grayson,* Green, (Greenup), Hancock(?), Hardin,* Harrison, Hart, Henry, (Jackson), (Jefferson), Jessamine,* Johnson,* Knott,* Knox,* Larue,* *Laurel,* Lawrence,* Lee,* (Lewis), Lincoln,* Logan,* (McLean), (Madison), Magoffin,* Martin, *Mason,* Meade, Menifee, Mercer, (Metcalfe), Monroe,* (Montgomery), Nelson,* Nicholas,* Owen, *Owsley,** Pendleton,* Perry, Pike,* (Powell), *Pulaski,** *Rockcastle,** Rowan,* (Russell), Scott,* *Shelby,** Simpson, Taylor,* *Trimble,** Warren,* *Wayne,** Whitley, Wolfe.

MARYLAND.—Allegany,* Frederick,* Howard, Montgomery, Prince George, *Washington.**

MASSACHUSETTS.—*Barnstable,** *Plymouth.**

NEW JERSEY.—*Bergen,* (Burlington), (Cape May), (Gloucester), (Mercer).

NEW YORK.—On *Long Island** and in Richmond County.

NORTH CAROLINA.—*Buncombe,** *Caldwell,** Caswell,* *Haywood,** Jackson, *McDowell,** *Madison,** Mitchell,* Watauga,* Wilkes,* Yancey.*

OHIO.—*Adams,** Auglaize, *Brown,** *Butler,** Clermont,* *Clinton,** Columbiana, Cuyahoga, Delaware, Fayette,* *Gallia,** Greene,* *Hamilton,** *Highland,** Jackson, *Lawrence,** (Meigs), Pike,* Preble, Ross,* *Scioto,** Vinton,* *Warren,** Washington.

PENNSYLVANIA.—(Adams), Bedford,* *Berks, Blair,** (Center), (Chester), *Clearfield,** *Clinton,** (Columbia), *Cumberland, Franklin,** (Huntingdon), (Lancaster), Lehigh, Luzerne,* (Lycoming), (Mifflin), *Montour,** *Northumberland,** Potter, *Snyder,** Schuylkill,* Tioga, *Union,** *York.*

TENNESSEE.—Anderson, *Bledsoe,** Blount,* Campbell, Cannon,* Carter,* Cheatham,* *Claiborne,** Clay, Cocke,* Coffee,* Cumberland,* Dekalb,* Fentress,* Franklin,* Grainger,* Greene,* Grundy,* Hancock,* Hawkins,* Johnson,* Macon,* Marion,* Morgan,* Overton,* Pickett,* Putnam,* Rhea,* Roane, Robertson,* Scott,* Stewart, Sullivan,* Unicoi,* Union, Warren,* White.*

VIRGINIA.—(Alexandria), Augusta,* Buchanan,* Dickenson,* Fairfax, Frederick,* Lee,* Nelson, Tazewell,* Wise.*

WEST VIRGINIA.—Berkeley,* Boone,* Brooke, Cabell,* Doddridge, Fayette,* Greenbrier, Hampshire,* Hancock, Hardy, Jackson, Jefferson, *Kanawha,** Lincoln,* Logan,* McDowell,* Mason,* Mercer,* Mineral,* Mingo,* Monroe, Morgan,* Pendleton, Pocahontas, Preston, Putnam,* Raleigh,* Ritchie, Roane, Wayne,* Webster, Wood,* Wyoming.*

BROOD XV—*Septendecim*—1907. (Fig. 18.)

This is one of the new 17-year broods indicated by the writer in Bulletin 18 (new series) of this Bureau, and consists of retarded eastern colonies of Brood XIV. The important colonies of this brood

are in Dutchess and Saratoga counties, N. Y. All the records from Bulletin 18 are reproduced below, with the exception of the report from Indian Territory, which falls distinctly within the 13-year lines, and has been transferred to Brood XXIX.

This brood is represented by the colony appearing at Tivoli, Dutchess County, and Galway, Saratoga County, N. Y., in June, 1890, as recorded by Prof. J. A. Lintner in his Seventh Report, pages 297–301. Mr. Davis records the occurrence of scattering individuals the same year on Staten Island. In a letter of June 2, 1890, Prof. J. B. Smith, New Brunswick, N. J., reports that the

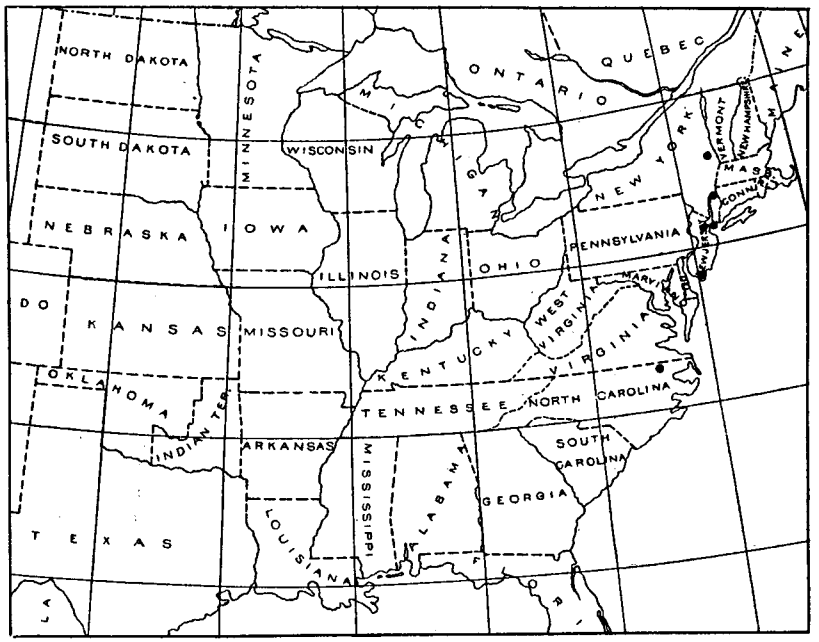

FIG. 18.—Map showing distribution of Brood XV, 1907.

periodical Cicada had been taken by several Newark (Essex County), collectors, and had also been observed at Anglesea, Cape May County.

Another record which perhaps applies to this brood is given by Mr. I. N. Smith, Scotland Neck, Halifax County, N. C., in letter of June 22, 1885. He reports that his "first recollection of the locust was about the year 1839 or 1840, when the whole of the white-oak lands were filled with them. * * * In 1855 or 1856 they appeared again, but nothing to compare with the period first stated. The locusts were all on the white-oak land and on the Roanoke River and not on the pine lands." Assuming the dates 1839 and 1856 to be the correct ones, this would throw this swarm of Cicadas into Brood XV.

and if there are any representatives left they should reappear in 1907.

The distribution, by States and counties, is as follows:

NEW JERSEY.—Cape May, Essex.
NEW YORK.—Dutchess, Richmond, Saratoga.
NORTH CAROLINA.—Halifax.

BROOD XVI—*Septendecim*—1908. (Fig. 19.)

This old Brood IX of Riley (VII of Walsh-Riley) is a very small and doubtful one, and represents a few isolated colonies in the extreme western portion of the range of the species, possibly two years belated swarms of Brood XIV. It was reported as occurring in 1857 in southeastern Nebraska, and a very definite record for Franklin County, Ark., which apparently pertains to this brood, was obtained in 1885. Mr. J. M. Pettigrew, writing under date of July 1, states that the cicadas were numerous in that county in May, 1857, and in 1874, doing some injury to small branches of fruit trees, especially apple. This record falls in the western central part of the State, and is surrounded by 13-year records, but is at an elevation of a thousand feet or more and, in view of the definiteness of the report, does not seem to be open to doubt. There is a doubtful record reporting the Cicada in Lee County, Iowa, in 1874, which seems to belong to this brood.

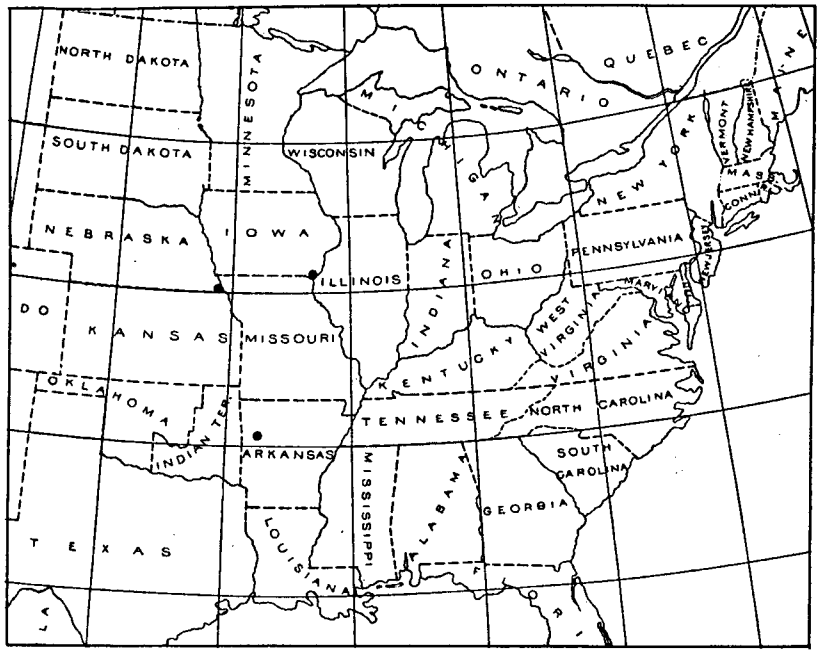

FIG. 19.—Map showing distribution of Brood XVI, 1908.

In Bulletin 14 and older publications a western outpost in Boulder County, Colo., was reported for this brood. This record is undoubtedly erroneous, and arises from the confusion of one or other of the mountain species of Cicada which also have life cycles of several years and duplicate somewhat the habits of the eastern species. Prof. C. P. Gillette, in answer to an inquiry by the writer, states that he does not believe that *septendecim* occurs in Colorado, inasmuch as he has not found a single example of it in the course of the insect collecting done there by himself and students during the last sixteen years, and he suspects that the insect reported is *Tibicen rimosa* Say, which might readily have been mistaken for *septendecim*.

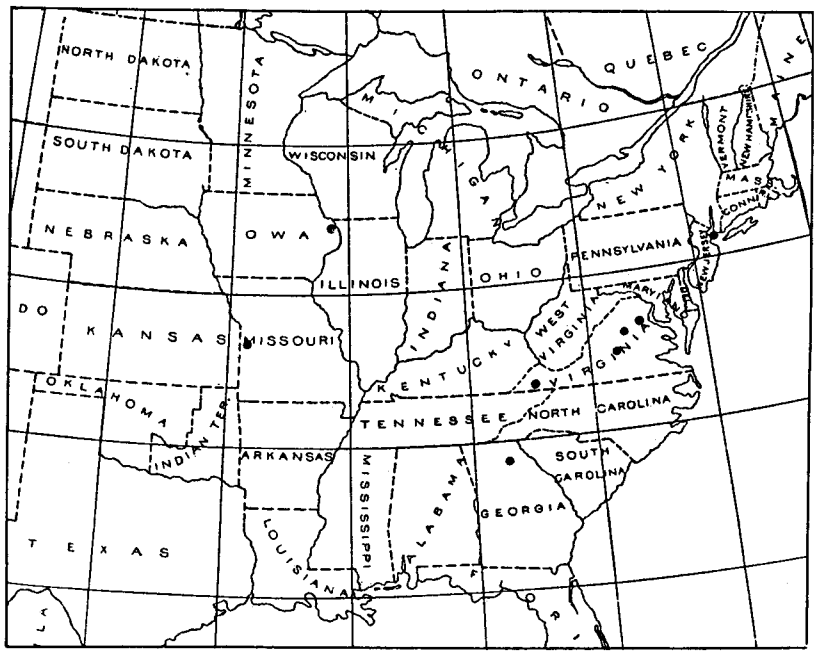

FIG. 20.—Map showing distribution of Brood XVII, 1909.

The distribution, by States and counties, is as follows:

ARKANSAS.—Franklin.
IOWA.—Lee (?).
NEBRASKA.—Richardson.

BROOD XVII—*Septendecim*—1909. (Fig. 20.)

This brood is a precursor of Brood I, and was indicated by the writer in Bulletin 18 (new series) of this Bureau. It comprises small or doubtful colonies only. The records given in that publication are reproduced below without change except for the addition of two new localities for Virginia, one in Appomattox County and the other in the southwestern part of Washington County.

A very definite record which may coincide with this brood is furnished by Mr. Theodore Pergande, of this Bureau, who states that Mr. Rosseau, of Charlottesville, Albemarle County, Va., informed him that the Cicada was very numerous in that place in 1875. His informant was positive as to the year from its being the one in which he made a trip to Europe.

Another record is given by Mr. John D. Macpherson, Manassas, Prince William County, Va., in letter of July 3, 1895. He writes:

> I came here on the 23d of June, leaving the Cicada in full song in Washington (Brood X). Finding none here I made inquiry and was informed that they appeared in full force in this county (Prince William) in the year 1875. This information I regard as reliable, the date being fixed as the year following the marriage and arrival of my informant in this county.

Mr. J. R. Honley, of Spanish Oaks, in a report received in 1898, states that the "locusts" appeared in Appomattox County in 1892, and Mr. A. M. Connell, in a postal of May 29, 1902, reports their appearance in the southwestern part of Washington County in 1841, 1858, 1875, and 1892. These Virginia swarms are evidently precursors of Brood I, with which they are therefore closely allied.

A western extension of this brood seems to be indicated in the record furnished by H. J. Giddings, Sabula, Jackson County, Iowa. He writes, "during last June (1892) the periodical Cicada was quite common here. * * * I thought it was unusual to find them in such numbers four years after their regular appearance. The last regular year was 1883." (See Insect Life, Vol. V, p. 200.)

If belonging to the 17-year race, the two records following should also be assigned to this brood. Mr. A. J. Julian, Woolleys Ford, Hall County, Ga., reports under date of June 14, 1898, that the Cicada was present there in 1892. Mr. J. W. Seaton, Strasburg, Cass County, Mo., writes under date of June 9 that the Cicada last appeared in that county in the summer of 1892 and in the summer of 1896, being numerous both years. The 1896 record refers to the 17-year Brood IV, and hence the record of 1892 is probably also of the 17-year race occurring in the same district.

The scattering specimens recorded by Mr. Davis as occurring on Staten Island in 1892 may also be assigned to this brood.

The distribution, by States and counties, is therefore as follows:

GEORGIA.—Hall.
IOWA.—Jackson.
MISSOURI.—Cass.
NEW YORK.—Richmond.
VIRGINIA.—Albemarle, Appomattox, Prince William, Washington.

Broods of the Thirteen-Year Race.

BROOD XVIII—*Tredecim*—1919. (Fig. 21.)

This is an unimportant brood, most of the records representing scattering specimens rather than dense swarms. It was originally established by Professor Riley as Brood XVI on the testimony of Dr. G. B. Smith, who gives in his Register a record of its appearance in Cherokee County, Ga, in 1828, 1841, and 1854. Its appearance in the same locality was also recorded by Dr. J. G. Morris in 1867, and this seems to be the most important swarm of the brood. The records obtained since relate to scattering occurrences in three other States.

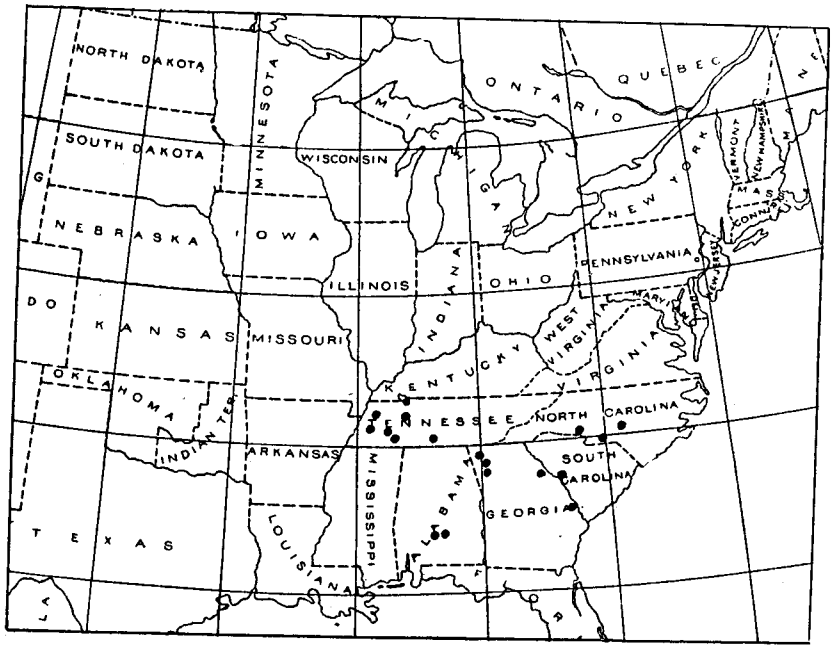

FIG. 21.—Map showing distribution of Brood XVIII, 1919.

This brood immediately precedes in time of appearance the largest 13-year brood known, namely, Brood XIX. The latter brood occupies the Mississippi Valley in the main, but with scattering swarms extending well over the Southern States and into Virginia, and thus overlaps the territory covered by Brood XVIII, indicating very plainly the origin of the latter as accelerated swarms of Brood XIX.

The localities for Brood XVIII as listed in Bulletin 14 are those given by Professor Riley in 1894.[a] None of them was verified in

[a] Annual Report, U. S. Department of Agriculture, 1893, p. 204. (The records on which localities for this brood are based are given in an editorial note in Vol. V, Insect Life, pp. 298, 299.)

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1893, but an additional and very doubtful locality (Montgomery, Ala.) was reported that year. The records obtained in 1906 added three counties for Georgia, six for Tennessee, one for North Carolina, and one for South Carolina, but gave again no confirmations of old records. The lack of confirmations, however, does not invalidate these old records nor necessarily mean the dying out of the swarms, as no particular effort was made to get reports from the exact localities.

The distribution, by States and counties, is as follows:

ALABAMA.—(Lowndes), (Montgomery) (?).
GEORGIA.—(Cherokee), (Cobb), Gordon, Oglethorpe, Screven.

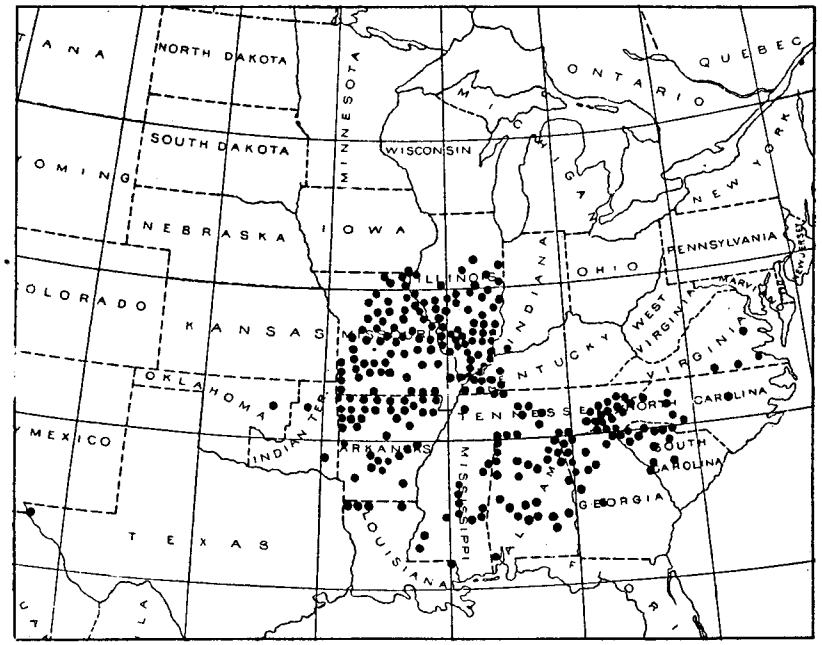


FIG. 22.—Map showing distribution of Brood XIX, 1907.

NORTH CAROLINA.—Anson, (Lincoln), (Moore).
SOUTH CAROLINA.—Edgefield.*
TENNESSEE.—Carroll, Dyer, Lauderdale, (Lincoln), McNairy, Madison, Stewart.

BROOD XIX—*Tredecim*—1907. (Fig. 22.)

This is the largest of the 13-year broods, and also the best recorded, perhaps, from the standpoint of distribution of all the broods. It is Fitch's Brood No. 3, in part, XIII of Walsh-Riley, and XVIII of Riley. Its existence has been known since 1803. Its limits were most carefully studied by Walsh and Riley in 1868, particularly for the Missouri and Illinois localities. As has elsewhere been explained (p. 31), there is a possibility that some of the northern counties, at least of Illinois and Missouri, listed for this brood belong to the 17-year Brood X, which appeared with Brood XIX in the year mentioned. Some additional data were obtained in 1881 and published in Bulletin No. 8, old series, of the Division of Entomology, and the records were brought down to 1894 in the circular issued by Professor Riley in that year. The later records, mostly in reply to the circular just mentioned, but including a good many reports received subsequent to the publication of Bulletin 14, considerably modify and extend the range of the brood. The record for El Paso, Tex., is open to much doubt. The relationship of this brood to Brood XXII has been elsewhere discussed.

Its reported limits are as follows:

ALABAMA.—Autauga, Blount, Bullock, Cherokee, Colbert, Cullman, Dallas Dekalb, Elmore, Etowah, Franklin, Hale, Jackson, Jefferson, Lamar, Lauderdale, Lowndes, Macon, Marshall, Mobile, Montgomery, Perry, Randolph, Russell, St. Clair.

ARKANSAS.—Baxter, Benton, Boone, Carroll, Clark, Clay, Conway, Crawford, Dallas, Drew, Franklin, Fulton, Garland, Grant, Greene, Hempstead, Hot Spring, Izard, Johnson, Lawrence, Logan, Lonoke, Madison, Marion, Newton, Prairie, Pulaski, Randolph, Scott, Searcy, Sebastian, Sharp, Stone, Van Buren, Washington, White.

GEORGIA.—Campbell, Catoosa, Chattooga, Cherokee, Floyd, Fulton, Harris, Pike, Polk, Rabun, Richmond, Walker, White.

ILLINOIS.—Adams, Bond, Cass, Champaign, Christian, Clark, Clay, Clinton, Coles, Crawford, Cumberland, Douglas, Edgar, Edwards, Effingham, Franklin, Gallatin, Greene, Hamilton, Hancock, Hardin, Iroquois, Jasper, Jefferson, Jersey, Johnson, Lawrence, Livingston, McLean, Macon, Macoupin, Madison, Marion, Massac, Monroe, Montgomery, Morgan, Perry, Piatt, Pike, Pope, Randolph, Richland, St. Clair, Saline, Sangamon, Scott, Shelby, Union, Vermilion, Wabash, Washington, Wayne, White, Williamson.

INDIAN TERRITORY.—Choctaw, Creek.

INDIANA.—Vanderburg.

IOWA.—Lee.

KENTUCKY.—Carlisle, Graves, Hopkins, McCracken, Marshall, Trigg.

LOUISIANA.—Bossier, Caddo, Claiborne, Morehouse, Washington.

MISSISSIPPI.—Attala, Choctaw, Clarke, Copiah, Franklin, Jasper, Lauderdale, Leake, Madison, Monroe, Oktibbeha, Scott.

MISSOURI.—Audrain, Barry, Barton, Benton, Bollinger, Boone, Butler, Callaway, Cedar, Chariton, Clark, Cole, Cooper, Dade, Dallas, Douglas, Franklin, Gasconade, Greene, Henry, Howard, Iron, Jasper, Jefferson, Knox, Laclede, Lawrence, Lewis, Linn, Livingston, McDonald, Macon, Madison, Marion, Moniteau, Monroe, Morgan, Newton, Oregon, Pettis, Phelps, Pike, Polk, Pulaski, Ralls, Randolph, Ripley, St. Charles, St. Clair, St. Francois, St. Louis, Saline, Schuyler, Shannon, Stoddard, Stone, Warren, Washington, Webster, Wright.

NORTH CAROLINA.—Cabarrus, Caldwell, Cherokee, Clay, Graham, Haywood, Iredell, Macon, Madison, Mecklenburg, Swain, Wake, Wilkes.

OKLAHOMA TERRITORY.—Payne.

SOUTH CAROLINA.—Aiken, Anderson, Chester, Greenville, Laurens, Oconee, Orangeburg, Pickens, Spartanburg, Union, York.

TENNESSEE.—Bedford, Blount, Cocke, Davidson, Gibson, Giles, Greene, Hamblen, Hamilton, Jefferson, Knox, Lawrence, Loudon, McMinn, Marion, Monroe, Montgomery, Rutherford, Sevier, Stewart, Wayne, Williamson, Wilson.

TEXAS.—El Paso (?).

VIRGINIA.—Brunswick, Halifax, Hanover, Prince George.

BROOD XX—*Tredecim*—1908. (Fig. 23.)

This is a small brood, founded on records given by Doctor Smith. Some of the localities cited were confirmed and others negatived on the recurrence of the brood in 1869, as reported by Professor Riley in Bulletin No. 8, old series, of the Division of Entomology. Since that date three doubtful localities have been added, one each for Virginia, North Carolina, and Georgia, possibly based on 17-year broods which appeared in conjunction with this brood.

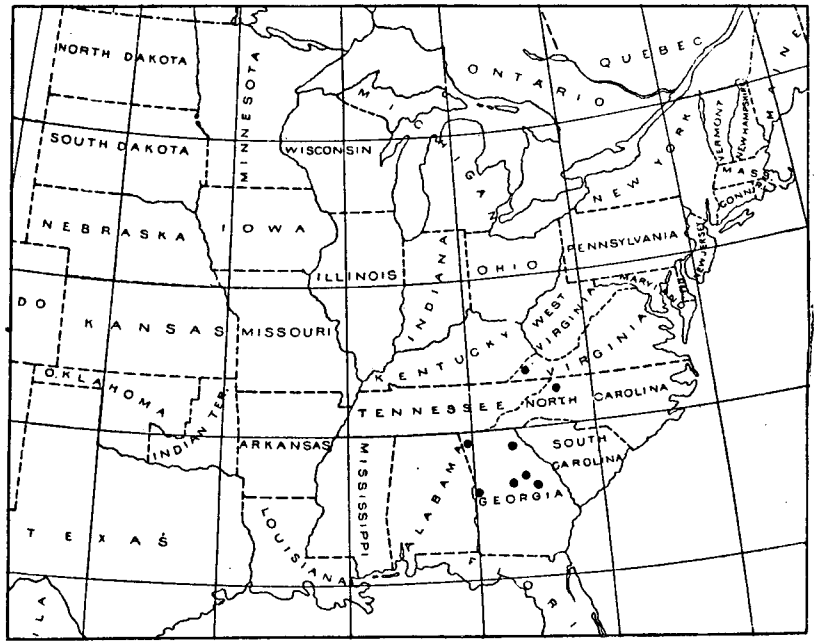


FIG. 23.—Map showing distribution of Brood XX, 1908.

The distribution, by States and counties, is as follows:

GEORGIA.—Banks, Greene, Jasper, Muscogee, Walker, Washington.
NORTH CAROLINA—Wilkes (?).
VIRGINIA.—Wise (?).

BROOD XXI—*Tredecim*—1909. (Fig. 24.)

This is one of the broods representing the extreme southern range of the Cicada, and was recorded by Doctor Smith in Florida as occurring in 1844 and 1857. Its existence was confirmed in 1870, when records were obtained indicating its extension also into Alabama, Mississippi, and Tennessee.

It is a brood which, according to report, does not seem to occur in dense swarms, but scatteringly, at least in its more northern range.

No records of its appearance which have come to our notice were made in 1883 nor in 1896.

The distribution, by States and counties, is as follows:

ALABAMA.—Lauderdale, Mobile.
FLORIDA.—Gadsden, Jackson, Washington.
MISSISSIPPI.—Jackson, Tishomingo.
TENNESSEE.—Hardin.

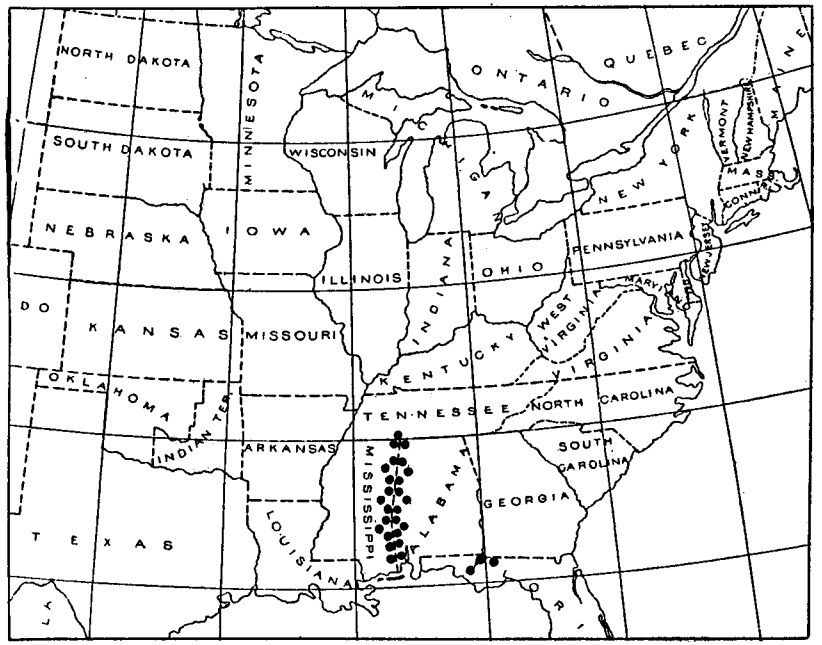


FIG. 24.—Map showing distribution of Brood XXI, 1909.

BROOD XXII—*Tredecim*—1910. (Fig. 25.)

This 13-year brood, which appeared last in 1897, is of small extent, but well established by many reliable records, the oldest of which dates back to 1806. It is Brood IV of Walsh-Riley and VI of Riley.

A summary of the distribution of this brood was given by Mr. Schwarz in Circular No. 22 of the Division of Entomology, issued in May, 1897. This inquiry resulted in the report of but one additional locality. The distribution and relationship of this brood is given by Mr. Schwarz in the circular referred to, as follows:

It is confined to parts of southern Mississippi and adjacent parts of Louisiana east of the Mississippi, the particular localities being given further on. Dr. D. L. Phares, of Woodville, Miss., has taken particular pains to ascertain the extent of this brood, and his lucid and concise account, already published in 1885, in Bulletin 8 (old series) of this Division, is herewith reproduced:

"Their western limit is the Mississippi River, the southern about 8 miles north of Baton Rouge, the eastern about 4 miles west of Greensburg, the county seat of Helena,

and 4 miles west also of Liberty, in Amite County, Miss., thus extending from 15 to 50 miles from the Mississippi River, and from the vicinity of Baton Rouge, 108 miles to the northern limit of Claiborne County, Miss., perhaps even farther. They therefore occupy East and West Feliciana, the northern part of East Baton Rouge, the northwest corner of Livingston and the western part of St. Helena parishes, La., and Wilkinson, Adams, Jefferson, Claiborne, and parts of Amite, Franklin, and possibly parts of one or two more counties in Mississippi."

The reports received since 1885 are mostly confirmatory of Doctor Phares's statement, but Mr. Thomas F. Anderson, of St. Helena, La., writes us that the parishes, or at least parts of the parishes, of Tangipahoa, Washington, and St. Tammany had to be added to the range of this brood. His statement is quite definite; still a confirmation of these new localities is desirable.

Brood VI [XXII] is evidently a forerunner of the very large 13-year Brood VII [XXIII], which will appear in 1898 in the Mississippi Valley. The geographical

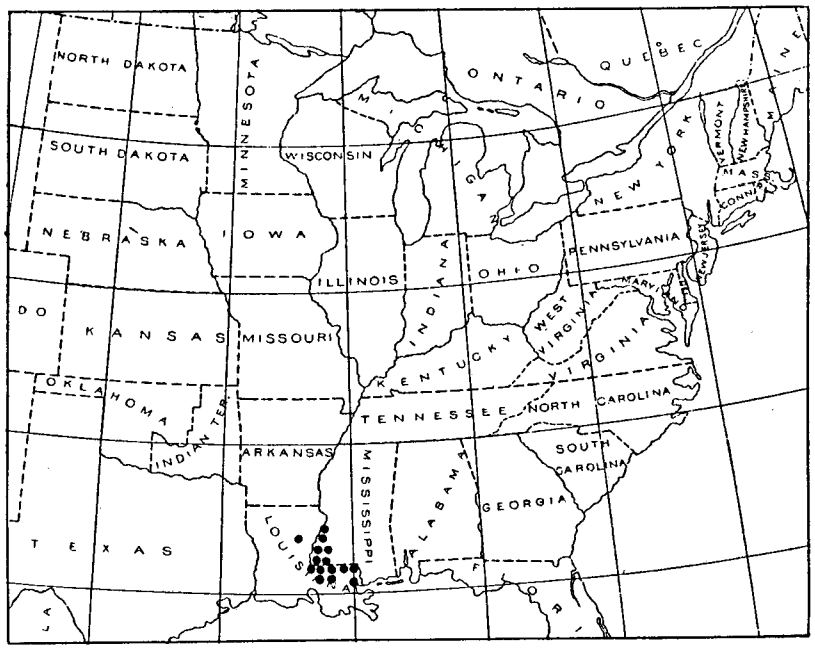


FIG. 25.—Map showing distribution of Brood XXII, 1910.

range of Brood VII [XXIII] was mapped out in the Annual Report of this Department for 1885, and it will be seen from this map that the southern limits of Brood VII [XXIII] almost precisely coincide with the northern limits of our Brood VI [XXII.]

One new locality in central Louisiana, in Catahoula County, has been added.

The brood occurs in the following States and counties:

LOUISIANA.—Parishes of East Baton Rouge, Catahoula, East Feliciana, Livingston, St. Helena, St. Tammany (?), Tangipahoa (?), Washington (?), and West Feliciana.

MISSISSIPPI.—Counties of Adams, Amite, Claiborne, Franklin, Jefferson, and Wilkinson.

BROOD XXIII—*Tredecim*—1911. (Fig. 26.)

This is Brood No. 5 of Fitch, Brood V also of Walsh-Riley, and Brood VII of Riley. There are two large 13-year broods, which honor Brood XXIII divides with Brood XIX. As indicated by Mr. Schwarz in Circular No. 30, both of these broods occupy the Mississippi Valley from northern Missouri and southern Illinois to Louisiana; but while Brood XIX occurs also in many other localities, Brood XXIII is confined more strictly to the Mississippi Valley region. At the time of the recurrence of this brood in 1898 a very careful investigation was undertaken by the writer of its distribution.

Several thousand replies were received in response to a circular

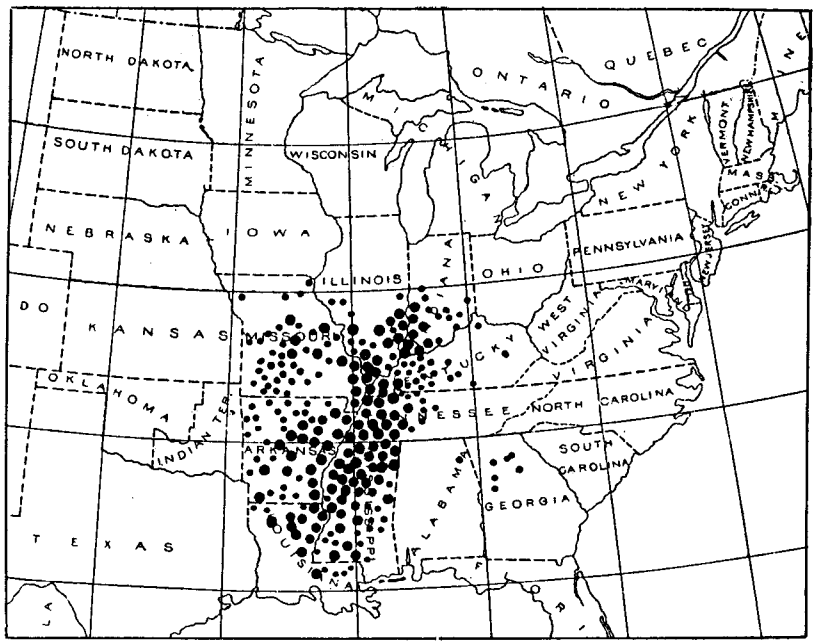


FIG. 26.—Map showing distribution of Brood XXIII, 1911.

sent out, many of which were negative, the investigation being extended throughout all States in which there was any likelihood of the appearance of the Cicada, and necessarily covering many counties and districts where the Cicada was not suspected. Local investigations were also undertaken by the official entomologists in several States, Professor Forbes adding four or five new counties for Illinois, Professor Garman adding six counties for Kentucky not previously reported, all in the eastern end of the State, and Professor Stedman adding one new county from Missouri. In all three of these reports our own records were confirmed for nearly every county. The results of this canvass up to June 20 were recorded in Bulletin No. 14

(new series), Division of Entomology, in an appendix. A large number of replies were received subsequent to that date, and the full report, with corrected list of localities, was published in Bulletin 18 (new series), pages 61–63. The State and county records given below are reproduced from this final report.

The reports for 1898 nearly all indicate the occurrence of the insect in enormous numbers. Unfortunately, however, there enters again with the records of this year some doubt as to the correct reference of some of the localities in Illinois, Indiana, and perhaps northern Missouri, or, in other words, where the territory occupied by the two races overlaps on account of the scattering presence of Brood VI. In most of the records assigned to Brood XXIII, however, in the States mentioned, the evidence points pretty strongly to the accuracy of the reference. Where there is uncertainty a query follows the county.

The counties marked with a star (*) indicate those in which the Cicada occurred in one or more dense swarms, in many cases several reports being received from the same county. In the unstarred counties the Cicada was reported in few or scattering numbers, or at least as not abundant. The counties in italics duplicate old records; the counties lacking confirmation by the records of this year are inclosed in parentheses and incorporated with the others.

The State and county records follow:

ALABAMA.—Etowah.

ARKANSAS.—*Arkansas,** Ashley, Calhoun, Carroll, *Chicot,** Clark,* *Columbia,* Craighead,* Crawford, Crittenden,* *Cross,** *Desha,** (Franklin), Fulton, Garland, Hot Spring, Howard, (Izard), (Jackson), *Jefferson,** Lafayette,* Lee,* Lincoln, Logan, Lonoke,* *Marion, Mississippi,** Monroe,* Newton, *Phillips,** Pike, Poinsett,* *Prairie,** *Pulaski,* Randolph, St. Francis,* *Saline,** (Searcy), Sebastian, Sharp, Union, Van Buren, Washington, Woodruff.*

GEORGIA.—(Cobb, Coweta, Dekalb, Gwinnett, Meriwether, Newton.[a])

ILLINOIS.—*Alexander,** Crawford,* Edgar, Edwards,* Gallatin, Hardin,* *Jackson,** Jasper,* Jefferson, Johnson, Lawrence,* *Macoupin, Madison,** Marion,* *Perry,** *Pike,* Pulaski,* *Randolph,* Richland, St. Clair, *Scott, Union,** Wabash,* *Washington,* Wayne,* White, Williamson.*

INDIANA.—Bartholomew, Daviess,* Fayette, Floyd, Gibson,* Jackson, Jennings, Knox,* Montgomery, Owen, *Posey,** Putnam, Ripley, Spencer, Sullivan,* Vanderburg,* Vigo,* Warrick.*

KENTUCKY.—Ballard,* (Barren?), Butler, Caldwell, Calloway, Carlisle,* Christian, Clinton, Crittenden, Daviess, Fulton,* Grant, *Graves,** Green, Hancock, Hardin, Hickman,* Hopkins, Livingston, Lyon, McCracken, McLean, Marshall, Muhlenberg, Ohio, Todd, *Trigg,** Union, Webster, Wolfe.*

LOUISIANA.—Bienville,* (Bossier), *Caldwell,** Claiborne, Concordia,* *East Carroll,** East Feliciana, *Franklin,** *Madison,** *Morehouse,* Ouachita,* Pointe Coupee,* (Red River), *Richland,** St. Helena, Tangipahoa, Tensas,* (Washington), *West Carroll.**

MISSISSIPPI.—Adams, *Alcorn,** *Amite,** Attala,* Benton,* *Bolivar,** *Calhoun,** *Carroll,** *Claiborne, Coahoma,** *Copiah,** *De Soto,** *Franklin,* Grenada,* *Hinds,** Holmes,* (Issaquena), Itawamba, (Jasper), Jefferson, *Lafayette,** *Lawrence,* Leake,

[a] None of these localities, all of which were queried, was confirmed in 1898, and the record of this brood in Georgia is undoubtedly erroneous.

Lee,* Leflore,* *Lincoln,** Lowndes, *Madison,** Marion, *Marshall,** *Montgomery,** Neshoba, *Newton,* Oktibbeha,* *Panola,** Pike,* Pontotoc,* Prentiss,* *Quitman,** *Rankin,** (Scott), *Simpson, Smith,* Tallahatchie,* *Tate,** Tippah, (Tishomingo), Tunica,* Union,* Warren,* Washington,* *Webster,** Yalobusha,* Yazoo.*

MISSOURI.—*Audrain,** Barry, Benton, *Boone,* Callaway, Camden, *Cape Girardeau,** Cedar, *Christian,* Clark (?), Clinton, Cole, Cooper, *Dade, Dallas,* Dent, *Douglas, Gasconade, Greene, Hickory,* Howell, Iron, *Jefferson, Johnson, Knox,* (Lawrence), Linn, Maries,* Miller, Morgan, *New Madrid,** *Osage,** Ozark, Pemiscot,* *Perry,** *Pettis,* Phelps, *Polk,* Pulaski, Reynolds (?), *St. Charles,** St. Clair, St. Francois, *St. Louis, Scott,** *Taney, Texas, Warren, Washington,** *Webster.*

OHIO.—Hamilton.

TENNESSEE.—*Benton,** *Carroll,** *Chester,** *Crockett,* (Davidson), *Decatur,** *Dickson,** *Dyer,** *Fayette,** *Gibson,** *Hardeman,** Hardin,* *Haywood, Henderson,** Henry,* *Humphreys,** *Lake,** *Lauderdale,** Lewis, *McNairy,** *Madison,** (Maury), Montgomery, *Obion,** Perry,* (Robertson), Rutherford, *Shelby,** Stewart, *Tipton,** Wayne,* *Weakley,** Williamson.

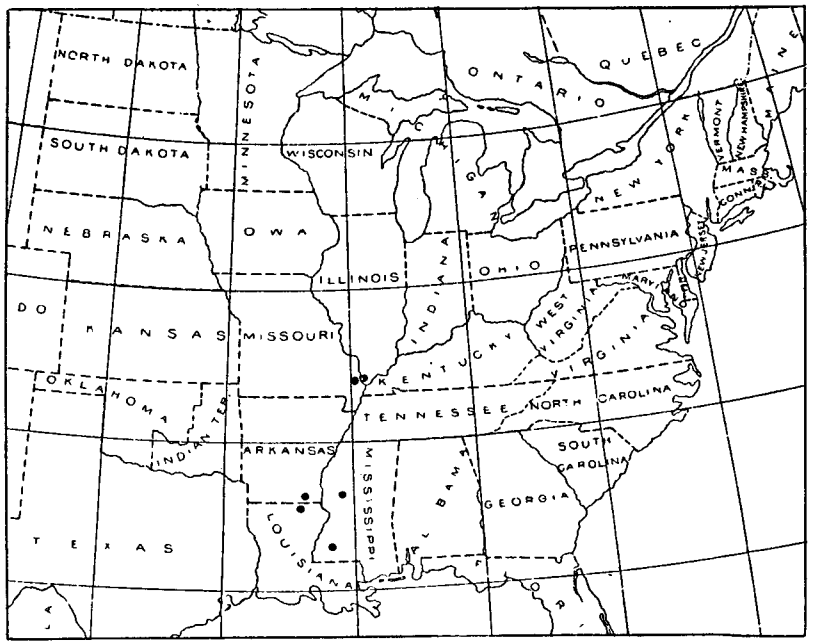


FIG. 27.—Map showing distribution of Brood XXIV, 1912.

BROOD XXIV—*Tredecim*—1912. (Fig. 27.)

This is one of the new *tredecim* broods indicated by the writer in Bulletin 18 (new series) of this Bureau on the strength of the following records:

Mr. P. Lynch, Commerce, Scott County, Mo., under date of December 24, 1874, reports that the Cicada appeared in the summer of 1873 in considerable numbers, coming in June and remaining about two months. "Their eastern limit in this county (Scott) was the Missis-

sippi River, but they were as numerous on the opposite side of the river in Alexander County, Ill."

Mr. W. S. Campere, Pickens Station, Holmes County, Miss., writes under date of February 27, 1875, that the cicadas appeared in great numbers in April, 1873. These two records would indicate a brood originating doubtless by retardation of individuals of Brood XXIII.

Subsequent to the publication of the records for this brood in Bulletin No. 18 (new series) of this Bureau two additional localities have been reported—one in Louisiana and one in Mississippi. Mr. Ben H Brodnax, of Brodnax, Morehouse County, La., reported in 1899 that the locusts first appeared in small numbers on May 2 and lasted only about ten days. On inquiry he found that they were heard scattered about the south Arkansas line (Ashley County) and down to the lower line of Morehouse Parish. No specimens were collected. This report carries the record of this brood into the edge of Arkansas.

Mr. George H. Kent, Meadville, Franklin County, Miss., in a letter of May 30, 1899, reports the appearance of a small brood in the western part of Franklin County between the latter part of April and May 15. Both of these records, as with the earlier ones, are probably from belated swarms of Brood XXIII, but may represent the start of a new brood.

The State and county distribution of the brood is as follows:

ARKANSAS.—Ashley.
ILLINOIS.—Alexander.
LOUISIANA.—Morehouse.
MISSISSIPPI.—Franklin, Holmes.
MISSOURI.—Scott.

BROOD XXV—*Tredecim*—1913.

(No Cicada records of the 13-year race have been reported corresponding with this brood number.)

BROOD XXVI—*Tredecim*—1914. (Fig. 28.)

This brood, No. X of Riley, was originally based on a very doubtful record given by Dr. Gideon B. Smith, to the effect that he was informed that the insect appeared in vast numbers in parts of Texas in 1849, but that he was unable to get any particulars. No confirmation of the occurrence of this brood in Texas has since been gained, and its existence is very doubtful. A more definite record was secured, however, by Professor Riley in 1875, from Dr. D. L. Phares. A gentleman reported to the latter that a swarm of cicadas was heard on the 10th of June in West Feliciana Parish, La., near the river and south of Bayou Sara. Some specimens were secured of this brood, all dwarfs. No other record seems to have been secured of this brood until the year 1901. In that year the occurrence of the brood in West Feliciana Parish was confirmed, locusts being reported by Mr. John

F. Griffin, of Wakefield, as occurring in small numbers throughout the parish between the 5th and 25th of May. An outpost in Mississippi is also reported by Mr. George H. Kent, Suffolk, Franklin County, who reports their appearance throughout the southwestern portion of the county in the month of May.

The records for this brood, therefore, are:

LOUISIANA.—West Feliciana Parish.
MISSISSIPPI.—Franklin County.
TEXAS.—(?).

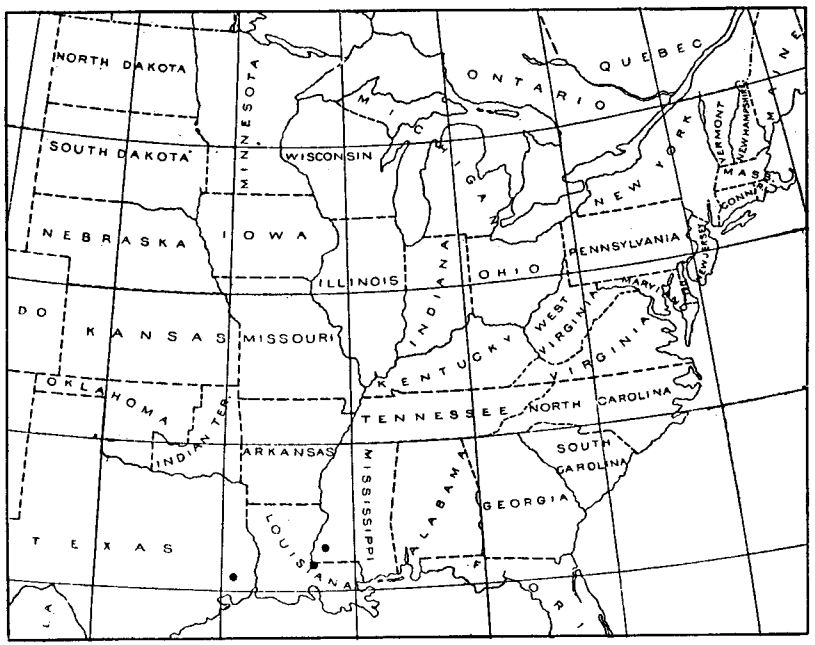


FIG. 28.—Map showing distribution of Brood XXVI, 1914.

BROOD XXVII—*Tredecim*—1915.

A small brood was reported for Franklin County, Miss., as appearing about May 20, 1902, by Mr. George H. Kent, of Suffolk.

BROOD XXVIII—*Tredecim*—1916.

(No Cicada records of the 13-year race have been reported corresponding with this brood number.)

BROOD XXIX—*Tredecim*—1917. (Fig. 29.)

Two records which can be assigned to this brood number were reported by the writer in Bulletin 18 (new series) of this Bureau.

Mr. C. J. Wellborn, Blairsville, Union County, Ga., writes under date of June 12, 1885, that "in May, 1878, locusts appeared south

of this place, and the northern limit then was the present southern limit of the territory covered now (by Brood X, 1885)."

Mr. James Pagon, Winnsboro, Fairfield County, S. C., writes that locusts appeared in South Carolina in 1878, but does not give definite localities. Both these records need confirmation.

A record submitted by the late W. S. Robertson, of Muskogee, Ind. T., in a letter dated June 17, 1879, of the occurrence of a brood of cicadas in 1839 at that point, was assigned, in the publication just referred to, to Brood XV, under the supposition that it probably belonged to the 17-year race. This record falls, however, in territory

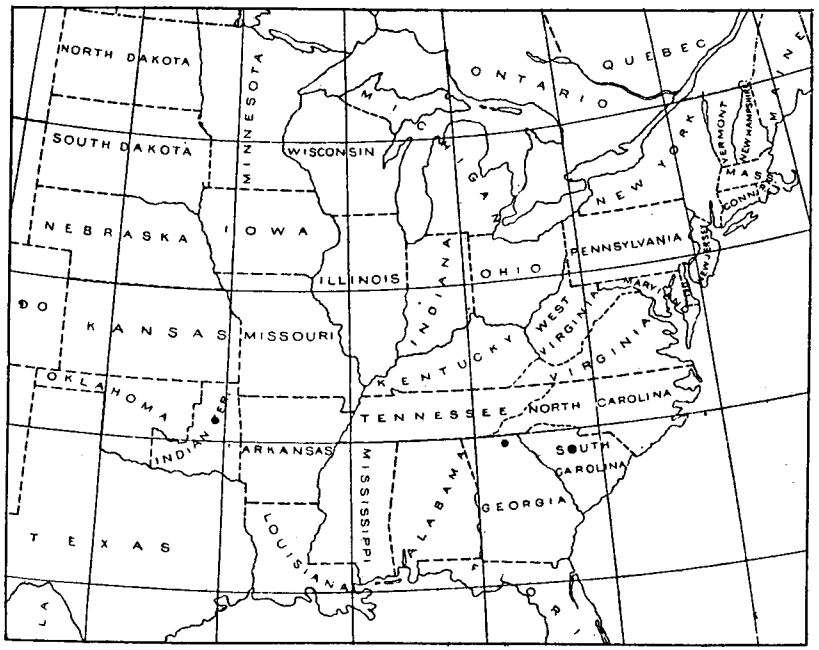


FIG. 29.—Map showing distribution of Brood XXIX, 1917.

which is distinctly 13-year, and would seem to indicate that it belonged rather to Brood XXIX.

The distribution of this brood, by States and counties, is as follows:

GEORGIA.—Union.
INDIAN TERRITORY.—Muskogee.
SOUTH CAROLINA.—Fairfield.

BROOD XXX—*Tredecim*—1918. (Fig. 30.)

This brood was established by the writer on a single record given in Bulletin 18 (new series) of this Bureau. This record follows:

Mr. B. H. Brodnax, Brodnax, Morehouse Parish, La., writes under date of May 13, 1892, that cicadas are scatteringly present, and in a later letter he asserts that the insect in question is the periodical Cicada with which he is familiar.

An addition to this record was received in 1898 in a postal from Mr. J. W. Seaton, Strasburg, Cass County, Mo., who reports that they appeared there in the summer of 1892, as they did also in 1896 (Brood XXI), being numerous both years.

The State and county records are:

LOUISIANA.—Morehouse.
MISSOURI.—Cass.

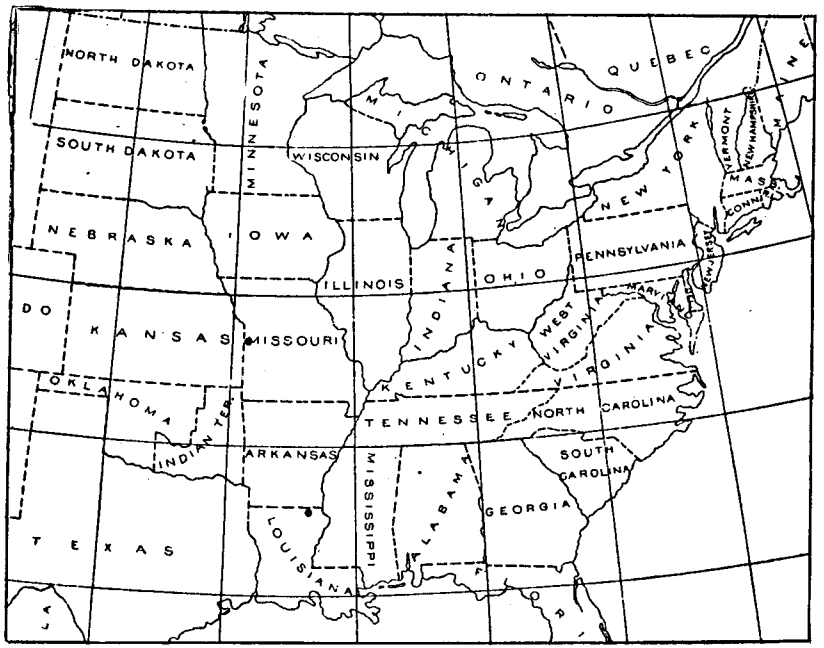


FIG. 30.—Map showing distribution of Brood XXX, 1918.

SYSTEMATIC POSITION AND STRUCTURAL DETAILS.

The periodical Cicada belongs to the Homoptera, one of the two divisions of the Hemiptera, or great order of sucking insects, familiar to the public mind under the name of "bugs," and including, in addition to the graceful and attractive species like the Cicada, such foul-smelling species as the plant bugs, squash bugs, and certain animal parasites. The members of the suborder Homoptera, to which the Cicada and its allies belong, are, however, distinctly removed from the lower suborder of "bugs" just referred to, namely, the Heteroptera, and as a rule lack the disgusting odor and habits of the latter and less esteemed suborder of sucking insects. The Homoptera as a rule comprise clear-winged insects, which subsist on the juices of

plants, and are active usually in flight and often beautiful in form and color. The cicadas are not only the largest and most striking insects of their suborder, some of the species measuring over 6 inches in expanse of wings, but in the male sex are endowed with the power of song, which last characteristic has invested them with great popular interest in all ages; and especially in the poetry of nature are they noteworthy, from the time of Homer to the present.

The old genus Cicada is represented by species in all parts of the world, over five hundred distinct forms being already known, and they are especially abundant in North America, nearly one hundred species having been described from the continent and adjacent islands. The more familiar of these insects to the popular mind are the common dog-day cicadas, or harvest flies, represented by several species, the most abundant of which is, perhaps, *Cicada tibicen* L. (*pruinosa* Say). The sleepy droning of these annually appearing species in July and August is commonly taken as a harbinger of greater heat and is a most familiar characteristic of midsummer.

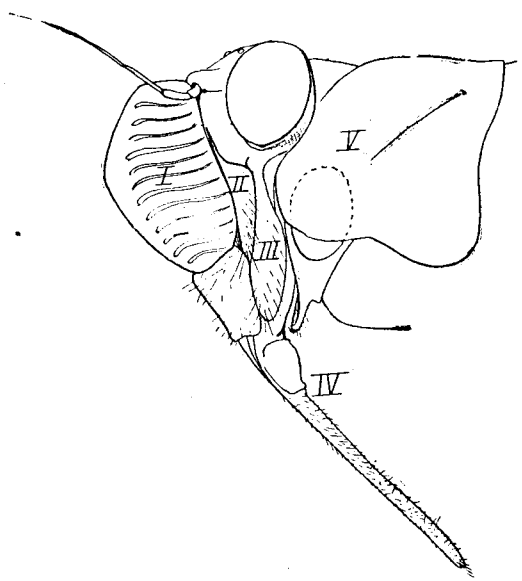


FIG. 31.—Head and prothorax of Cicada, lateral view, showing parts in normal position. For description, see fig. 33. (Author's illustration.)

The periodical species is much more slender and graceful than the majority of the annual visitors, but structurally is not very dissimilar. It is medium sized, for the most part black in color, with orange-red eyes and limbs, and with the margin of principal veins of the four nearly transparent wings similarly colored.

In discussing the structure of this insect particular attention will be given only to the important organs, viz, those for taking food, or the beak, the instrument for piercing plants and depositing eggs, or the ovipositor, and the organ of song in the male insect.

A cursory examination of one of these insects from above reveals its rather robust body, covered by two pairs of transparent parchment-like elliptical wings, which rest roof-like over the abdomen; the short transverse head, with great oval prominent eyes at the lateral angles, the three minute ocelli arranged in a triangle on top, and the very

short, thread-like antennæ projecting between the compound eyes. Viewed from beneath, the triangular prolongation of the head into the three-jointed beak it to be noted; the legs, not especially large or strong except for the anterior femora, which are much thickened; in the female the complex instrument for the deposition of eggs projecting from a fissure or slit in the lower surface of the abdomen, and the blunter abdomen of the male without the fissure beneath, but with two large ventral plates at the base of the abdomen covering the sounding disks of the vocal apparatus. The latter is located on either side of the base of the abdomen and appears as two inflated ribbed drums of lighter color than the general body surface.

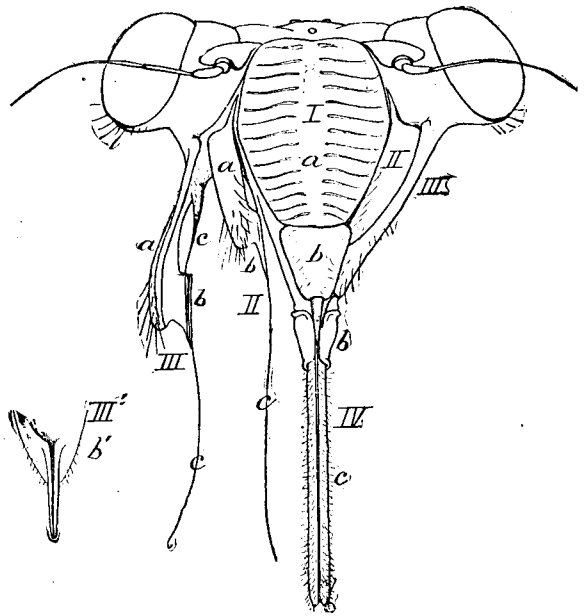


FIG. 32.—Head of Cicada, front view, showing the normal position of mouth parts on the left, and with the mandible and maxilla drawn out on the right. For description, see fig. 33. (Author's illustration.)

The structure and workings of the more important organs, namely, the beak, the ovipositor, and the vocal apparatus, follow in some detail.

THE MOUTH PARTS, OR BEAK.

In the order of insects to which the periodical Cicada belongs it is possible to trace all the essential parts, though vastly modified, found in the mouth of true biting insects, namely, the upper lip (labrum), the main pair of jaws (mandibles), the second, or lower, pair of jaws (maxillæ), and, beneath, the lower lip (labium). Within also are the two tongues, one projecting from the roof of the mouth

(epipharynx) and the other (hypopharynx) attaching to the upper base of the lower lip. These tongues are short and of service, probably, in facilitating the suction necessary in raising the fluids of the plant to the mouth. They do not extend beyond the mouth cavity, and never enter the plant tissues.

The upper lip is comparatively short, and serves its normal purpose as a covering for the adjacent parts of the mouth. What correspond to the short, powerful biting jaws of gnawing insects are in the Cicada greatly elongated and thread-like, and brought together to form a sort of piercing and sucking apparatus, which is inclosed in the greatly elongated lower lip. The latter is three-jointed and deeply grooved

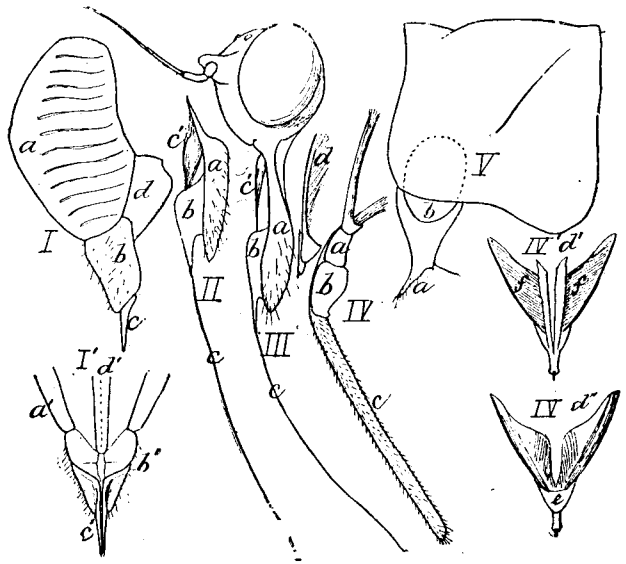


FIG. 33.—Head and prothorax of Cicada, lateral view, with parts separated to show structure: I, *a*, clypeus, *b* and *c*, labrum, *d*, epipharynx; I′, same from beneath; II, mandible, *a*, base, *b*, sheath for seta, *c*, mandibular seta, *c′*, muscular base of latter; III, maxilla with parts similarly lettered; IV, labium, with three joints as follows, *a*, submentum, *b*, mentum, *c*, ligula; the hypopharynx is shown at *d*, from side, *d′*, from above, and *d″*, from beneath; V, prothorax. (Author's illustration.)

above so as to be almost tubular, and acts as a support and sheath for the piercing seta-like jaws, and also assists in conveying the liquids from the point of contact with the plant to the mouth cavity. The long lower lip just described is the piercing beak in popular belief, yet in point of fact it never enters the tissues of the plant, the puncture being made solely by the fine, stiff, needle-like jaws or setæ, which can be projected at will by the insect with great force from the tip of the beak. (See figs. 31, 32, 33, and 34,*a*.)

The feeding habits of the adult Cicada are discussed on pages 101–102. The main feeding is, however, during the long adolescent period, comprising the larval and pupal existence of the insect under the soil,

when the taking of food is a constant feature. The structure of the mouth parts in these preliminary stages is identical in essentials with that of the adult, and the characteristic features are illustrated in the foregoing figures with subjoined explanations.

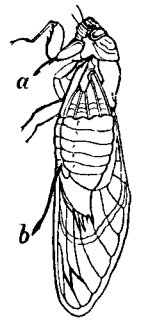


FIG. 34.—The periodical Cicada: Side view of female to show beak, *a*, and ovipositor, *b*. (After Riley.)

In the taking of food by the larvæ and pupæ, as they rest on the rootlets in their earthen cells, the tip of the beak, namely, the lower lip, is brought to bear on the root, and by alternating longitudinal thrusts of the setæ, especially the upper pair, which are the stronger and which represent the great jaws or mandibles of biting insects, the soft, succulent layers of the cambium beneath the bark are reached, the slender setæ being supported, strengthened, and directed by the stronger and encircling sheath-like lower lip. The irritation caused by this puncture induces a flow of sap, which passes up between the setæ to the lower lip and within this along the basal portion of the setæ into the mouth or throat by suction, as in higher animals.

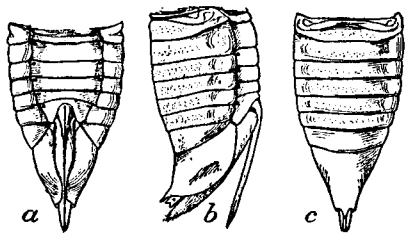


FIG. 35.—Abdomen of female Cicada showing ovipositor and attachments: *a*, ventral, *b*, lateral, and *c*, dorsal view. (Author's illustration.)

THE OVIPOSITOR.

The ovipositor (fig. 34,*b*; fig. 35), or twig-piercing and egg-laying organ, of the female Cicada is also a very complex instrument. It issues from a groove, or fissure, on the underside of the abdomen, and at rest is nearly concealed except at the tip by the broad overlapping sides of the eighth dorsal segment. The ovipositor proper is protected and covered when at rest by two valves, which form a sort of sheath, or scabbard. The inclosed ovipositor is a very tough, horny instrument, spear-shaped, and serrated at the extremity, and consists of three pieces, namely, a back portion (probably two pieces grown together), which acts as a supporting or connecting piece for the two lateral blades. These lateral pieces, or blades, slide up and down in alternation on tongues projecting from the cen-

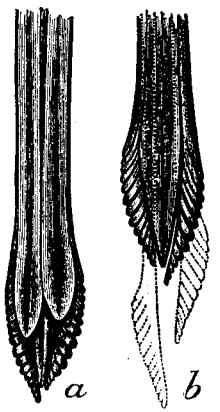


FIG. 36.—Tip of ovipositor of Cicada, much enlarged: *a*, from above, *b*, from beneath, with dotted portion to show the alternating motion of the side pieces. (Author's illustration.)

tral or supporting piece, have serrated cutting edges, and are the chief agents in piercing twigs preparatory to the deposition of eggs (fig. 36). The relative position of the three parts of the ovipositor and the nature of the locking tongues, grooves, and clasps, which make one tube of the whole, are illustrated in the accompanying cross sections (fig. 37).

The different pieces of the ovipositor attach to flat plates partly concealed within and attaching to the wall of the abdomen, and are operated by powerful muscles both in making incisions in the twigs and in passing the eggs from the oviduct (which opens at the base of the ovipositor) through the tube formed by the three parts of the instrument, until they reach their final lodgment in the twig. The act of oviposition will be described in another place.

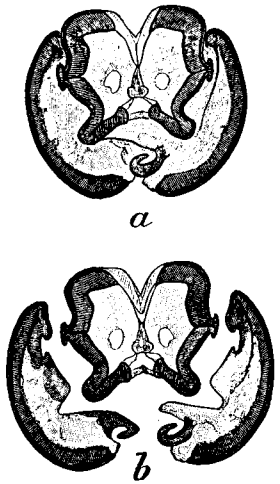


FIG. 37.—Cross section of ovipositor of Cicada: *a*, with parts attached in natural position; *b*, separated to show interlocking tongues and grooves. (Author's illustration.)

THE MUSICAL APPARATUS.

Perhaps the most interesting feature of the anatomy of the Cicada to the popular mind is the musical apparatus, by means of which it makes its peculiar note, or song. This apparatus and the sounds produced by its possessor have been studied and described by many naturalists, beginning with the very earliest, and, in fact, the fullest and most accurate description of the method of of producing sounds and the anatomical structure of the vocal organ in these insects is the one given, early in the last century, by that famous French pioneer in the study of the biology and anatomy of insects, Réaumur.[a]

The work of Réaumur was confirmed and added to a hundred years later by a most painstaking study of living specimens by another French student, Solier,[b] and for a minute technical description of the anatomy and workings of the sound apparatus the reader is referred to these authors.

The special modification and structure of these parts in our periodical species have been studied by the more important older writers, as Potter and Smith, and more recently by W. J. Burnett[c] and E. G. Love.[d]

[a] Histoire des Insects, Vol. V (1740), pp. 158–170, pl. 17.
[b] Ann. Soc. Ent. France, 1837, Vol. VI, pp. 199–217.
[c] Proc. Bost. Soc. Nat. Hist., 1851, Vol. IV, p. 72.
[d] Journ. N. Y. Micros. Soc., 1895, XI, pp. 39–42.

As already noted, the gift of song is found in the male insect only, and the true sound apparatus consists of two small ear-like or shell-like inflated drums situated on the sides of the basal segment of the abdomen. These drums are caused to vibrate by the action of powerful muscles, and the sound is variously modified by adjacent smaller disks—the so-called "mirrors" or sounding boards—and issues as the peculiar note of the species, which once heard is never likely to be forgotten, or, if heard again, mistaken for that of some other insect. The true sound organs are entirely exposed in the periodical Cicada except for the covering afforded by the closed wings of the resting insect. In other cicadas these drums are usually protected by overlapping valves or expansion of the body wall.

The sounding drum, or "timbal," as Réaumur termed it, of the periodical Cicada is a tense, dry, crisp membrane numerously ribbed or plated with the convex surface turned outward. The ribs are chitinous thickenings or folds in the surface of the parchment-like drum, and strengthen the drum while perhaps rendering it at the same time more elastic. The sound is produced by the rapid vibration, or undulation, caused by the springing or snapping in and out of these corrugated drums. Two powerful muscles of very peculiar structure situated within the base of the abdomen set these drums in motion, producing the rattling so-called song of the Cicada, very much, as has been suggested, as sound is produced by pressing up and down the bottom of a tin pan which is somewhat bulged.

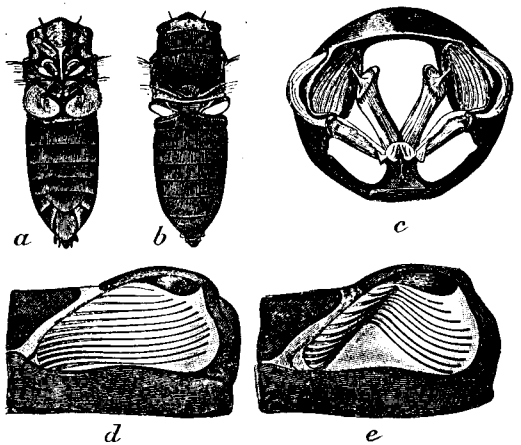


FIG. 38.—The musical apparatus of the periodical Cicada: *a*, view from beneath, showing the plates (light colored) covering the sounding disks; *b*, dorsal view, the timbals showing as light-colored areas; *c*, section at base of abdomen, showing attachment of large muscles to timbals; *d*, timbal greatly enlarged, in normal position; *e*, same drawn forcibly in by the action of one of the muscles, as in singing. (Author's illustration.)

Beneath each "timbal" in the base of the abdomen of the insect is a large sound or air chamber, and a third occurs in the thorax joining the first two. These are closed by the body walls and membranes, and the two abdominal ones beneath by the very peculiar "mirrors," or "spectacles"—the tense, mica-like membranes situated at the base of the abdomen and protected and covered by the semicircular rigid disks projecting from the thorax. These transparent

membranes are often mistaken for the true sound organs, but they are rather sounding boards, or drums, to increase and transmit the sound vibrations induced by the play of the timbals. That they are not essential to the production of sound can be shown by slitting them or removing them altogether without there being any cessation of the note. Much more important modifiers of sound are the semicircular disks projecting from the thorax over the "mirrors," which, if closed artificially or by the insect, deaden the sound very much, or if opened or cut off, allow it to escape in greater volume. In singing, also, the insect modifies the song notes and their volume by raising and lowering the abdomen, thus opening and closing these disks, and the act of singing is also accompanied by a sort of trembling of the thorax. The position assumed by the male when singing is always with the head upward. The abdomen is then elevated and apparently inflated, and with the beginning of the sound is slowly brought down against the limb, when the note ceases. After a rest of a few seconds this operation is repeated. These abdominal movements vary in different species of Cicada and determine in a measure the peculiar notes of each.

THE SONG NOTES OF THE PERIODICAL CICADA.

The song of the different species of cicadas is very distinctive, and one familiar with the music of these insects can as readily recognize the particular species by its peculiar notes as one knows the different birds or mammals by theirs. The general character of the notes of the periodical species has been thus described by Dr. G. B. Smith:[a]

> The music or song produced by the myriads of these insects in a warm day from about the 25th of May to the middle of June is wonderful. It is not deafening, as many describe it; even at its height it does not interrupt ordinary conversation. It seems like an atmosphere of wild, monotonous sound, in which all other sounds float with perfect distinctness. After a day or two this music becomes tiresome and doleful, and to many very disagreeable. To me it was otherwise, and when I heard the last note on the 25th of June the melancholy reflection occurred—shall I live to hear it again?

As one approaches a colony of these insects a peculiar roar, not unlike the noise of a factory or a distant reaper, falls on the ears, and this becomes louder and more intense as one draws nearer, having at times to one standing in the midst of a colony a peculiar all-pervading and penetrating effect. The individual notes are somewhat obscured under these circumstances, but in the lulls the characteristic sounds strike the ear, and the peculiarity is never to be forgotten, especially the mournful falling note at the conclusion of each effort. Nearly all the principal writers on the Cicada, and notably Potter, Smith, and Fitch, have attempted to analyze the song note of this insect,

[a] Scientific American, March 22, 1851.

but the most careful study made is that by Professor Riley,[a] who distinguishes three important notes as characteristic of different seasons or conditions of the aerial life of the male insect.

The loudest and most characteristic note, and the one which is perhaps most familiar to the popular mind, is the note described by Fitch as "represented by the letters tsh-e-e-E-E-E-E-e-ou, uttered continuously and prolonged to a quarter or half minute in length, the middle note deafeningly shrill, loud, and piercing to the ear, and its termination gradually lowered until the sound expires." The length of this note given by Fitch is probably the maximum term and is unusual. Ordinarily it is much shorter, ranging from two or three to five or ten or even twenty seconds. This note is the characteristic one of the height of the season, when great numbers of males are singing together, and is rarely made by solitary individuals or when there are only a few together. Some instinct also seems to prompt the singing in unison, and as it rises at such moments the intensity and volume of sound has a startling and weird effect.

The second important note is what is ordinarily known as the "Pha-r-r-r-aoh" note, and is made early in the season, or when the males are few in number and recently emerged. The termination of this note is notable even more than the last for its peculiar mournful cadence and lowering of pitch, which is very characteristic. It lasts but two or three seconds. It has been compared, rather fancifully, I think, by Professor Riley to the whistling of a train passing through a short tunnel, or, when made by several individuals, more accurately to the croaking of certain frogs.

A third, but less important, note is the clicking or intermittent chirping, consisting of from 15 to 30 short, quick sounds, sometimes double, the whole lasting about five seconds, and resembling the sharp clicking of the chimney swift or some of the field crickets.

When disturbed and at the moment of taking flight the insect is apt to make a short cry or sharp chirp.

All of these notes are said to occur in the small *cassinii* form, but of higher pitch and less volume, but the clicking note seems to be the characteristic one of this variety.

The strength and clearness of all the notes vary with the weather conditions. They are loudest when the air is dry and warm and clear, or between the hours of 11 and 3 o'clock. On wet days, or when the air is unusually moist, the sound is much diminished, and heavy or continued rains stop it for the time altogether.

While it is almost universally true that the song of the Cicada is never heard between sunset and sunrise, they will, on very rare occasions, when disturbed, start up singing in concert in the middle of

[a] Science, September 25, 1895.

the night. Prof. A. D. Hopkins noted an instance or two of this kind in connection with the brood of cicadas appearing in West Virginia in 1897. He says:

> I was fortunate enough to hear the starting of one of these concerts on a clear, moonlight night in June. One male in an apple tree near the house suddenly called out as if disturbed or frightened. His neighbors in the same tree were thus apparently awakened. One started the familiar song note, which was at once taken up by numbers of other males, and, like the waves from a pebble dropped into still water, the music rapidly spread until it reached the edge of the thick woods, where it was taken up by thousands of singers, and the concert was in as full blast as it had been the previous day. This continued a few minutes, until all had apparently taken part and the song had reached its highest pitch, when it began to gradually subside, and in a short time silence again prevailed.

THE SO-CALLED STING OF THE CICADA.

With every general outbreak of this insect are associated many accounts in local papers of its stinging human beings, the sting often resulting, it is stated, more or less seriously to the person stung. Such accounts were especially abundant in the great Cicada year 1868, and in every important Cicada year before and since similar reports have been made. So great was the fear in 1868, as noted by Professor Riley, that in some cases fruits were avoided as being stung and poisoned, and even drinking water was sometimes under suspicion.

So far as investigation of the reports has been possible they have proved to be either utterly without foundation or much exaggerated. Referring again to Doctor Smith's manuscript, it is seen that he spent much labor in carefully investigating such accounts, and found in every case that he followed up, where death had been reported as caused by the "bite" or sting of the "locusts," that the story was entirely fabulous. In the cases of apparent stinging he suggests that the sufferer had probably been stung by a wasp, as will be later explained, and soundly argues on the susceptibility of some people to whom the slightest scratch becomes a source of danger.

Professor Potter, referring to the Cicada, says in this connection: "It can not defend itself against an ant or a fly. We have handled them, male and female, time after time. We have mutilated them, but never could provoke them to resentment."

Professor Riley says that of the thousands which he has handled, and the hundreds of other persons, including children, who have also handled these insects, not a single bona fide case of stinging has, to his knowledge, resulted.

That the periodical Cicada can pierce the flesh with its sucking beak, or, more properly, the fine needle-like filaments contained in it, or perhaps extremely rarely with the ovipositor in the case of the female, is quite within the bounds of possibility, and some apparently well-authenticated cases or reports by reliable observers bear out this view.

There is not a particle of evidence, however, to show that such penetrating is attended with the injection of any poisonous fluid, and the injurious consequences which follow them in rare cases are evidently due to unusual sensitiveness on the part of the individual, as suggested by Doctor Smith, or a bad condition of the blood, which would cause any wound to be attended with serious consequences. In this connection it is to be remembered that there are well-authenticated instances of most serious, if not fatal, results following the bites of such insects as the mosquito, and other biting flies, the result of the bites of which are very trivial in common experience.

With all the reports of stings by the Cicada which have been made it is not to be questioned that some of them have a basis in fact. As suggested by Doctor Smith, and afterwards fully elaborated by Doctor Walsh,[a] many of these reports are undoubtedly cases of wrong determination, and the stinging had probably no direct connection with the Cicada. There are, for example, several large digger wasps which provision their larval galleries with adult cicadas for the maintenance of their young. One of the commonest of the digger wasps is the species *Sphecius speciosus* Dru., described later on under the heading of the enemies of the Cicada (pp. 132–134). As first suggested by Doctor Smith, and afterwards more fully shown by Doctor Walsh, it is not unlikely that this or some allied wasp, flying with its rather heavy burden, might strike against or alight on some human being, and upon being brushed off would retaliate by stinging the offender and then flying away, leaving the Cicada behind. In the absence of the wasp the Cicada would very naturally be accused of the offense. The usual prey of this wasp, which appears rather too late in the season to account for all the cases of stinging reported, is the later appearing annual cicadas.

The rare cases of stinging by the Cicada that have any basis in fact may be accounted for, as already suggested, by a thrust either of the ovipositor or the sucking beak.

From the structure of the ovipositor, as already described, it will at once be perceived that there is nothing impossible in a wound being made by this instrument. The objections to this suggestion are that the ovipositor when not in use in placing eggs in twigs is concealed in a sheath in the insect's abdomen, and also that the piercing of a twig or other substance by the ovipositor is a slow and laborious process, and therefore would not account for the quick sting usually described. In no case has an egg been found in the flesh, and in fact it is improbable that an insect would be allowed to rest long enough on the flesh to accomplish the insertion of an egg. Furthermore, tests were made and reported by Doctor Walsh[b] and later by Professor Riley, showing

[a] American Entomologist, I, pp. 7, 8, September, 1868. [b] Loc. cit.

the absurdity of the theory that the stinging in question is done by the aid of this instrument, the female not being able to puncture the soft, yielding flesh at all. In one test reported by Professor Riley, Mr. William Muir, of St. Louis, removed a female from a tree while she was in the act of ovipositing, and placed her on his finger. Although she instinctively endeavored to continue her work, she was not able to make the least impression on the soft, yielding flesh. A second experiment was made by Mr. Peter A. Brown, of Philadelphia, who himself made several punctures upon his hand with the ovipositor without experiencing any more serious results than would have followed pricking with a pin or other sharp instrument. In a third experiment, Doctor Hartman, of Pennsylvania, introduced some moisture from the ovipositor into an open wound and it caused no inflammation whatever.

The ovipositor having been removed as the probable source of stinging, the beak only remains, and it is unquestionably by means of this instrument that practically all the so-called stings of the Cicada are made. The structure of the beak has already been discussed, and it is not at all improbable, though certainly a rare occurrence, that the Cicada, when held or caught, may thrust out the slender setæ and puncture the skin. Many other hemipterous insects are known to "sting" in this way and to cause some severe momentary pain. The sensitiveness of the individual is, however, in the case of the Cicada, the sole criterion of injury. The authentic reports of Cicada stings show some variations in the effects, but as a rule the result is much less serious than the sting of a bee and not much more than the puncture of a needle, the wound usually healing immediately.

TRANSFORMATION TO THE ADULT STAGE.

PERIOD OF EMERGENCE.

The date of the issuing of the cicadas from the ground after their long concealment varies a little with the latitude, being later in the North than in the South. In the accounts of this insect published by Professor Riley and most other writers up to the present time it has been stated that there is very little divergence in the time of issuing between the northern and the southern broods, the latter half, or more strictly the last week, of May being the normal period for the emergence of the insect throughout its range. That there may be, however, a considerable difference in time, depending on elevation and temperature, in a given district and in the northern and southern parts of the country, also determined undoubtedly by temperature, has been fully established. The variation in the dates of appearance is illustrated by the following records:

Doctor Phares, writing of the occurrence of Brood XXII in 1871, states that a few males began to appear about the 20th of April, but that the bulk of the brood did not emerge until the 7th and 8th of May, when they came forth from the earth in vast numbers, continuing to emerge in diminishing numbers until the 18th of May. It will be remembered that this is the most southern of all the broods—lying in the southwest corner of Mississippi and the adjoining parts of Louisiana.

Mr. John Bartram, writing of the brood appearing in 1749, states that in the neighborhood of Philadelphia an abundance of these insects which had just escaped from their skins was observed on the morning of May 10 and that they continued to issue in great numbers for a week or more, beginning to sing on the 13th and to oviposit on the 16th, and disappearing altogether by the 8th of June.

In the great brood year of 1868 Professor Riley noted that in the vicinity of St. Louis "they commenced to issue on the 22d of May, and by the 25th of the same month the woods resounded with the rattling concourse of perfect insects." At Washington, D. C., in the Cicada year 1885, scattered individuals appeared on May 23, and they issued, perhaps, most abundantly on the night of the 27th. Those emerging within the city were somewhat earlier in appearance than was the case in the neighboring woods across the Potomac in Virginia, probably for the same reason that the trees in the city put out their foliage a little earlier than in the near-by woods.

Mr. Davis, writing of Brood II as it appeared in 1894 on Staten Island, New York, says that as early as May 19 many cicadas had emerged, the first individuals of the swarm being noted six or seven days earlier.

Mr. A. W. Butler, writing of the brood appearing in 1885 in Franklin County, Ind., says that while in a few localities individuals were seen as early as May 28, in other places not distant they did not emerge until June 4, and later.

Mr. Hopkins made a careful study of the dates of emergence in West Virginia in 1897 in connection with Brood V, and found very considerable variation in time of appearance both between the northern and southern borders of the brood and between the lowest and highest elevations within the area covered by the brood. For the former a difference of nearly two weeks was indicated by the records, and for the latter a difference of nearly four weeks. This variation, he says, appears to be due to the difference of climate between the northern and southern sections and between low and high elevations, in the former case amounting to $3\frac{1}{2}$ degrees and in the latter to over 10 degrees in average summer temperature. He deduces from his observations, as a general rule, that there is about three and one-half days difference in the time of the first general appearance of the Cicada for

each degree of difference in the average summer temperature, whether it be due to latitude or elevation.[a]

An interesting case of artificial acceleration in the appearance of these insects is recorded by Professor Riley as follows: Dr. E. S. Hull, of Alton, Ill., having placed some underground flues for forcing vegetables, the unnatural heat caused the cicadas to emerge by the 20th of March and from this time on until May. Other instances of acceleration are given in the discussion of the subject of retardation or acceleration in times of appearance as an explanation of the formation of the different broods. (See p. 24.)

Notwithstanding the difference in time of emergence in the above citations, the fact nevertheless remains true of the great uniformity evidenced in the time of emergence, namely, the last week in May, for the great bulk of the territory covered by the different broods of the Cicada, and this fact is one of the noteworthy features in the life history of the insect.

The males precede the females by several days and disappear earlier in the summer, both by reason of being shorter lived and also on account of their earlier appearance, so that it often happens that while the woods are still filled with females actively engaged in ovipositing, the males are altogether absent and their songs are unheard.

DURATION OF THE ADULT STAGE.

Under normal conditions the Cicada remains in evidence in the woods five or six weeks, occasional individuals occurring later, but as a rule their disappearance is almost as sudden as their appearance and is complete in the first weeks in July. Mr. Butler, writing of the 1885 brood in Indiana, says that twenty-three days after the appearance of the Cicada a perceptible decrease in numbers was observed, chiefly from a disappearance of the males. On July 15, nine days after they had disappeared from the river valley districts, they were still abundant and active in more elevated situations. Mr. Davis, writing of the brood of 1894 on Staten Island, says that by the third week in June the cicadas commenced to die of old age, and yet the males were still singing and the females were abundant in certain localities as late as the 8th of July, while by the 15th of the same month all had disappeared.

Mr. Hopkins found on the hills near Morgantown, W. Va., that the dates of the Cicada appearance were about normal, the first adults appearing on May 20, the first general appearance not coming, however, until the 24th. Cold weather intervening, there was a subsidence again until the 30th, when they emerged again in enormous

[a] Bulletin 50, W. Va., Agric. Exp. Station, p. 17.

numbers. Oviposition began on the 13th of June, and by the 17th of the month the leaves on the wounded twigs commenced to wither. All had disappeared by the 4th of July.

METHOD OF EMERGENCE.

In escaping from the soil the pupa burrows directly upward, but not always in a straight line, and under normal conditions emerges directly, leaving a small round hole about the size of a man's little finger. While it is generally true that they do not pierce the surface at all until they are ripe for transformation, they seem to have a frequent habit of penetrating nearly to the top of the ground some time before they actually issue and remaining usually within their burrows or sometimes emerging, but concealing themselves under logs, stones, etc., awaiting the proper moment to come forth. Usually throughout the month of April they are to be found thus near the surface, as has been recorded by many observers.

On the authority of Professor Potter the 10th of April is usually the date for their appearance near the top of the ground. Here they are often discovered by hogs and eaten with avidity, their holes coming within a quarter of an inch of the surface and penetrating downward from 6 to 12 inches.

CICADA HUTS, OR CONES.

Under special or peculiar circumstances, not always easily explainable, the Cicada pupæ construct little cones, or chimneys, of earth above the surface of the soil, continuing and capping their holes, several weeks before the time of issuing. In addition to the names Cicada "huts" or "cones," these curious structures have been variously termed "towers," "roofs," "chimneys," "turrets," and "adobe dwellings."

The earliest reference to them, if the writer mistakes not the significance of the language, and one which has hitherto been overlooked, is by Professor Potter.[a] He refers to the "roofs of their tenements" as being "neatly arched and so firmly cemented that water is never found in them, although all of the surrounding grounds are overflowed and perfectly saturated," and, stating that "the locust is not singular in this provision," he refers, in the same connection, to the crayfish and other shellfish and some insects as building houses along water courses, where the soil is wet, resembling "small chimneys," as a provision against "inundation and drowning."

The first definite account of the Cicada huts we owe to Mr. S. S. Rathvon, of Lancaster, Pa., who described them as occurring in localities where the drainage was imperfect. He says:

[a] Notes on the *Locusta*, etc., pp. 17, 18 (1839).

We had a series of heavy rains here about the time of their first appearance, and in such places and under such circumstances the pupæ would continue their galleries from 4 to 6 inches above the ground, leaving an orifice of egress even with the surface. In the upper end of these chambers the pupæ would be found waiting their approaching time of change. They would then back down below the level of the earth (as at *d*, fig. 39) and, issuing forth from the orifice, would attach themselves to the first object at hand and undergo their transformations in the usual manner.

Professor Riley had the accompanying figure (fig. 39) made from one of the chambers furnished by Mr. Rathvon. This chamber measured about 4 inches in length, with a diameter on the inside of five-eighths inch and on the outside of 1¼ inches.

As will be later noted, the exit hole at the base of the turret in this instance was probably abnormal, the insect issuing, as shown by later observers, almost invariably from a hole clawed through the summit of the cone.

The next instance of the occurrence of these cones of which we have a record is a rather remarkable one, and is given by Prof. J. S. Newberry.[a] These cones appeared in May and June, 1877, in a shallow cellar of a house which had been erected on the site of an old orchard at Rahway, N. J. The cellar had been dug to the depth of about a foot, and had been closed until about the time of the emergence of the cicadas, when it was opened and the bottom was found to be thickly beset with mud cones or tubes from 6 to 8 inches high. The explanation for these curious structures suggested by Professor Newberry is that the cicadas, finding a dark chamber, were apparently attempting to work up to daylight. What is probably the true explanation of their occurrence will be given later. An excellent photograph of one of these structures, which considerably exceeds 6 inches in length, accompanies Professor Newberry's paper.

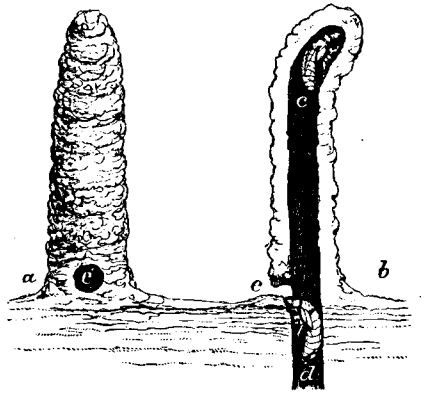


FIG. 39. Pupal galleries of the Cicada: *a*, front view; *e*, orifice; *b*, section; *c*, pupa awaiting time of change; *d*, pupa ready to transform. (After Riley.)

The references cited include all the records of the occurrence of these cones up to 1894. In that year, however, these structures were noticed in many localities in New York and New Jersey on the appearance of Brood II, and excellent opportunities were afforded for their study, advantage of which was taken by several competent observers who were so situated that careful examinations could be made.

[a] School of Mines Quarterly, vol. 7, January, 1886, 2 pp.

PHOTOGRAPH OF CHAMBERS OF THE PERIODICAL CICADA, GENERAL VIEW, TAKEN AT NEW BALTIMORE, N. Y., MAY, 1894. (AFTER LINTNER.)

The results of these investigations have cleared up much of the obscurity which has hitherto surrounded these elevated burrows.

The first person to note these structures in 1894 was Mr. William T. Davis, who reported their occurrence in April on Staten Island, New York, stating that the pupæ had been found on the 8th of that month under boards on the edge of a meadow, where they had been erecting cones of earth above the damp ground. In a later article he says:

> On the 22d of April many pupæ were found in the woods along Willow Brook under stones, logs, and the chips about stumps of trees cut down in winter. Many more were without protection of this kind, and their presence was indicated by the small irregular cones of earth among the dead leaves. A heavy footfall near the cone was sufficient to cause the insects to retreat, but if they were approached silently and suddenly knocked over their constructors would be found within.

Some of the cones were 3 inches high, but they did not average more than 2 inches. The experience of Mr. Davis corroborates the theories of Professor Potter and Mr. Rathvon that the cicada cones, occurring in moist situations, are designed to lift the insect above such undesirable conditions.

Early in the spring of 1894 the attention of Doctor Lintner, the New York State entomologist, was called by correspondents to the occurrence of these cones and an investigation of the subject was undertaken. A preliminary report was published in 1895,[a] but his final report was not published until May, 1897.[b] In describing the phenomenon in his Tenth Report, he says that the cones frequently occurred in many thousands and occasionally hundreds of thousands together, in some cases being intermingled with the ordinary open burrows. At New Baltimore, N. Y., 16 miles south of Albany, as early as the last week in April the pupæ had brought up, apparently from a considerable depth, masses of soft clay-like material and molded it above the ground into conical and cylindrical structures for their temporary occupancy. In places the ground was almost covered with them, as many as twenty-five being counted to the square foot. The cones inclined at a considerable angle from the perpendicular and measured from 2 to $3\frac{1}{2}$ inches in height, and the chamber within was uniform in diameter with the hole in the ground. In emerging the pupa made a round opening in the upper part of the chamber for its escape.

In the Twelfth Report cited, a long list of localities in New York is given where the cones were found in 1894, together with notes on the character of the chambers and accompanying conditions of the soil, and also on the method of their construction. One of the plates illustrating this report is reproduced in this bulletin (see Pl. II). It

[a] Tenth Report Insects New York, pp. 420–423.
[b] Twelfth Report Insects New York, pp. 279–286.

is a reproduction of a photograph of a small area of a cone-covered district.

Two very elaborate accounts of these structures, by Mr. Benjamin Lander and Dr. E. G. Love, were published in 1894–95, the authors seeming very near the actual truth in their explanation of the phenomenon. Mr. Lander describes the occurrence of the cones as noted by him as follows:

On the 4th of May, 1894, while in the woods on the summit of South Mountain, at Nyack, N. Y., I came upon a spot that had recently been burnt over. On this area I observed vast quantities of the Cicada structures, entirely closed, averaging about 2½ inches in height, the aggregation ending at the very edge of the burnt section. So thickly studded was the ground that often eight or ten would be found in the space of a square foot; in one case I counted twenty-three in such a space. Subsequent explorations showed that the Cicada city extended over an area of not less than 60 acres. Eight large aggregations were discovered by me on top of the Nyack hills and the Palisades, covering many acres, and one near a stone quarry at a lower elevation—none of them in a place subject to overflow. Later, when only the ruins of the domes remained, I visited two areas where large numbers had been found, one in ground thinly covering massive sandstone and another hard by a quarry, where the top soil was thin.

The explanation offered by Mr. Lander is that the dome builders, owing to the shallowness of the soil, determined either by the nearness of the underlying rocks or of a subsoil of a character preventing the insects working in it effectively, had responded more quickly to the heat of spring and early summer, and the pupæ coming prematurely to the surface closed and extended their burrows as a means of protection while awaiting maturity. The extension of the gallery above the ground, though not suggested by Mr. Lander, may be explained by the same instinct which impels the insect to burrow upward from its subterranean cell.

In substantiation of his theory, Mr. Lander calls attention to the weather records for March and April, 1894, which indicate an unusually high temperature throughout the region of the domed burrows, causing wild plants to bloom a month before their ordinary season. The occurrence of these structures over burned areas, which would be acted upon more quickly by the sun, supports his belief. Additional support of the same kind is an instance recorded by Prof. J. B. Smith[a] in a letter received from Mr. J. H. Willets, of Port Elizabeth, N. J. The latter states that "On April 24 a fire from the South Jersey Railroad burned over several hundred acres of woodland, leaving the earth bare. Six days afterwards these fresh holes and raised tubes appeared, and yesterday the whole surface was literally covered with them." In further description he says:

Imagine yourself standing out in the woods in south Jersey on 100 acres of recently burned ground with millions and millions of raised tubes of new earth (clay ground)

[a] Annual Report State Entomologist of New Jersey for 1894.

PHOTOGRAPH OF CHAMBERS OF THE PERIODICAL CICADA IN WOODSHED, WASHINGTON, D. C., 1902. (ORIGINAL.)

raised above the surface from 2 to 4 inches and from 1½ to 2 inches in diameter, sealed at the top, with a hole inside extending down in the earth 12 inches at least, * * * and you will see mentally what I saw yesterday physically.

In this instance also, on the authority of Mr. Lander, the turrets ended abruptly at the edge of the burned area. The other instances of these structures cited by Mr. Lander also bear out his theory. As a rule, they were located on rocky cliffs with uniformly shallow soil or in other situations where the soil in which the Cicada could work was shallow. In the midst of one of the largest colonies a deep gully occurred, 300 or 400 feet wide, in which the soil was a deep loam. Here there were no domed burrows, although the hills on either side were covered with them, and yet at the proper season the cicadas appeared in the ordinary way in this gully in almost incredible numbers, leaving their customary small holes of exit even with the surface.

Some confirmatory records were obtained by Mr. Lander in 1898.[a]

The occurrence of these cones, as described by Professor Newberry (p. 92), is confirmatory of this theory, a shallow covering of soil over pupæ of a few inches only being left by the slight excavation made. A similar instance occurred in the District of Columbia in connection with Brood X in 1902, and represented the only occurrence of these structures observed that year in this vicinity. Mr. William Tindall, living on Washington Heights, at the northwest section of the city, discovered some of these curious structures in his woodshed, and an investigation of the premises developed the fact that this woodshed was studded with Cicada cones of perfect construction, varying from 1 inch to 6 inches in height. Evidently a tree had stood about where the woodshed was built, and the cicadas had undergone their development successfully in the ground beneath. All of those coming to the surface outside of the shed escaped through simple holes without any structures above ground, but every individual which came up within the shed built a turret or cone. The ground floor of the shed was somewhat moist, rain running under, but it was rather drier than the ground outside, so that the cones could not have been built on account of the moisture. There had perhaps been a slight removal of surface soil in this shed, bringing the cicadas nearer to the surface and thus leading them to extend their galleries. Plate III is from a photograph taken of the cones as they appeared in the shed, and Plate IV illustrates half a dozen of these cones, nearly natural size, two of which have been cut away to show the interior character of the gallery.

Dr. E. G. Love, who also studied the problem of the Cicada huts very carefully, agrees in the main with Mr. Lander, but differs somewhat in his explanation. As to the conditions of their occurrence, he writes as follows:

[a] Journal of the N. Y. Ent. Soc., Vol. VII, September, 1899, pp. 212–214.

They are found in both wet and dry places; on the low and on the high ground; singly and in colonies of many thousands. One hut, even in a damp soil, may be surrounded by a dozen holes, from which the insects emerge without making any huts, and often where we may expect to find them they are never seen.

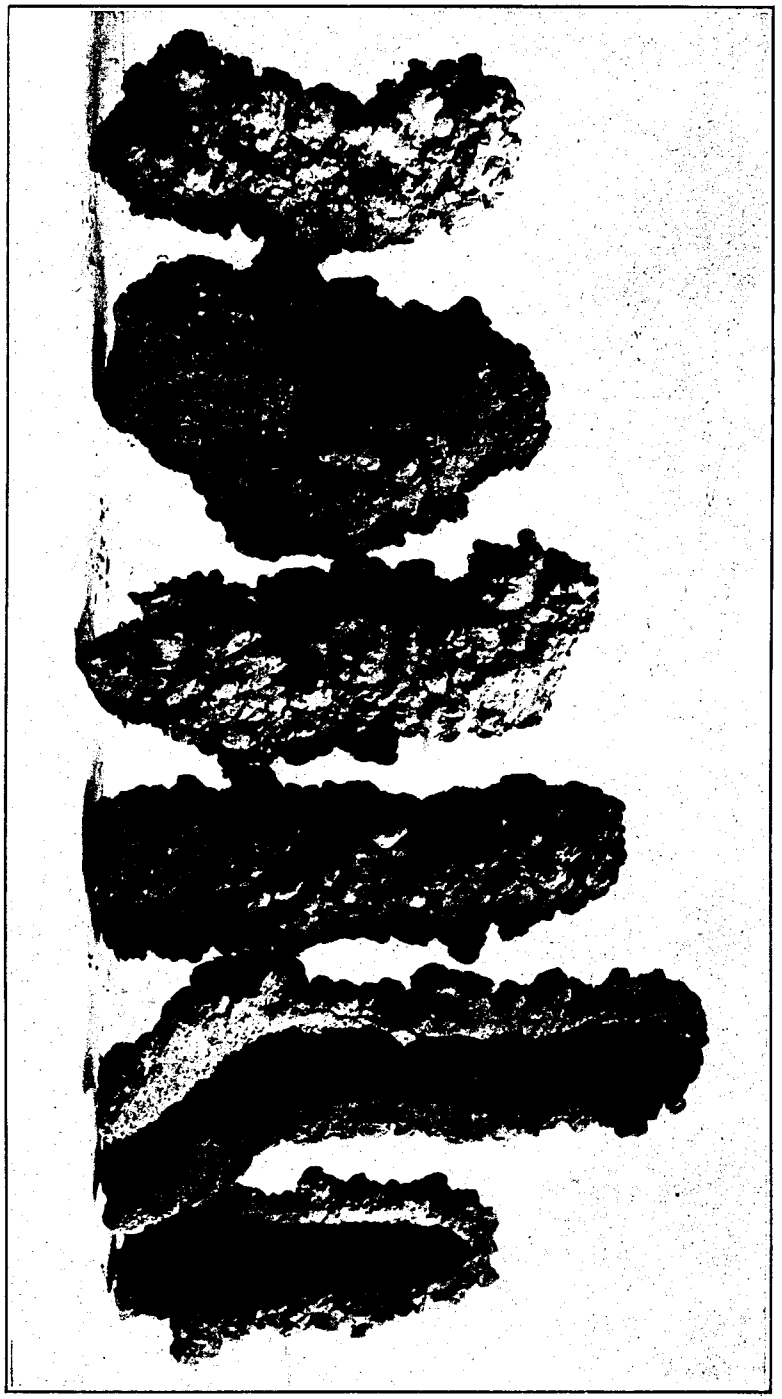
Accepting the theory proposed by Mr. Lander for the condition found to exist in the Nyack region, Doctor Love does not deem it entirely adequate, as he says:

The huts are sometimes found in places in which the soil is of great depth and which are not especially exposed. Such was the case at Baychester, where only a few huts were found, and these in deep soil and so well protected that it was only after careful search that they were discovered.

He offers the supplementary explanation that since it is hardly possible that the Cicada larvæ can determine instinctively the distance to be traveled in their upward journey nor the time required to accomplish it, which will vary with the nature of the soil to be tunneled and the directness of the line followed in their excavations, it may often happen that individuals reach the surface before they are prepared to assume the adult condition, and the number so doing would be greater when the conditions all united to favor a short passage. In protected localities where the soil is deep the larvæ lying near the surface will be more likely to emerge before their pupal changes are complete, and would thus be led to the construction of these cones. This, he says, would also explain their seeking temporary shelter, as they do, under logs and stones, as has been previously noted.

The explanation offered for the construction of the Cicada cones by Mr. Lander, as supplemented by Doctor Love, seems, on the whole, satisfactory and adequate, so far as the conditions studied by these writers are concerned. The conditions as described by Mr. Rathvon do not inform us as to the nature of the soil, but both in the Rathvon case and the later instance described by Mr. Davis, the wet character of the ground would seem to indicate a soil of a considerable depth. This would seem to give a basis of reason for the explanation suggested by Mr. Rathvon and accepted by Professor Riley. A complete hypothesis, therefore, seems to be in a union of the explanations offered, namely, that the cone-building habit is induced either by a shallow soil, proximity of the pupæ to the surface, or conditions of unusual warmth which brings the pupæ to the surface in advance of their normal time, and more rarely to unfavorable conditions of excessive moisture. The mud caps are to protect the burrow from cold until the time of issuing arrives.

The explanation of the occurrence of these structures on high ground suggested by Professor Riley is certainly untenable. He surmised that the individuals constructing cones in such situations did so because impelled by habit that had become fixed and hered-



PHOTOGRAPH OF CHAMBERS OF THE PERIODICAL CICADA, NATURAL SIZE, IN WOODSHED, WASHINGTON, D. C., 1902. (ORIGINAL.)

itary in the course of a long period of existence in low wet situations. The strict limitation of these cones to areas presenting peculiar conditions thoroughly disproved this theory.

Some notes on the character of the huts may be appended. The fact that there is no exit orifice at the ground, as described by Mr Rathvon, is confirmed by the studies made by the observers cited above, the insect invariably clawing its way out at the top. Mr. Lander notes one instance where the pupal shell remained attached and stuck in the summit of the burrow, the mature insect having escaped. According to Mr. Lander, also, the huts are probably constructed at night, the insect taking advantage of the moist air, which would prevent the too rapid drying of the earth used in making the little tower and also of the delicate soft insect itself. The chambers are constructed with soft pellets of clay or mud brought up from below and pressed firmly into place. On examination it will be seen that they are well rounded and rather firmly compacted within, although the marks of the claws of the pupæ are usually visible and leaves and sticks are often incorporated in the walls. No one has actually observed the insects while at work on these structures, and, although Mr. Lander repeatedly broke off a number of cones to see if they would be repaired, the insect failed to do so while being watched. Subsequently the broken portions were found to be recapped, but at some little distance below the broken edge. In this connection may be quoted the observation of Mr. Lawton, of Nyack, cited by Doctor Lintner. Mr. Lawton found that in every case except one the pupa repaired the cone soon after the injury by bringing up pellets of mud and roofing over the broken portion about half an inch from the top. The repairs were begun on one side and gradually extended over the opening horizontally, there being no attempt to form a dome-shaped roof. In some instances the repairing of the chamber began within a quarter to half an hour after injury had been caused, and within three or four hours the opening was entirely closed over. On one occasion a pupa was caught with a pellet of mud in its claws.

The fact that these cones had been noted on only two or three occasions prior to 1884 led to the belief that they were very rare and abnormal. Their extraordinary abundance in 1884 in connection with Brood II would seem to indicate that they are by no means as rare as heretofore supposed, and it may be inferred that the absence of records is simply due to the lack of examination, especially in localities where the conditions would be favorable for their appearance. This view is confirmed by the announcement in a recent letter from Mr. Davis of the discovery of a cone April 30, 1898, on Staten Island belonging to Brood VI, which appeared that year. He says that the cone was just appearing above the dead leaves, which, with the ground also, were

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"soaked after the wet days just past." This belief is participated in by Doctor Lintner in his last report on this interesting subject.[a] It should not be forgotten, however, that the great mass of the insects emerge without making any superficial construction whatever.

THE ACT OF TRANSFORMATION.

The phenomenon connected with the transformation of the periodical Cicada from the pupal to the adult stage is a very interesting one and always fills the observer with considerable wonderment. As remarked by Mr. Butler, when these insects emerge from the ground it is usually with a rush, and a lively scramble ensues for each elevation near the point of their emergence. Trees, bushes, weeds, poles, stumps, fences—in fact, everything upon which they can get above the level of their recent homes is ascended. The instinct which has caused them to burrow to the surface of the ground still drives them in the same direction upward, and they seem to make up in activity for their long subterranean periods and their weeks of waiting near the surface when the time has finally arrived for their emergence. The different steps undergone by the insects in transforming from the pupal to the adult stage have been perhaps most accurately described by Professor Riley, as given below.[b] The plate accompanying his description is reproduced in this bulletin as a frontispiece.

The unanimity with which all those which rise within a certain radius of a given tree crawl in a bee line to the trunk of that tree is most interesting. To witness these pupæ in such vast numbers that one can not step on the ground without crushing several swarming out of their subterranean holes and scrambling over the ground, all converging to the one central point, and then in a steady stream clambering up the trunk and diverging again on the branches, is an experience not readily forgotten and affording good food for speculation on the nature of instinct. The phenomenon is most satisfactorily witnessed where there is a solitary or isolated tree.

The pupæ (frontispiece, figs. 1 and 2) begin to rise as soon as the sun is hidden behind the horizon, and they continue until by 9 o'clock the bulk of them have risen. A few stragglers continue until midnight. They instinctively crawl along the horizontal branches after they have ascended the trunk, and fasten themselves in any position, but preferably in a horizontal position on the leaves and twigs of the lowermost branches. In about an hour after rising and settling, the skin splits down the middle of the thorax from the base of the clypeus to the base of the metanotum (frontispiece, fig. 3), and the forming Cicada begins to issue. * * *

The colors of the forming Cicada are a creamy white, with the exception of the reddish eyes, the two strongly contrasting black patches on the prothorax, a black dash on each of the coxæ and sometimes on the front femora, and an orange tinge at the base of wings.

There are five marked positions or phases in this act of evolving from the pupa shell, viz, the straight or extended, the hanging or head downward, the clinging or head upward, the flat winged, and, finally, the roof winged. In about three minutes after the shell splits the forming imago extends from the rent almost on the same plane with

[a] Twelfth Report Insects New York, p. 283.

[b] Annual Rept. Dept. of Agriculture, 1885, pp. 237, 238.

EMPTY PUPAL SHELLS OF THE PERIODICAL CICADA CLINGING TO LEAVES, BROOD X, 1902, WASHINGTON, D. C. REDUCED. (ORIGINAL.)

the pupa, with all its members straight and still held by their tips within the exuvium (frontispiece, fig. 4). The imago then gradually bends backward and the members are loosened and separated. With the tip of the abdomen held within the exuvium, the rest of the body hangs extended at right angles from it, and remains in this position from ten to thirty seconds or more, the wing pads separating, and the front pair stretching at right angles from the body and obliquely crossing the hind pair (frontispiece, figs. 5 and 6). They then gradually swell, and during all this time the legs are becoming firmer and assuming the ultimate positions. Suddenly the imago bends upward with a good deal of effort, and, clinging with its legs to the first object reached, whether leaf, twig, or its own shell, withdraws entirely from the exuvium, and hangs for the first time with its head up (frontispiece, figs. 7 and 8). Now the wings perceptibly swell (frontispiece, fig. 8) and expand until they are fully stretched and hang flatly over the back, perfectly transparent, with beautiful white veining (frontispiece, fig. 9). As they dry they assume the roofed position (frontispiece, fig. 10), and during the night the natural colors of the species are gradually assumed (frontispiece, fig. 11).

The time required in the transformation varies, and, though for the splitting of the skin and the full stretching of the wings in the flat position the time is usually about twenty minutes, it may be, under precisely similar conditions, five or six times as long. But there are few more beautiful sights than to see this fresh forming Cicada in all the different positions, clinging and clustering in great numbers to the outside lower leaves and branches of a large tree. In the moonlight such a tree looks for all the world as though it were full of beautiful white blossoms in various stages of expansion.

A more realistic idea of the important stages in this transformation is furnished perhaps by a series of photographs kindly given to the writer by Mr. Robert A. Kemp, of Frederick, Md. (see Pl. VI). A more natural position is given if figs. 1 and 2 are turned so as to make the twigs perpendicular rather than oblique.

THE ADULT INSECT AND ITS HABITS.

NUMBERS AND LOCAL DISTRIBUTION.

In the case of a well-established brood under favorable conditions, the enormous numbers of these insects in the soil is most vividly conveyed by the accompanying photograph (fig. 40) taken by Mr. Kemp in 1902 (Brood X), near Frederick, Md. Within the foot-square area in the center of the photograph are no less than 84 openings, which would indicate for the ground surrounding a fairly good-sized tree the emergence of from 30,000 to 40,000 Cicada pupæ.

Mr. McCook took the trouble to count or estimate the burrows under various trees. Under one tree he counted 9,000 burrows, and under another, a small birch, the number of exit holes was estimated at 22,500; and since many of the burrows interlaced under ground and several insects emerged from the same opening, even these figures do not indicate the actual number. In another case 668 openings were counted in a space 10 by 4 feet, and 17 distinct openings in a space 6 inches square.

Mr. Davis, referring to Brood II on Staten Island in 1894, says:

About some of the trees the pupa shells became so numerous that they completely hid the ground itself. At dusk the sound of the many insects climbing up the tree

trunks was quite audible, particularly vigorous pupæ ascending the trees to the height of 30 feet.

Plate V, showing empty pupal shells clinging to leaves, still further illustrates the large number of these insects which often emerge.

As noted by Mr. Farmsley, of Louisville, Ky., the cicadas do not appear very numerously on tops of mountains within an infested area, but gradually decrease in numbers as one ascends, the greater scarcity being noticeable both to the eye and the ear, the rattling chorus growing less and less strong.

On the authority of Dr. Hopkins, the diminishing of the Cicada in numbers as one ascends to higher elevations is apparently not always true. Dr. Hopkins describes driving for a day through the Cicada district of West Virginia in 1897 on the occasion of the reappearance of the 17-year Brood V, and states that as he approached the eastern

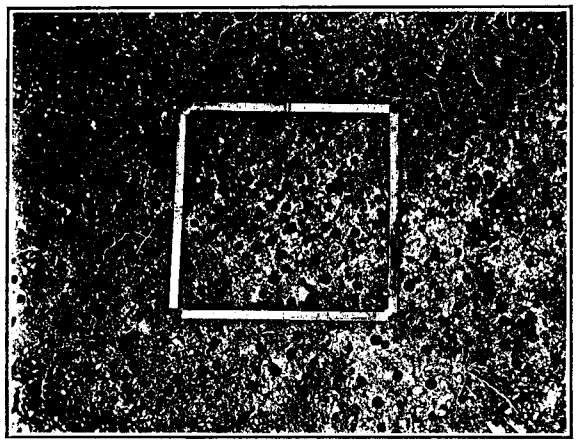
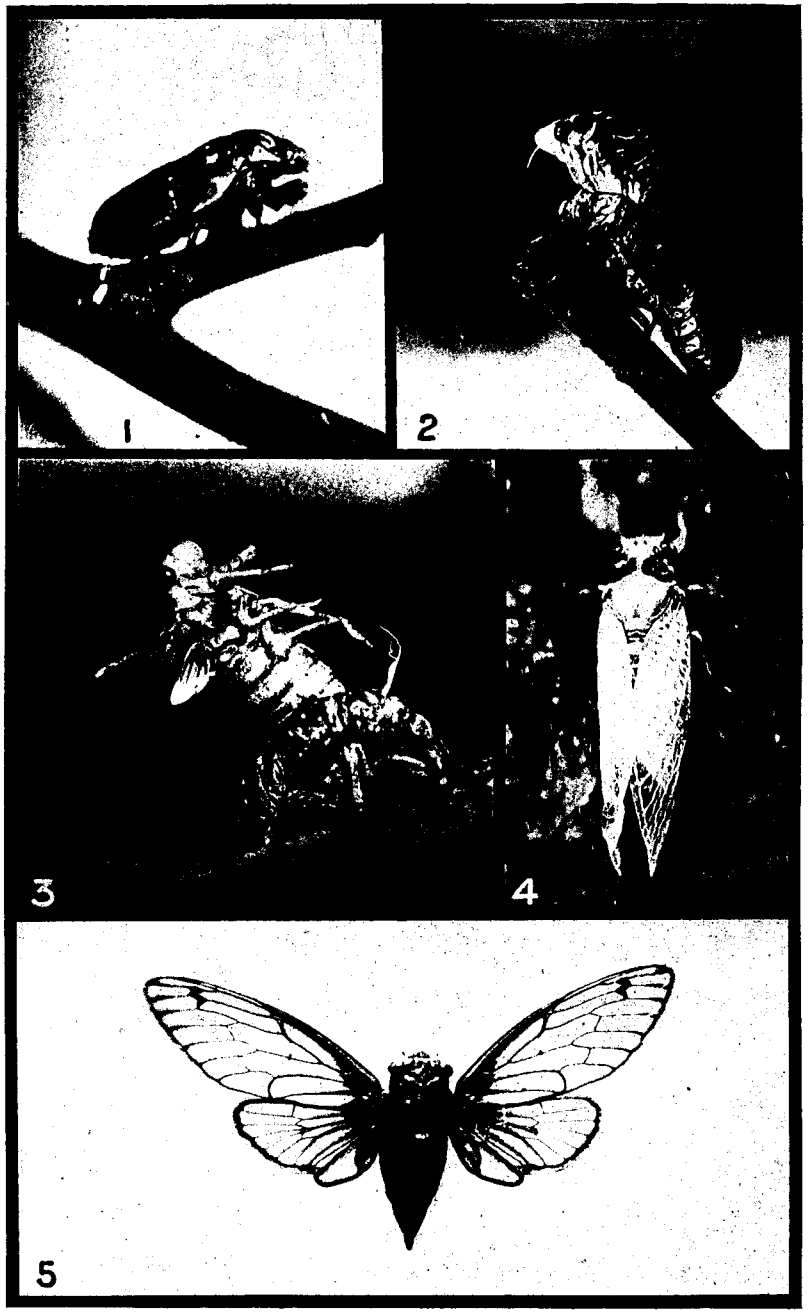


FIG. 40.—Exit holes of the periodical Cicada at surface of soil. The rule shows the large number of holes occurring, in this instance, in a square foot of ground

borders of Preston County the cicadas became more numerous, and as the mountain west of Cranesville was ascended the Cicada was found, at an elevation of 2,600 to 2,800 feet, to occur in far greater numbers than at any point previously traversed. The leaves and twigs of the trees were literally covered with the insects, and the twigs were bending from their weight. This point seems to have been the eastern border of the swarm, and a few rods farther up the cicadas became very scattered and soon ceased altogether.

They often also appear in greatest number in rather well-defined districts within the general range of the brood, or, in other words, are irregular in local distribution. This variation in abundance is due in some cases to differences in the character of the soil and in others, perhaps, to varying surface conditions, as of timber growth, etc. They prefer, apparently, white-oak groves, and are most abun-



THE TRANSFORMATION OF THE EMERGED PERIODICAL CICADA.

1.—Pupa ready for transformation. 2.—Adult beginning to issue from pupal shell. 3.—Adult nearly free from pupal shell. 4.—Freshly transformed adult, the coloring immature. 5.—Adult, several hours after transformation, the coloring mature. About natural size.

dant where the land is high and well drained and the soil a rich, sandy loam, with a sandy or soft clay subsoil. The irregularity of local distribution is confirmed also by the experience of Mr. Davis on Staten Island, who reports of the 1894 brood that the cicadas were very rare in sandy districts, while in districts less sandy they appeared by thousands. He says also that they occurred by millions on certain hills and in certain bits of woodland, yet at a short distance away, under apparently unaltered conditions, they were very scantily represented.

The local abundance of the Cicada in well-defined districts is to be explained by the fact, already noted, that the winged insect is sluggish and scatters but little from the point of emergence, which, with favoring circumstances, tends constantly to concentrate rather than to scatter the species.

THE FOOD HABITS OF THE ADULT INSECT.

At the time of the writing of Bulletin 14 the observations of many entomologists who had studied the periodical Cicada were practically in accord that the taking of food in the adult stage was not a necessary feature of the aerial life of the insect and was of comparatively rare occurrence. Feeding to a limited extent had been shown, however, by the observations of Walsh and Riley,[a] and an additional instance is noted by Riley in Bulletin 8.[b] The observations by Mr. Davis[c] were referred to in Bulletin 14, reporting that the black birch and sweet gum are favorite food plants, and that it is not uncommon to see rows of cicadas along the branches of these trees with their beaks embedded in the bark. Various other entomologists had noted a little feeding, but the opinion was general that the feeding habit was unusual and not necessary to the insect. Statements had also been made that such feeding was limited to the female, and that the male could take no food inasmuch as its digestive organs were rudimentary. No special harm from feeding, at any rate, had ever been noticed, even where the insect occurred in countless myriads.

With the recurrence of Brood X in 1902 Mr. A. L. Quaintance, then entomologist of the Maryland experiment station, had his attention called to the feeding of the periodical Cicada and made a thorough study of the subject.[d] A correspondent called the attention of Mr. Quaintance to the feeding of the Cicada in his orchard, and an examination of a local orchard confirmed this fact, which he afterwards noticed in various localities in Maryland. Cicadas in

[a] American Entomologist, Vol. I, p. 67, 1868.
[b] Bul. 8, o. s., Div. Ent., U. S. Dept. Agric., p. 14.
[c] Natural Science Assn. Staten Island, 4, September, 1894, pp. 33–35.
[d] Bul. 37, n. s., Div. Ent., U. S. Dept. Agric., pp. 90–94, Pl. I.

numbers together were often observed with their beaks stuck straight down against the bark in the attitude of feeding, and in numerous instances the insects were observed when disturbed extracting the thread-like setæ from the plant tissue. Early in the morning or late in the evening also the limbs of young apple and pear trees were frequently quite wet with sap which had exuded from the punctures made with the setæ of the cicadas. This exudation of sap was frequently noticed to immediately follow the withdrawal of the sucking apparatus of the insect to such an extent as to run down the trunk a distance of 4 or 5 inches.

Feeding was also observed in forest trees growing near the college buildings by means of an opera glass. In the case of forest trees the insects commonly go to the upper branches and hence are not near enough for observation from the ground, a fact which may account somewhat for the failure hitherto to have observed this habit of taking food.

Professor Quaintance also made cross sections of the wood, showing that the setæ had actually penetrated deeply into the sapwood of the trees. Both sexes were shown to feed to an equal extent, and dissections of the insects themselves showed the stomach to be distended to several times its usual size with sap taken from the trees, and the alimentary canal was found to be perfect in both sexes and not rudimentary in the male, as hitherto believed. The intestine was very minute, but could be traced from the œsophageal to the anal opening.

Professor Quaintance's observations undoubtedly indicate that the Cicada in the adult stage normally takes food in the same way as do other hemipterous insects, and the fact that when these insects are kept in confinement for a few days without food they invariably die would seem to indicate the necessity of liquid food. Mr. Quaintance himself, however, queried if the amount of feeding might not vary with different broods; and that the Cicada necessarily and always takes food has not yet been fully established.

The taking of food by the Cicada at any rate seems to cause the trees normally very little injury and is not accompanied apparently by any special poisoning of the wood which causes the death or sloughing off of bark, as is more or less the case with the San Jose scale, for example; and the belief expressed in Bulletin 14 may be perhaps adhered to, that, so far as real injury is concerned, the feeding in the adult stage is a negligible feature.

THE CICADA AS AN ARTICLE OF FOOD.

The fact has already been alluded to that the common name "locust," given by the early colonists to this insect, was undoubtedly owing to a confusion of the Cicada with the migratory locust of the

Orient, which has been an article of diet from the earliest times, and is so employed at the present day, in various places in northern Africa and eastern Asia. A similar locust is also now highly esteemed as a food article in the island of Madagascar. All of these locusts belong, however, to the class of insects known as grasshoppers, and on this continent the Rocky Mountain grasshopper or locust has also, as is well known, been long used as an article of food by certain Indian tribes.

That the Cicada was eaten by the red men of America, both before and after the coming of the colonists, is indicated in a memorandum, dated 1715, left by the Rev. Andreas Sandel, of Philadelphia, who, referring to the use of locusts as food in eastern Asia, states also that the Cicada is so used by the Indians. Dr. Asa Fitch corroborates this statement, giving as his authority Mr. W. S. Robertson, who informs him "that the Indians make the different species of Cicada an article of diet, every year gathering quantities of them and preparing them for the table by roasting in a hot oven, stirring them until they are well browned."

No practical test was made with the Cicada as an article of human food until the experiments instituted by Professor Riley and carried out by Doctor Howard in the early summer of 1885. The following is an account of Doctor Howard's experiments:

> With the aid of the Doctor's (Riley's) cook he had prepared a plain stew, a thick milk stew, and a broil. The Cicadæ were collected just as they emerged from pupæ, and were thrown into cold water, in which they remained overnight. They were cooked the next morning, and served at breakfast time. They imparted a distinct and not unpleasant flavor to the stew, but were not at all palatable themselves, as they were reduced to nothing but bits of flabby skin. The broil lacked substance. The most palatable method of cooking is to fry in batter, when they remind one of shrimps. They will never prove a delicacy.[a]

Mr. T. A. Keleher, who sampled some of the dishes above described, has informed the writer that he found the cicadas fried in batter to be most palatable, and that he much preferred them to oysters or shrimps.

The great liking manifested by various animals for the pupæ before and after they have emerged and for the transforming adults has already been referred to. Doctor Hildreth, writing in 1830, says:

> While here they served for food for all of the carnivorous and insect-eating animals. Hogs eat them in preference to any other food; squirrels, birds, domestic fowls, etc., fatten on them. So much were they attracted by the Cicadæ that very few birds were seen around our gardens during their continuance, and our cherries, etc., remained unmolested.[b]

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[a] Proc. Ent. Soc. Washington, Vol. I, p. 29.

[b] Journal of Science, 1830, Vol. XVIII, p. 47.

He also states that when the cicadas first leave the earth they are plump and full of oily juices; so much so that they are employed in making soap.

Mr. John Bartram, writing of the brood which appeared near Philadelphia in 1749, and referring to the pupæ as they appeared near the surface of the ground toward the end of April, says that they were then full of a thick white matter like cream and that hogs rooted up the ground a foot deep in search of them. Dr. Potter refers briefly to the fact that great numbers of them are "devoured by hogs, squirrels, all kinds of poultry, and birds, which live and fatten on them."

That they are sometimes considered to be poisonous when made an object of food is indicated in the following quotation from Doctor Phares. He says:

> Many species of domestic and wild birds, quadrupeds, and other animals eat the cicadas greedily and with impunity. In 1859 they were said to have killed a few hogs in Amite County. They have no poison about them, yet it is not to be wondered at that an occasional hungry hog or other animal, eating very largely of such food, should become sick or even die. Dogs become very fond of them. One evening I watched a bitch catching and eating so many that I expected her to become sick from her rich feast of fat things, but she was in no way injured. Indeed, I have never seen any animal injured or otherwise.

As has been indicated elsewhere, the liking of domestic animals and birds, especially the English sparrow, for the cicadas, both in their newly emerged condition and in the mature state, is one of the most potent influences in exterminating or greatly reducing the abundance of this insect in thickly settled districts.

The use of the newly emerged and succulent cicadas as an article of human diet has merely a theoretical interest, because, if for no other reason, they occur too rarely to have any real value. There is also the much stronger objection in the instinctive repugnance which all insects seem to inspire as an article of food to most civilized nations. Theoretically, the Cicada, collected at the proper time and suitably dressed and served, should be a rather attractive food. The larvæ have lived solely on vegetable matter of the cleanest and most wholesome sort, and supposedly, therefore, would be much more palatable and suitable for food than the oyster, with its scavenger habit of living in the muddy ooze of river bottoms, or many other animals which are highly prized and which have not half so clean a record as the periodical Cicada.

OVIPOSITION AND ITS EFFECT ON THE PLANT.

The Cicada becomes almost perfectly hardened and mature during the first day of its aerial life, and does not wait many days before beginning the important business of its existence in the perfect stage, namely, depositing the eggs for another brood. Courtship occupies a comparatively short time, and the sexes are found together usually

within a week after the emergence of the first individuals. Within two weeks the egg punctures begin to appear here and there in the twigs. From this time on oviposition proceeds very rapidly, and thousands of individuals may often be noted working at the same time on the same tree.

PLANTS SELECTED.

The fact that the Cicada is not especially choice in its selection of trees in which to place its eggs is patent to any careful observer, although a preference is generally shown for oaks and hickories, and the apple among the fruit trees. Any plant which presents itself is, however, accepted, often herbaceous ones and occasionally evergreens, although the sticky resinous sap of the latter seems to be distasteful to these insects. No careful, complete list of plants in which they oviposit has been made, although several observers have made rather extensive lists, notably Mr. Butler and Mr. Davis, the latter having observed the cicadas laying their eggs in between seventy and eighty trees, bushes, and herbaceous plants on Staten Island in 1894, and states also that he had evidently not nearly reached the limits of plants. In some cases even the large petioles of plants, like the horse-chestnuts, had been oviposited in. A list of plants could be given which have been put on record, but it would have but little value, as in every district in which they appear they will oviposit in practically all plants which come their way, with the exception of pines, as already stated, which are ordinarily exempt.

That they are not very choice in this matter is shown by a case of faulty instinct reported by Mr. Hunter Nichols, who observed a female to alight on the iron rod of a bridge and attempt to insert her eggs, even extruding them to the number of seven, some of which remained attached to the rod and the others falling to the ground. Other similar cases of error on the part of the insect are noted by Mr. Davis. In one instance a female had attempted to insert her eggs in the very hard stem of catbriar (*Smilax rotundifolia*) and in another place had thrust her ovipositor entirely through the stem of a plant only to find that it was hollow.

The part of the plant selected for a receptacle for the eggs is almost invariably the twigs of the previous year's growth. When larger limbs are chosen, as occasionally happens, the female evinces her dislike for them by constructing only a nest or two instead of the long series of slits which are usually characteristic of her work on limbs of newer growth.

RESULT TO THE PLANT OF OVIPOSITION.

The effect on the plant of the cutting of the smaller twigs by the female in depositing her eggs has been often described, and is apt to be especially noteworthy and disastrous in the case of such favorite trees as the oak, hickory, and apple, and in the case of the latter, especially in young orchards surrounded by woods, or in recent clearings. (See fig. 41.) The weakening of the twigs by the punctures causes many of them to be partly broken off by the winds, and the brown, withered leaves are conspicuous for the remainder of the summer. Many of the twigs break off entirely and fall to the ground, and the general twig pruning which results is often of considerable extent, giving the forests, as sometimes described, a gloomy appearance, or as though scorched by fire, from the number of the extremities of twigs thus injured. With large shade trees, and particularly trees in forests, the damage is not often excessive, and the recovery is usually complete, or nearly so, within two or three years. With fruit trees and nursery stock, on the other hand, and especially on newly cleared ground or in the vicinity of forests or groves where the Cicada abounds, the injury is apt to be very considerable.

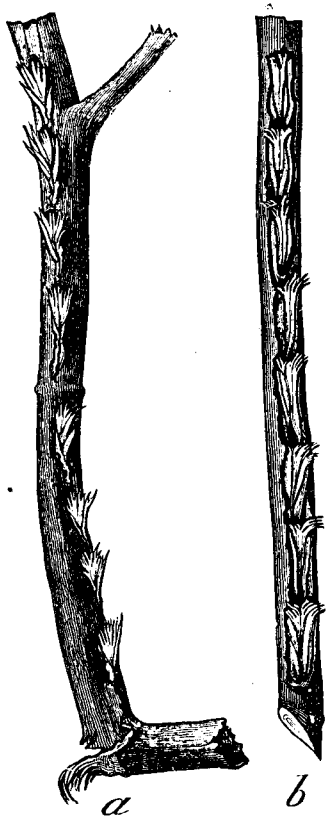

FIG. 41.—Egg punctures of periodical Cicada: *a*, twig showing recent punctures, from front and side, and illustrating manner of breaking; *b*, twig showing older punctures, with retraction of bark and more fully displaying the arrangement of fibers. Natural size (after Riley).

FIG. 42.—Twig showing scars from punctures after the second year. (After Riley.)

The following extract from a letter from Mr. William G. Wayne, of Seneca Falls, N. Y., illustrates the injury sometimes experienced. Referring to the Hudson River Valley brood, appearing in 1826, he says:

> They destroyed the fruitage of the orchards almost completely. Nearly all the tender branches of the trees were so wounded in the deposit of the eggs that they broke from the main stems in the following year and fell to the ground, thus completely denuding the trees of their fruit-bearing branches.[a]

Peach, pear, and apple trees suffer most, and even grapevines are often badly injured. With fruit trees in vigorous condition and growing rapidly, however, the wounds heal in a few years so that often the scars can scarcely be detected; but, as shown by Dr. A. D. Hopkins, with recently transplanted trees, the growth of which is slow, and with the fruiting and terminal branches of old trees which lack vigor, the wounds often do not heal for many years.

Another form of injury has been charged to this insect by some of the earlier writers, viz, that after filling the twigs with her egg clusters the female completely or partly severs it, causing it to break off and die. This opinion is totally without foundation in fact, and is undoubtedly based partly on the observation that many twigs are broken by the winds and partly on a confusion of the work of the Cicada with that of certain oak-pruning beetles, which after ovipositing in the branches, cut them nearly off, causing them to fall to the ground, thus furnishing their larvæ the dead or dying wood in which they develop.

The absurdity of the theory that the Cicada purposely cuts the limbs to weaken them and cause them to break off is shown by the fact that wherever a limb is broken, through the weakening from excessive puncturing or other causes, and falls to the ground, the drying up of the limb invariably causes the eggs to shrivel and die. The breaking off of limbs, therefore, is purely accidental, and is confined, so far as due to the Cicada, to the smaller terminal twigs which have been too thickly oviposited in, the female by so doing defeating her own object. The proportion of such broken and fallen twigs, while often great enough to give the tree a deadened appearance, is small in comparison with the many thicker and stouter limbs which remain attached, and probably more than 90 per cent of all the eggs, and more than 99 per cent of those that ultimately hatch, are laid in twigs which never break off, though often much injured. A very few young may come from twigs which are partly broken off, but in such instances the flow of sap has not been entirely stopped.

The after effect of the egg punctures on the twigs is shown in the deformity which characterizes their subsequent growth. In the process of healing the punctures usually assume a wart or knot-like appearance, as represented in the accompanying illustration of an apple twig (fig. 42). The effect of punctures in hard-maple twigs after the lapse of seventeen years is shown in fig. 43, and on various plants in Plate I (see p. 12), these illustrations being kindly loaned me by Dr. Hopkins.[b] Though ultimately healing over exteriorly with the growth

[a] Lintner, Second Report Insects New York, p. 177.

[b] Bulletin 50, W. Va. Agr. Exp. Sta., Pls. II and IV.

of the surrounding wood, there remains in the center of the twig a dead spot, and the white glistening egg shells of the escaping larvæ have been found in place six years after they have been inserted in the twig by the female Cicada.

Considerable danger follows the work of the Cicada, in that as long as the wounds remain open or as dead spots on the limbs they are not only a source of weakness in the case of winds, but they offer attractive situations for the attacks of various wood-boring insects. If left to themselves the limbs might entirely recover, except for the scars, but the borers gaining entrance through these spots complete the work

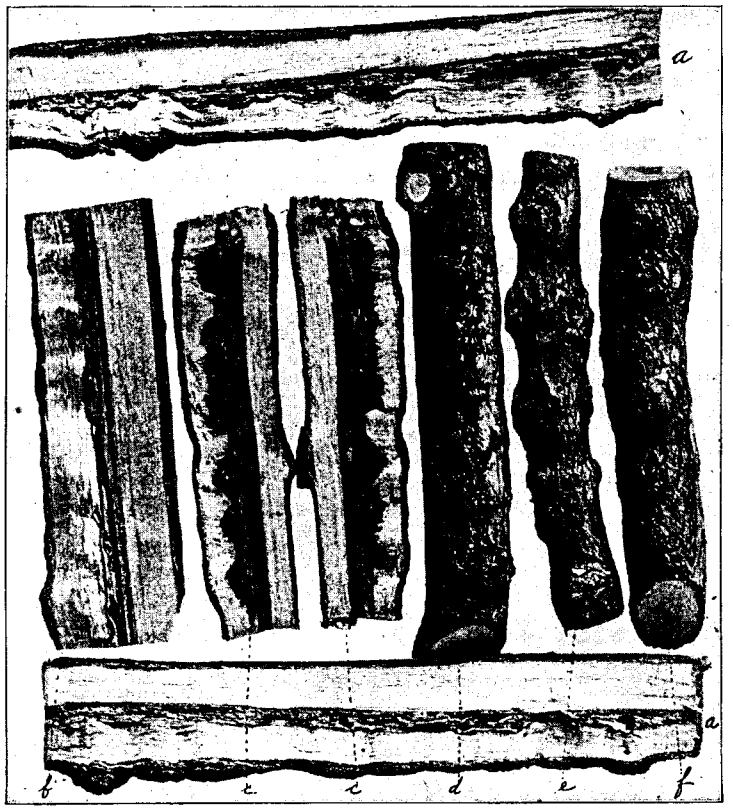

FIG. 43.—Periodical Cicada scars in hard-maple twigs after seventeen years. (Hopkins.)

of destruction which the Cicada began. Furthermore, such open wounds or pockets in the twigs of fruit trees Doctor Hopkins has shown to be favorite points of attack for the woolly aphis (*Schizoneura lanigera* Hausm.), the presence of which not only prevents the wounds from healing but causes additional abnormal growth, adding considerably to the injury to the branches, and making them more liable to the attacks of other insects.

METHOD OF INSERTING THE EGGS.

The work of the female Cicada in inserting her eggs is an interesting subject for study, and so little does she mind the presence of an observer that the operation can be closely watched without her exhibiting any alarm. The position taken is almost invariably with the head upward or directed toward the tip of the branch, the work being steadily prosecuted in that direction. When her course is interfered with by the occurrence of side shoots, instead of moving to one side or the other she reverses her position and thus extends her row of punctures in a straight line completely to the base of the intervening shoot. The branch selected is ordinarily of a size which the female can surround and clasp firmly with her legs to give her the strong attachment necessary to enable her to force her ovipositor into the woody tissues.

The exact method of making the egg fissure and depositing the eggs has hitherto, in the main, been either very briefly referred to, or the actions of the insect have been inaccurately interpreted. The description of this process, hitherto generally accepted and quoted, is that given by Doctor Harris, substantially as follows: Raising her body somewhat above the twig, the point of her ovipositor is brought to bear on the bark at an angle of 45 degrees, and is thrust slowly and repeatedly into the bark and wood, the two lateral saws working in alternation. When fully inserted the instrument is pried upward by a motion of the abdomen, raising and loosening in this way little fibers of wood which, remaining attached, form a sort of covering for the egg fissure or nest. The cutting normally extends nearly to the pith or about one-twelfth of an inch in depth, and is continued until space is made to receive from ten to twenty eggs. After preparing the egg nest as described, the female moves back to the point of commencement and again thrusts in her ovipositor, using the two side pieces as grooves or channels to convey the eggs into the twigs, where they are placed in pairs, separated by a central tongue of woody fiber, which has been left undisturbed, and which is wider at the bottom than at the top. Two eggs having been

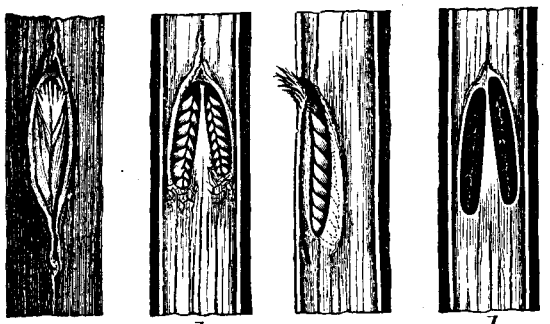

FIG. 44.—Egg nest of the periodical Cicada: *a*, recent puncture, front view; *b*, same, surface removed to show arrangement of eggs, from above; *c*, same, side view; *d*, egg cavity exposed after eggs are removed, and showing the sculpture left by the ovipositor. All enlarged (after Riley).

inserted in the portion of the fissure first made, the ovipositor is withdrawn and again inserted, and two more eggs are placed in line with the first; this operation being continued until the egg nest is filled. A step or two forward is then taken, and after a brief pause a new egg nest is begun. About fifteen minutes is occupied in preparing and filling one of these nests with eggs.

The above account is substantially correct so far as the superficial appearances are concerned. Instead, however, of first making an egg nest and afterwards filling it with eggs in pairs, as described, the female deposits the row of eggs on one side as she makes the original cutting in the bark. She then moves back, and, swinging a little to one side, inserts through the same hole the second row of eggs parallel with the first, thus leaving a small bit of undisturbed wood fiber between the two rows of eggs. This method of inserting the eggs corresponds to that known to be true of allied insects which deposit their eggs in practically the same manner, and is confirmed also by the careful observations made by Mr. Ira H. Lawton, of Nyack, N. Y., in 1894, and reported by Professor Lintner.[a] Mr. Lawton found that the placing of each row of eggs occupied a little over twenty minutes, or, for the construction and filling of the double egg nest, some forty-five minutes. During the cutting of the fissure the ovipositor made about eighty strokes per minute, and after four chambers were made the female would indulge in a short rest.

The number of nests made in a single twig varies from four or five to fifteen or twenty, the latter number being not at all unusual, and as many as fifty egg nests in a line, each containing fourteen to twenty eggs, have been found in a single limb. The punctures are often made so close to each other that they sometimes run together, so as to form a continuous slit for 2 or 3 inches.

The Cicada passes from one limb or from one tree to another until she has exhausted her store of eggs, which have been estimated to number from four to six hundred. By the time the egg-laying is completed the female becomes so weak from her incessant labor that she falls to the ground and perishes or soon becomes a victim to her various natural enemies.

THE GROWTH AND HATCHING OF THE EGGS.

The eggs remain in the twigs for six or seven weeks after being deposited. Professor Potter was one of the first to determine this rather unusually long egg period by marking certain egg clusters and watching them until the young larvæ were disclosed. He reports that from eggs deposited on the 5th of June he witnessed the hatching of the young on the 28th of July. This statement is also corroborated by

[a] Twelfth Report Insects New York, p. 275.

Doctor Smith. Miss Morris and others record a shorter period, and there is undoubtedly considerable variation due to weather conditions, but the normal period, as shown by the abundant records of this office, and many observers, since those noted, ranges, as stated, from six to seven weeks. Some interesting instances have been noted of retarded development of eggs in plants yielding gummy exudations which had hermetically closed the nests from the outer air. Professor Riley notes a case of this kind where the eggs remained sound and unhatched until the end of the year, long after the trees had shed their foliage. Except in the extreme south, where all of the periods are somewhat earlier, the eggs are deposited chiefly in the month of June and most abundantly about the middle of this month, and the hatching period ranges from the middle of July to the first of August.

The egg is a very delicate, pearly-white object, about one-twelfth of an inch long, tapering to an obtuse point at either end and slightly curved. The shell is very thin and transparent, the form of the larval insect showing through some time before hatching. As is the case with most insects that oviposit in the living parts of plants, the eggs of the Cicada receive a certain nourishment from the plant and actually increase in size before hatching, by absorption of the juices from the adjacent plant cells.

FIG. 45.—Egg of periodical Cicada, much enlarged, showing young about to be disclosed. (Author's illustration.)

Discussing the development of the embryo, Doctor Potter says that on the fifteenth day a change in color in the egg may be noted, and from this time on there is a gradual increase in size, the embryo slowly assuming form—the eye becoming especially prominent some ten days before hatching (fig. 45).

The larval Cicada makes its escape by rupturing the eggshell over the back, from the upper end downward about halfway, by muscular movements, accompanied with an inflation of the head and forward parts of the body. The rupture in the shell once made, the larva works its way out by twistings and contortions until the tip of its body only remains in the egg slit of the shell. The entire insect, however, is still inclosed in an extremely delicate and almost invisible membrane (amnion), and after resting a short time the violent movements are again resumed, and by wriggling, twisting, and inflating its head, thorax, and anterior parts the thin enveloping skin is burst open, and by gradual efforts, coupled with contractions and expansions of the body, the larva draws itself out, leaving the thin white skin held in the tip of the eggshell. The larvæ nearest the opening come out first, the others following in regular order, each usually pushing out the abandoned eggshell of the preceding one, though commonly several eggshells remain attached to the loose woody fibers of the egg nest.

Almost at the moment that it becomes free, the larva begins to run actively about with the quick motions of an ant, but soon goes to the side of the limb, loosens its hold, and deliberately falls to the ground, its specific gravity being so slight that it passes through the air as gently as a feather and receives no injury. The peculiar instinct which impels this newly hatched larva to thus precipitate itself into space without the least knowledge of the distance to the ground or the result of its venture has been often commented upon, but is not more remarkable than other features in the life history of this species.

On coming to the earth the larva immediately penetrates it, usually entering at a crack or fissure, or at the base of some herbaceous plant, and begins the long period of its subterranean life.

The newly hatched larva (fig. 46) is about one-sixteenth of an inch long and differs considerably in general form from the later larval stages, while at the same time presenting the general structural characteristics shown in the latter. It has, for example, a much longer and distinctly eight-jointed antenna, and the head is longer in proportion to the body. It is yellowish white in general color, except the eyes and the claws of the anterior legs, which are reddish. It is sparsely covered with minute hairs. In form it is quite elongate and subcylindrical, and it is particularly notable for its very prominent front legs.

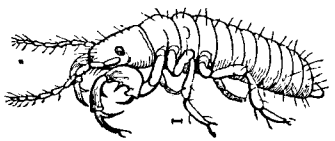

FIG. 46.—Newly hatched larva, greatly enlarged. (After Riley.)

THE UNDERGROUND LIFE OF THE CICADA.

EXPERIMENTAL PROOFS OF THE LONG UNDERGROUND LIFE.

The life and habits of the periodical Cicada above ground, which have so far only been discussed, are open to easy study and have been fairly well understood, certainly since the time of Hildreth, Potter, and Smith; but from the time of the disappearance of the young larva beneath the soil and thereafter, throughout its long hypogeal existence, observations are difficult and with the earlier observers were limited to the occasional or accidental unearthing of specimens, and no consecutive series of observations of a definite brood or generation was attempted. The proof for the 17-year or 13-year period for the development of the Cicada was, therefore, based solely on chronological records, but so noteworthy were the recurrences of the important broods and so full and complete were the records, some broods having been regularly recorded on the occasion of each visit for nearly two hundred years, that there was no possibility of doubting the accuracy of the time periods from such records alone; nevertheless, this unusual feature in

the life of the Cicada always arouses skepticism in the minds of persons who have not given the matter study and have not examined the historical records. To silence such objectors, rather than because of the need of experimental proof, Professor Riley was for many years interested in demonstrating by actual rearing experiments the period of underground development of this insect; in other words, to follow a particular generation through its subterranean life of seventeen or thirteen years, as the case might be, watching its development and preserving examples of the different stages.

The great difficulty of conducting to a successful termination experiments of this sort will be appreciated when the long period over which the experiments must necessarily extend is remembered. The extreme delicacy and softness of the larvæ themselves, especially in the first years of their existence, introduces an additional difficulty, as the slightest touch or pressure injures or crushes them and renders them unrecognizable. It is therefore often difficult to find them, even when the soil is very thickly tenanted.

The difficulty of carrying out breeding experiments with the Cicada under any but natural conditions is illustrated by various efforts in this direction undertaken by this Bureau. In one instance a number of newly hatched Cicada larvæ were allowed to penetrate the soil about a potted oak tree of small size. None of these larvæ survived for a single year. In another instance the larvæ were allowed to penetrate the soil in large breeding tanks, each containing young trees, the tanks being planted out of doors in the soil. These were left undisturbed for a number of years, and although the conditions were seemingly very favorable for a successful outcome, when an examination was finally made, no traces of the larvæ were found.

The earliest systematic attempts to follow the development of the Cicada were made in the field in Missouri by Professor Riley, and subsequently continued under the latter's direction by Mr. J. G. Barlow, an agent of the Bureau. They consisted in making diggings from year to year under trees which were known to have been thickly stocked with eggs. The first records approaching in any way to completeness were obtained with the 13-year Brood XIX, beginning with its appearance in 1881. Observations on this brood were continued by Mr. Barlow at Cadet, Mo., with a fair degree of regularity until July, 1891, when they unfortunately terminated.

During the ten years over which these observations extended the insect had developed through all four larval stages and was ready to enter the first pupal stage. The first molt occurred after a period of from one year to eighteen months, the second molt after an additional period of two years, the third molt after an additional period of three years, and the fourth molt after an additional period of

three or four years, leaving in this 13-year brood three or four years more for the pupal stages.

A much more careful series of experiments was instituted in connection with the 17-year Brood X, beginning with its last appearance in 1885. At the time that the eggs of the 13-year Brood XXIII were being distributed to various points in the North, in order to determine the effect of the temperature and climate (see pp. 18–20), quantities of egg-laden twigs of the 17-year brood noted, collected in Virginia, were distributed under certain linden and oak trees on the grounds of the Department of Agriculture at Washington, D. C. Larvæ came from these twigs in some numbers and went into the soil under the trees, but not in such abundance as could have been wished for the successful outcome of the experiment. This brood was followed in its underground life from 1885 to 1896, at which time the specimens had become so rare that extensive digging resulted in the discovery of very few individuals, and further search was abandoned. With this brood the first molt occurred after one year, the second molt two years later, the third molt three or four years later, and the fourth molt after an additional three or four years, thus occupying upward of ten years with the four larval changes and bringing the insect into the last larval stage with some six or seven years for the subsequent larval and pupal life. If any adults emerged at the end of the 17-year period in 1902 they were not observed.

A SUCCESSFUL SEVENTEEN-YEAR BREEDING RECORD.[a]

A much more promising experiment, because of more abundant material, was instituted on the Department grounds in 1889 with the 17-year race which appeared in that year and which had its return appearance during May and June of last summer (1906). This brood is practically unrepresented in the District of Columbia, and did not occur at all on the Department grounds. A very large quantity of egg-infested twigs was obtained from North Carolina, Long Island, Kentucky, and Ohio, several cartloads altogether, and were distributed under oak and other trees on the grounds of the Department of Agriculture. The eggs in most instances were hatching when received and were placed under the trees in the very best condition for the larvæ to enter the soil, and many thousands, probably hundreds of thousands, of larvæ actually went into the soil under these trees. This experiment was made during the first year of the writer's connection with the Bureau of Entomology, and the later examinations were made chiefly under his direction. Three years after the planting the soil under the trees where the egg-bearing twigs had been distributed

[a] The records of the plantings on the Department grounds of the eggs of Brood X in 1885 and Brood XIV in 1889 are given in Appendix B, of Bul. 14.

was found to be thickly filled with larvæ, so much so that a single spadeful of earth would often turn up half a dozen or more. In the spring of 1897 the larvæ had reached the fourth stage and were still very abundant in the soil. Examinations were made from time to time showing these larvæ to be still present in the soil about the trees where the eggs had been distributed, going through the slow process of growth and transformation which has been described elsewhere. That a successful outcome was sure to be had in this experiment was demonstrated in the early spring of 1906, the year for the appearance of this brood, the ground about the planted trees exhibiting many of the exit holes of the insects which are made to the surface long before the insect emerges. These holes under certain trees were so numerous as to indicate the emergence of thousands of cicadas. Under one tree a count and estimate were made of more than five thousand openings, and under other trees the openings ranged from a few hundred to from one to three thousand. The actual emergence took place between May 14 and 21. The writer visited the grove on two evenings and witnessed the issuance of numbers of cicadas and collected some specimens. In spite, however, of the considerable number of cicadas which actually emerged, none was seen on the trees during the days and weeks following emergence. Each morning about the planted trees would be found a considerable group of blackbirds (*Quiscalus quiscula*), which evidently had been feasting on the newly-issued cicadas. The cast pupal shells were numerous on the trunks of the trees and especially on the foliage, and also on the ground, but scarcely a single Cicada escaped the sharp eyes of these birds, and the characteristic song was not heard during June in this grove, although thousands of adults had come forth.

At none of the examinations were Cicadas found of this brood under any of the trees except where eggs had been distributed, and no emergence holes appeared under other trees. The record from the planting to the emergence of this insect is therefore complete, and gives the demonstration by actual transfer and breeding record of the long period of the 17-year brood, a demonstration which, as indicated at the outset, was entirely unnecessary to show the correctness of this extraordinary hypogeal term.

The absolute failure of these insects to establish themselves when planted in such enormous numbers, and even when the underground period had been successfully passed, owing to the relentless onslaught of birds, is a striking illustration of what is happening every year with the different broods in nature, especially in thinly forested regions, and accounts for their great reduction in numbers and the practical disappearance of many local swarms formerly abundant. It also shows that there may be emergences in considerable numbers

without their being reported, unless some observer chances on a pupal shell or notes the exit holes in the ground about the trees; hence the slight value of a negative report as opposed to a positive one.

HISTORY OF THE LARVAL AND PUPAL STAGES.

A careful study of the material collected in the course of the experiments described in the last section demonstrates the interesting fact that this species, in spite of its very long period of growth, presents the same number of adolescent stages as is found in insects which go through their entire development within a single year or even of the more rapidly multiplying species, which have many annual generations. But six distinct stages are found, four of which belong to the larval condition and two to the pupal. In other words, the larval and pupal changes in the periodical Cicada are normal and are not increased by its long preparatory existence.

It has been inferred hitherto, and notably by Professor Riley, that owing to the continual use of the claws in burrowing, this species found it necessary to shed its skin and undergo a molting once or twice a year, and instead of the normal number of changes or molts there were probably from twenty-five to thirty. An examination of types of the different larval stages which Professor Riley had provisionally separated demonstrates that the differences on which these supposed stages were based are either individual and exceptional or due to the difference of age within the same stage, and that as far as structure and size of the hard parts of the larva and pupa are concerned the normal number of stages only is represented in this species.

For the separation of these different stages of growth useful characters are found in the size and structure of the legs, and especially of the anterior pair, in the antennæ, and in the development of the wing sheaths. It is the rule with insects that with each molt there is a decided increase in the size of the head and hard parts generally, and with the periodical Cicada especially it is also very doubtful if there is ever a molt without a decided change of the sort indicated. Its life beneath the ground in its moist cell over a rootlet is a very quiet one and free from any of the wearing action of rain or the drying of the outer air, so that the need of a molting or change of skin would apparently be much less than that in an exposed or much more active insect. It probably also very rarely has occasion to burrow to any considerable extent and probably often remains for years in the same cell, which it enlarges from time to time without change of location. For these reasons the writer is inclined to believe that moltings only occur when change of form becomes necessary by the increased size of the insect, and this seems to be borne out by definite structural peculiarities, which easily permit us to recognize the different stages or determine the age of any larva within a year or two. The larva of a particular molt or stage

of growth will vary considerably in size of the body and the softer parts, representing perhaps a difference in age in some cases of one or two years, but the hard parts will present a very uniform size and character.

The peculiar structure of the enlarged anterior legs furnishes perhaps the best means of distinguishing the adolescent stages of this species from other cicadas and the modification which these limbs undergo with the different molts the best means of determining the age of the larvæ. The peculiarities of the anterior legs consist in the enormous enlargement of the femora and tibiæ and their development into structures which resemble somewhat the cutting mandibles of biting insects or recall the fossorial forelegs of the mole cricket. The peculiar structure of these legs is in fact especially designed for digging, tearing, and transporting earth in the course of the insect's subterranean life. As already indicated, the amount of burrowing in the early stages is not necessarily very great in any one year, but during the entire seventeen years conditions may occasionally arise which will demand a considerable activity on the part of the young Cicada.

The details of the structure of the front legs, which are given in the technical description of this species, are quite characteristic and diverge notably from the similar parts of other species. The anterior tarsus of the periodical Cicada exhibits also a rather peculiar metamorphosis during the adolescent life of the species. In other words, during the first larval stage and in the pupal stage it is similar to the other tarsi but considerably longer, being attached to the inner side of the greatly enlarged tibia and at a considerable distance from the clawlike tip of the latter. The fore tarsi are of service to the young larva in walking and climbing and in the same way to the pupa after its emergence from the soil, facilitating its climbing trees or other objects; in other words, covering the periods between the hatching and entering the soil and between the emergence of the pupa and the disclosure of the imago. During its long subterranean life, however, these long, slender tarsi, being distinctly in the way in digging in the earth and of no service, become rudimentary with the first molt and nearly disappear in the subsequent larval stage. They reappear in the first pupal stage, but in this and the subsequent pupal stage, while the insect is still below the soil, they are folded back along the tibiæ, so as to be practically functionless (see fig. 51), and are only unfolded and brought into service after the pupa has emerged from the ground.

The more detailed description of the different stages which follows will facilitate the easy recognition of any particular stage. The chief points to be considered in determining both the age of the larva and whether or not it belongs to the periodical species are the measurements of the corresponding parts of the legs and antennæ, but pa-

ticularly the variation in the structure of the peculiar comb-like organ which is found on the apical margin of the front femora, together with the important differences in the hairy covering of the body and legs.

TECHNICAL DESCRIPTION OF THE DIFFERENT STAGES.

First larval stage.—The newly hatched larva (fig. 47, *a*) is about 1.8 mm. long from tip of head to the extremity of the abdomen, is rather slender and of a nearly uniform thickness throughout, presenting, however, the general characteristics of the later larval stages. The body is clothed with numerous scattering long hairs. The general color is creamy white, with prominent, deep red, almost black, eye spots. The antennæ, beak, and legs are, relatively with other stages, very large in comparison with the size of the body. The anterior legs are developed in general as in the later stages, though lacking the femoral comb-like organ which begins in the second stage and the minute second subapical tooth on the tibia which appears in the fourth stage. The anterior tibiæ are also more slender and the mandible-like tip is more sharply pointed. The row of stiff hairs for retaining the earth excavated in burrowing, so prominent in the later stages, is but sparsely represented. The anterior tarsus is inserted considerably within the tip of the tibia, projecting beyond the latter, and is armed at its extremity with two nearly equal, curved claws, similar to those on the middle and hind tarsi. The basal joint of the two-jointed tarsi in all the feet is very minute and with difficulty detected, and in fact becomes still more inconspicuous in later larval development. The antennæ are seven-jointed, as in all the subsequent larval and pupal stages (one of the characters distinguishing this species from other allied species, particularly *C. tibicen*, which has an additional joint); but the presence of a very prominent antennal tubercle gives an appearance of eight joints, the number which I have hitherto assigned to it. The first true joint is robust and a little shorter than

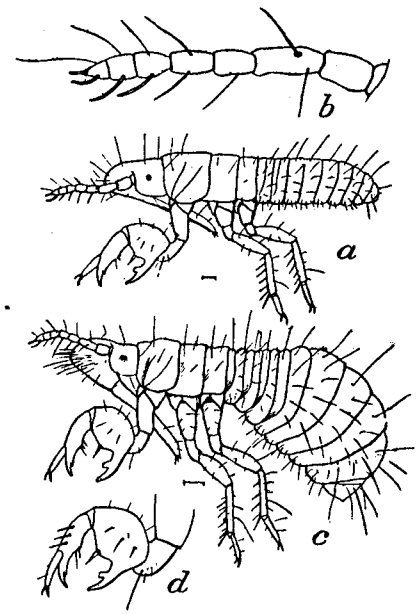

FIG. 47.—First larval stage: *a*, newly hatched larva; *b*, antenna of same; *c*, larva eighteen months old; *d*, enlarged anterior leg of same. (Author's illustration.)

the second, the two following are subequal and shorter than the first, the fifth is shorter than the fourth, and the sixth and seventh are subequal and shorter than the fifth, the last tapering regularly from the apex, which is armed with curved spines, one long and one short. The terminal three joints form something of a club tip. During this stage the larva increases in length to more than 3 mm. and the abdomen swells and becomes more robust. The length of the hard chitinous parts remain, however, unchanged, as follows: Anterior femora, 0.27 mm.; anterior tibiæ, 0.30 mm.; hind tibiæ, 0.33 mm.

This stage lasts more than a year, the first molt usually occurring during the second year after hatching. (See fig. 47.)

Second larval stage.—The average length of the larva in this stage is about 4 mm. The more horny parts now measure: Anterior femora, 0.50 mm.; anterior tibiæ, 0.55 mm.; hind tibiæ, 0.80 mm. The general appearance is unchanged from the later development in the preceding stage. The eye-spots are still present, though reduced. The under surface of the head is armed with some rather long hairs, and a very regular row of minute spines occurs on the anterior face of the hind and the middle femora. The prominent apical tibial spur of the middle and the hind pair appears with this molt, being previously represented, if at all, by a simple spine. The third joint of the now distinctly elbowed antennæ is as long as the second, and the three terminal joints are rather more compressed into a club-like tip than in the first stage. The chief characteristics of this second stage, however, are in the anterior legs (fig. 48). The femora now possess a rudimentary comb of three teeth, the upper tooth being very broad and projecting beyond the two succeeding sharp ones, of which the lower is the larger. The central tooth of the femora, which was rather minute, or, more properly, a mere spine in the first stage, is now very much larger and broadened at the base into a prominent triangular projection. The tarsus is reduced to a horny rudiment about three times as long as wide, and is closely applied to the inner surface of the tibial "jaw" which extends twice the length of the tarsus beyond the latter.

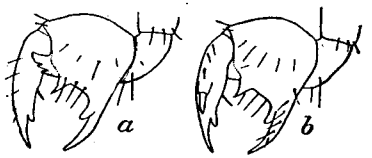

FIG. 48.—Second larval stage: *a*, anterior leg, outer face; *b*, same, inner face. (Author's illustration.)

This stage, as already stated, is assumed during the first two or three months of the second year of the insect's existence and lasts nearly two years.

Third larval stage.—Length, 6 to 8 mm.; anterior femora, 1.20 mm.; anterior tibiæ, 1.35 mm.; hind tibiæ, 1.85 mm. Eye-spots still more reduced; numerous parallel rows of short hairs on the head are notice-

able; hairy armature of legs more distinctly outlined; a row of small spines on either side of middle and hind tibiæ, while the rows of bristles on the inner margins of the anterior femora and tibiæ for holding the excavated earth are well developed. Anterior tarsus reduced to a mere tapering spur about two and one-half times as long as wide at base. The femoral comb has one additional tooth, making four in all, counting the blunt upper one (fig. 49). The antennal joints decrease in length from the basal to the terminal, the basal two and the terminal two being, however, of nearly equal length, respectively. The wing cases are foreshadowed by minute pads. Sexual differences very faintly discernible.

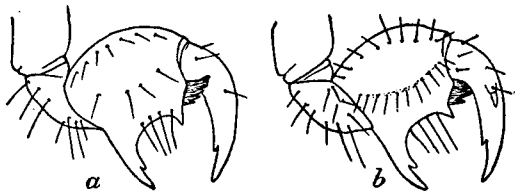

FIG. 49.—Third larval stage: *a*, anterior leg, outer face; *b*, same, inner face. (Author's illustration.)

The larva is in this stage at the completion of the fourth year of its existence.

Fourth larval stage.—Length, 10 to 15 mm.; anterior femora, 2.40 mm.; anterior tibiæ, 2.70 mm.; hind tibiæ, 4 mm. Eye-spots reduced to from three to six minute black points, rows of hairs on head easily discernible and prominent; spines on femora and tibiæ of all legs, and particularly the anterior pair, more numerous and longer and stouter than in the preceding stages. The anterior tibia has a small tooth within the larger blunt subapical one. The femoral comb has again an additional tooth, making five in all. Antennæ as in the preceding stage. Rudimentary wing cases somewhat more prominent than in the last stage, but still inconspicuous. (See fig. 50.)

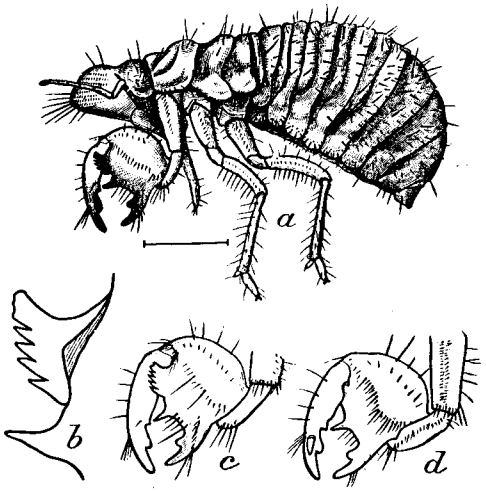

FIG. 50.—Fourth larval stage: *a*, full grown larva, much enlarged; *b*, outline of femoral comb: *c*, anterior leg, outer face; *d*, same, inner face. (Author's illustration.)

The larva is in this stage at the completion of the eighth year of its existence, and the stage probably lasts three or four years.

First pupal stage.—Length in the early condition of this stage about 17 mm.; anterior femora, 3.30 mm.; anterior tibiæ, 3.60 mm.; hind tibiæ, 5.80 mm.; width of head, 6 mm. Eye-spots entirely wanting; eye prominences well developed, as in later pupal stages. Wing cases extend to the tip of the third segment. Third antennal joint one-third longer than second, fourth as long as second, others decreasing in length. The anterior tarsi reappear perfectly developed, and are nearly as long as the tibiæ, and are folded along the inner face of the latter; the first joint is very minute, and the second or last very long—longer than the middle or posterior pairs—and armed with two curved claws at the tip, of which one is rather longer than the other. Femoral comb with an additional tooth, a very minute one being distinctly separated from the large blunt upper tooth. The anterior tibiæ have within the large blunt subapical tooth, which has occurred all along hitherto, two minute saw-teeth instead of the one present in the preceding stage (fig. 51). The hairs of the legs and body are arranged as hitherto, but are rather more numerous and longer, and this is particularly true of the anterior limbs. The sexual characters which have been foreshadowed in the two later larval stages are now distinctly defined.

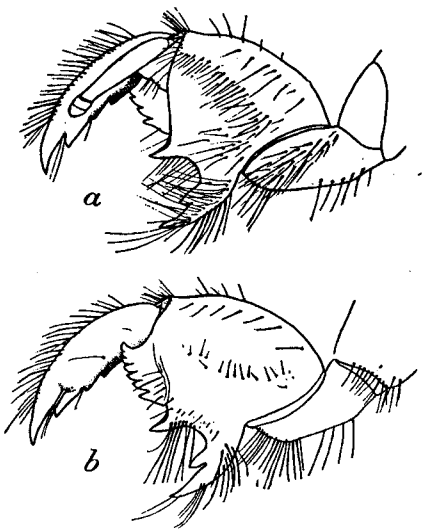

FIG. 51.—First pupal stage: *a*, anterior leg, inner face, showing tarsus bent back against the tibia, *b*, same, outer face. (Author's illustration.)

Second pupal stage.—This stage does not present any differences from the last except in the greater size of the specimens, which is noticeable in the relative dimensions of the parts hitherto measured for comparison. The length of the adult pupa varies from 27 mm. in the case of the males to about 35 mm. in the case of the larger females. The adult pupa of the male presents the following length of the parts referred to: Anterior femora, 3.80 mm.; anterior tibiæ, 4.30 mm.; hind tibiæ, 6.70 mm.; width of head, 6.70 mm. In the case of the female: Anterior femora, 4.20 mm.; anterior tibiæ, 5 mm.; hind tibiæ, 7.50 mm.; width of head, 7.50 mm. The anterior tarsus in all unearthed specimens is folded closely back against the face of the tibia, but in all aerial specimens is unfolded and projects forward to be of service in climbing.

THE HABITS OF THE LARVA AND PUPA.

During its long life beneath the soil, in its small moist oval cell, which at first is not larger than a "birdshot," but is gradually enlarged to accommodate the slowly-increasing size of the inmate, little opportunity is afforded for much variation in mode of existence and habits. The interesting features to be considered are the feeding and burrowing habits, which together comprise the principal activities of its subterranean existence.

THE FOOD OF THE LARVA AND PUPA.

The food taken by this insect beneath the soil is necessarily fluid, as is also the case with the perfect insect, as well as with all other insects of the order Hemiptera. That the Cicada should obtain its nourishment in a manner different from the other members of its order would not be anticipated, but, nevertheless, a good deal of difference of opinion has been expressed as to the nature of the food of this insect in its subterranean life, as also its method of feeding. Both Professor Potter and Doctor Smith were of the opinion that the insect in its underground life obtained its nourishment from the surface moisture of the roots of plants through capillary hairs at the tip of the proboscis—a curious misapprehension, as the hairs mentioned arise from the sheaths, and have no connection with the true piercing and sucking setæ. Professor Potter expresses himself on this subject as follows:

> In all places they are found attached to the tender fibrils of plants. When they are disturbed or driven from them they seek for others the moment they are at liberty. This is their only aliment, not the substance of the roots of the plants, which they can not divide and comminute without teeth or jaws to use them, but the mere aerial exhalation from their surface. This well-established fact would seem to account for the slowness of their growth, and furnishes a reason for so long a subterraneous residence.

This absurd view of the method of nourishment of the larva and pupa is on a par also with the belief of the same authors, reviving the statement of Aristotle, that the adult insect subsists on "the dewy exhalation of vegetable barks," which was supposed to be swept up by a brush of hairs on the tip of the proboscis. Doctor Smith claims a basis for this theory of the feeding habits in personal observation, and it has been supposed by others to be supported by the well-known fact that the Cicada will occasionally issue from the ground that has been practically cleared of timber and under cultivation for a number of years, and that other species are known to issue from the prairies. These facts lose much of their significance when it is remembered that any vegetation, even annual, as of farm crops, would supply ample root growth for the Cicada larva during the growing period of summer, and in the colder months they undoubtedly lie dormant in their earthen cells.

Perhaps the first writer to point out and demonstrate the true method of feeding of the larva and pupa of this insect in their underground existence was Miss Morris, of Germantown, Pa. That the Cicada larvæ and pupæ pierce small roots with their sucking beaks and feed on the juices of the plant, as do other plant-feeding hemipterous insects, as their normal, if not their sole method of subsisting was fully proved by her investigation, and has been confirmed repeatedly in the diggings made by the writer, and there can no longer be any possibility of doubt in the matter. In practically every case, in the writer's experience, where the cell in which the larva rested was taken out in condition for examination a small root, one-sixteenth to three-sixteenths inch in diameter, was found to border usually the upper end of the cell, and in several instances larvæ were found with their beaks so securely embedded in the root that they were not easily loosened. In other instances the roots showed, by the slight swelling and reddish discoloration beneath the bark, unmistakable signs of having been punctured.

The root-feeding habit can be best witnessed in light, rich soils, and in the plantings of the brood of 1889 under oak trees on the Department grounds the soil beneath these trees was so thickly inhabited that between the depths of 6 and 12 inches every spadeful of earth would throw out numbers of the larvæ, and a most excellent opportunity was afforded for the study of their habits. In hard, packed soils, perhaps scantily supplied with roots, the difficulty of getting out the cells in perfect condition is such that one might easily be led into error, and the comparative rarity of the larvæ in such soils adds further to the difficulty of determining their feeding habits.

It is for this reason, I have no doubt, that the opinion has obtained in some quarters that the larvæ subsist not on the roots of plants, but on the nourishment obtained from the surface moisture of the roots, or the general moisture of the earth, which might be supposed to contain more or less nutrient material arising from the decomposition of the vegetable matter. That the moisture of the surrounding soil may, and doubtless does, supply the very delicate, thin-skinned larvæ and pupæ with a certain amount of liquid by absorption through the skin may be admitted, and in fact when the larvæ are taken from their natural surroundings and exposed to the air they very rapidly dry and shrivel. Larvæ are doubtless occasionally found in cells away from roots, and this may be explained by the fact of their being at that time either undergoing one of their long resting or hibernating periods, which may be of frequent occurrence in such an extremely long-lived species, or they may be burrowing in search of roots on which to subsist.

THE LOCATION IN THE SOIL.

There has been great difference of opinion as to the depth beneath the soil reached by the larvæ and pupæ. In all of the extensive excavations which have been made on the Department grounds in following the results of the experimental plantings, specimens have rarely been found at a greater depth than 2 feet below the surface and usually between 6 and 12 inches, especially in the first years of the life of the insect. This experience is corroborated by the examinations made by Professor Riley in Missouri, and is fully confirmed by the interesting manuscript notes left on this subject by Doctor Smith, which are here reproduced:

> The depth in the earth to which it descends depends upon that of the vegetable soil, and its location is at the bottom of the soil, except perhaps in some of the deep soils of the West and the alluvial soils, where the depth of its descent is probably only sufficient to protect it against the inclemency of the weather. This is generally from 12 to 18 inches and sometimes 2 feet. It never changes its locality from the time it enters the earth till it emerges. The cells in which they shut themselves up are, inside, well finished and smooth, of a sufficient size to accommodate them; but outside they are mere lumps of clay and afford by their appearance no clew to their internal character. It is this fact that has caused all the doubt and mystery about their place of residence and habits during their long continuance in the earth. 'A gentleman in the winter of 1850–51 was excavating on the side of a low hill for the purpose of building a wall on West Baltimore street. The excavation was about 150 yards long and 6 to 18 feet deep to the level of the paved street. This hill had been covered in former years with trees and shrubbery, and had been one of the fields of observation in 1834. I watched this excavation daily and found the cells of the locusts thrown down in the greatest abundance. The lumps of earth containing the cells would roll down the heaps of earth just as others did, affording not the slightest indication of their internal contents. But as the pick or the spade of the workmen struck a cell in its place in the banks it readily broke open and the larva was exposed. When the excavation was completed the observer standing in the street had a fine view of the broken cells in the bank. From one end of the bank to the other the cells were plainly visible, appearing like small augur holes, and all in a regular stratum of earth about 18 inches below the surface of the earth, from 2 to 4 or 5 inches apart, and none more than 1 or 2 inches higher or lower than the others. The internal size of the cells was from 1½ to 2 inches long and about three-fourths of an inch wide, forming an oblong cavity very smooth in its walls. The particles of earth of which the cells were composed had evidently been agglutinated together by some viscid fluid secreted by the insect. This is their habitation during the whole seventeen years, or until they prepare for their ascent.

In the face of the testimony given above there are records also by apparently trustworthy observers which seem to indicate that the larvæ are capable of going to much greater depths. An instance of this sort is reported by Mr. Sadorus, of Port Byron, Ill., who built a house in 1853 and found that they came up in his cellar in 1854. Others have reported finding them at a depth of 10 feet or even more below the surface. A rather remarkable instance is recorded by Mr. Henry C. Snavely, of Lebanon, Pa., in which the Cicada pupæ are reported to have worked their way through a hard mass of cinders about 5 feet in thickness, which had been firmly compacted.

It is difficult to say how many of these reported occurrences at unusual depths are due to an unobserved tumbling of specimens from higher levels, but where the insects have been observed to issue through the bottom of cellars or similar situations the information would seem to be reliable. The fact remains, however, that all of the extensive diggings in the investigation of the early history of this insect here in Washington and elsewhere have confirmed the statements of Doctor Smith; in other words, the insects have always been found, as stated, within 2 feet of the surface and in greatest numbers between the depths of 8 and 18 inches.

A curious feature in connection with the underground life of this insect is its apparent ability to survive without injury in soil which may have been flooded for a considerable period. Doctor Smith records a case of this kind where a gentleman in Louisiana in January, 1818, built a milldam, thus overflowing some land. In March of the following year the water was drawn off and "in removing a hard bed of pipe clay that had been covered with water all of this time some 6 feet deep the locusts were found in a fine, healthy state, ready to make their appearance above ground, that being the year of their regular appearance." Another case almost exactly similar is reported by Mr. Barlow. In this instance the building of a dam resulted in the submerging of the ground about an oak tree during several months of every summer, ultimately resulting in the death of the tree. This went on for several years, until the dam was washed away by a freshet, when digging beneath the tree led to the discovery of the Cicada larvæ in apparently healthy condition from 12 to 18 inches below the natural surface of the ground. In both of these instances the ground may have been nearly impervious, so that the water did not reach the insects nor entirely kill all of the root growth in the submerged soil.

THE METHOD OF BURROWING.

The actions of the Cicada beneath the soil are not readily investigated, the newly hatched and more active individuals disappearing rather rapidly and seeming to be quite at home in the earth, as their natural element. The method of burrowing of the larger and partly grown specimens, as witnessed in captivity under fairly natural conditions, is, as has been described in the manuscript notes of the Bureau, as follows: The larva scratches away the walls of its cell with the femoral and tibial claws, grasping and tearing the earth and small stones just as one would do with the hands, bracing itself against the sides of its cell mainly by its hind and middle legs, the former in their natural position and the latter stretched out over the back. If it is rising, so that the earth removed naturally falls to the lower end of the burrow, it simply presses the detached portions on all sides, and

especially on the end of the cavity, by means of its abdomen and middle and hind legs. If the direction of the larva, however, is downward, the loose soil has to be gathered and pressed against the upper end of the cavity, which is accomplished by making the soil into little pellets by means particularly of the front femora and placing these pellets on the clypeal part of the head, carrying them upward and pressing them firmly against the top of the cavity. The stiff hairs that cover the head and border the inner side of the fore tibiæ and femora assist very materially in securing the earth while it is being transported.

From time to time the burrowing insect rests and cleans the adhering earth from its forelegs very much as a cat washes its face with its paws. The large, strong forelegs are moved over the roughened front of the head, the stiff hairs springing from the latter acting like a comb or brush to free the spines of adhering earth.

DAMAGE OCCASIONED BY LARVÆ AND PUPÆ.

During its underground life the Cicada has been charged with damaging, and even killing, fruit trees. At first thought this is not an unnatural inference when one remembers the immense numbers in which the insect often occurs. The most specific charge brought against them in this particular is the account published by Miss Morris in 1846.[a] Miss Morris having suspected for a number of years that the failure of certain fruit trees over 20 years old was mainly due to the ravages of the larvæ of the periodical Cicada, had an examination made of one of them, a pear tree that had been declining for a number of years without apparent cause. She says:

> Agreeably to my expectation I found the larvæ of the Cicada in countless numbers clinging to the roots of the tree, with their suckers piercing the bark and so deeply and firmly placed that they remained hanging for a half an hour after being removed from the earth. From a root a yard long and about an inch in diameter I gathered 23 larvæ; they were of various sizes, from a quarter of an inch to an inch in length. They were on all the roots that grew deeper than 6 inches below the surface. The roots were unhealthy, and bore the appearance of external injury from small punctures. On removing the outer coat of bark this appearance increased, leaving no doubt as to the cause of the disease.

In this particular instance there is some reason for believing that the damage to the tree had been caused by the larvæ. The fact remains, however, that no damage has ever been detected in forests, where the Cicada emerges in countless myriads, the trees presenting as vigorous and robust a condition as in other districts where no cicadas occur, and this is true also of old original trees and planted trees in parks or private grounds. In orchards also where the insects have been so abundant that the ground was almost honeycombed after

[a] Proc. Acad. Nat. Sci. Phila., December, 1846 (1848), vol. 3, p. 133.

their emergence the trees themselves exhibited a good state of vigor and an inspection of the roots revealed no material injury save some small swellings or callosities with slight discoloration which might have resulted from the punctures.

The underground development of the Cicada is so very slow, thirteen or seventeen years being occupied in attaining a size which with other species is achieved in as many days or weeks, that the very slow absorption of nutriment from the roots can scarcely have any effect on them, and the only injury, and this is very slight, is probably due to a poisoning of the roots, perhaps by the beak of the insect, as indicated by the slight discoloration of the cambium at the point of puncture. Callosities and other irregularities are, however, rare, and have never been observed by the writer. Very often also there are, undoubtedly, long periods of rest or dormancy, during which no food at all is taken.

Referring to the injury noted by Miss Morris, it is a well-known fact that fruit trees have a natural term of life, and after twenty years they are very apt to show weakness and loss of vigor, and cease to be profitable. It is possible, therefore, that this is the true explanation of the condition of the trees noted by her rather than that it was due to the presence of the larvæ of the Cicada.

THE NATURAL ENEMIES OF THE CICADA.

The fact that the periodical Cicada appears above ground so rarely prevents its having any peculiar or specific parasitic or natural enemies. We can not conceive of any parasite breeding solely either in the adult Cicada or in its eggs which could persist during the long period of years when no host was available. Equally remarkable also would be a parasitic insect the term of whose life should be so extended that it could live in the body of the Cicada larva during the years of its slow growth beneath the soil. Of the larger enemies of the Cicada, such as birds and mammals, the habit of feeding on the Cicada is necessarily acquired anew with each recurrence of a Cicada year.

All these facts have a very potent influence in protecting the periodical Cicada, which, as we have already pointed out, is particularly helpless, and were it not for these natural protective influences the very existence of the species would probably be early brought to an end.

During their subterranean existence, the larvæ and pupæ, when near the surface, are doubtless subject to the attacks of various predaceous coleopterous larvæ, and many of them are unquestionably destroyed by this agency. Upon leaving the ground to transform they present an attractive food for many insectivorous animals, and the pupæ and transforming adults are vigorously attacked by many

different reptiles, mammals, and birds, and by cannibal insects, such as ground beetles, dragon-flies, soldier-bugs, etc., while such domestic animals as hogs and poultry of all kinds greedily feast upon them. The preference shown by hogs running wild in woods for the Cicada is especially marked, and we have elsewhere commented on the fact of their rooting up the ground to get the pupæ in April and May, before the cicadas have appeared at the surface of the ground for transformation. The birds are, perhaps, the most efficient destroyers of the Cicada, and, as we have already noted, the English sparrow is particularly destructive to them in and near cities, and, indeed, bids fair to completely exterminate them in such locations.[a]

In the perfect state they are attacked by at least one parasitic fly (*Tachina* sp.), which lives internally in the body of its host. One of the large digger wasps, to be later described, also preys upon the adult, provisioning its larval galleries with the stung and dormant cicadas. The Cicada is also attacked by a fungous disease, sometimes so abundantly as ultimately to destroy most of the male and many of the female insects.

In the egg state the Cicada has many very effective enemies, comprising mainly parasitic flies belonging to the orders Hymenoptera and Diptera, and also various predaceous insects belonging to the orders Hemiptera, Neuroptera, and Coleoptera. A number of well-known predaceous mites, and other mites whose habits seem to be predaceous in this particular, are also found associated with the eggs of the Cicada under such circumstances as to leave little doubt of their feeding upon the eggs. All of these insect and mite enemies of the Cicada are more or less general feeders, and are simply attracted in numbers to the Cicada, and especially to the eggs in the case of the egg parasites, on account of the abundance of the food presented. In other words, we are furnished with a striking example merely of ready adaptation to new and favorable conditions. This is true also of the fungous disease of the Cicada, which is probably normally present in other species of Cicada which are annual in appearance.

[a] This is well illustrated by the following experience in 1902 (Brood X) in the city of Washington, as recorded by the writer: "Within the city very few of the cicadas which came out survived more than a few hours, being quickly snapped up and destroyed by the English sparrow. The numbers within the city were greatly diminished by the English sparrow at the appearance seventeen years ago, the destruction by this bird at that time having been noted by Professor Riley and others to be very considerable. The sparrows' work this year, however, was much more effective, the cicadas being fewer in numbers; and I doubt whether a single individual, certainly very few, ever reached the egg-laying period. For two or three days in the midst of the trees on the Museum grounds a few song notes were heard, but ceased very soon. In the woods in the country about the city, especially out toward Chevy Chase, the Cicada appeared in very considerable numbers, and here did not suffer very much from the attacks of birds, and for the most part went through the normal aerial existence successfully." (Proc. Ent. Soc. Washington, V, 1903, p. 24.)

INSECT PARASITES.

As already noted, among the more effective natural enemies of the Cicada are the other insects which prey upon the eggs in the twigs, on the newly-hatched larvæ, and also, but to a much less extent, on the adults. The more common and characteristic of the insect enemies of the different stages of the periodical Cicada are given below:

Dipterous Enemies.

Some four species of two-winged flies have been found to subsist as larvæ on the eggs of the Cicada, but none of these has been reared to the adult stage and, therefore, their specific identification is impossible.

One of these bears some resemblance to an asilid, or, perhaps, more remotely, to a bombylid larva, and was found by Mr. E. W. Allis at Adrian, Mich., feeding on the contents of the eggs of the Cicada, piercing the thin shells and extracting the juices. These larvæ are very minute, not much exceeding a millimeter in length.

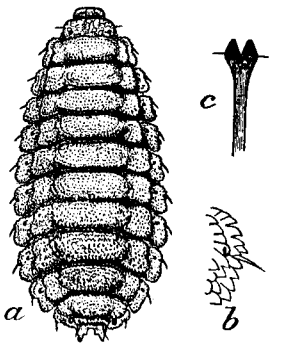

Fig. 52.—Cecidomyiid egg parasite of the periodical Cicada: Larva, much enlarged, with anatomical details at side. (Original.)

The most interesting of the dipterous egg parasites is a cecidomyiid, which was found in February, 1886, with eggs deposited in sumac the previous season. When examined, all the eggs had hatched except in some instances where they had been sealed up by the rapid growth of the wood, so as to prevent the escape of the larvæ. One of the eggs thus inclosed was of an orange color, in distinction from the normal yellowish-white, and from it, on March 2, an orange-colored cecidomyiid larva emerged. Other larvæ, apparently of the same species, were secured in May from eggs in alder twigs. From none of these, however, were adult flies obtained. The larvæ ranged in length from 1 to 1.5 millimeters. Their general characteristics are indicated in the accompanying illustration (fig. 52).

The fly parasite of the adult Cicada seems to belong to the family Tachinidæ, which includes a number of species similarly attacking grasshoppers as well as many other insects. The larvæ of these flies, which have not been carried to the adult stage, sometimes to the number of half-dozen or more, will occur together in the body of a Cicada, which they have almost or quite completely eaten out.

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Hemipterous Enemies.

A few predaceous Hemiptera were found associated with Cicada eggs under such circumstances as to leave little doubt but that they were subsisting on them. Among these were two species of Thrips, which were found both in the larval and adult stages in several instances about the eggs on which they had been feeding. The material that has been preserved of these Thrips is not now in condition to be worked up. Both species are probably undescribed.

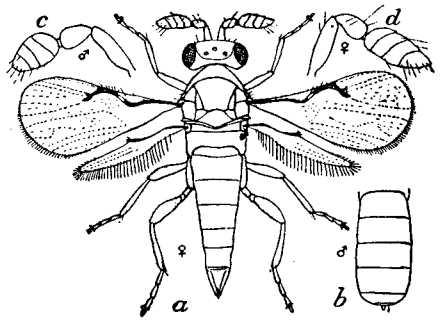

Fig. 53.—Egg parasite, *Lathromeris cicadæ: a*, female; *b*, abdomen of male; *c*, antenna of male; *d*, antenna of female. All greatly enlarged (original.)

Hymenopterous Enemies.

The hymenopterous enemies of the Cicada comprise a number of egg parasites, which are the more important agencies in limiting the numbers of the insect, and the large digger wasp already mentioned. The fact that the eggs and the newly hatched larvæ are much sought after by various species of ants was early commented upon, Doctor Potter stating that they are constantly infested by legions of ants, both before and after they are hatched. He says:

> Even the little red species, the most diminutive of the race, will shoulder the eggs and the young and bear them off to their cells. In all our researches we found them in battalions systematically arrayed for wholesale plunder and devastation.

Doctor Smith corroborates Professor Potter, stating that he has himself observed a small red ant, scarcely as large as its intended victim (a young Cicada larva), seize the latter, shoulder it, and start off at a great speed.

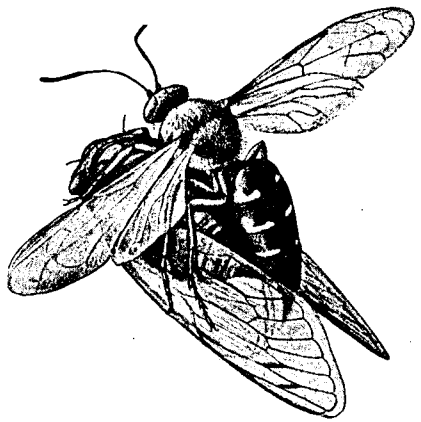

Fig. 54.—Female Sphecius carrying a Cicada to her burrow. Natural size (after Riley).

The Parasites of the Eggs.

Several egg parasites were reared from the eggs of the Cicada, but with one exception were not abundant in the course of extensive breedings. Single individuals were secured of a mymarid, a trichogrammid, and two chalcidids. The excepted species, however, has been reported as occurring in enormous numbers, and warrants a more careful account.

Attention seems to have been first called to this parasite by Mr. William T. Hartman in a letter dated October 5, 1868, to Doctor Walsh. In this Mr. Hartman states that in getting some twigs, from

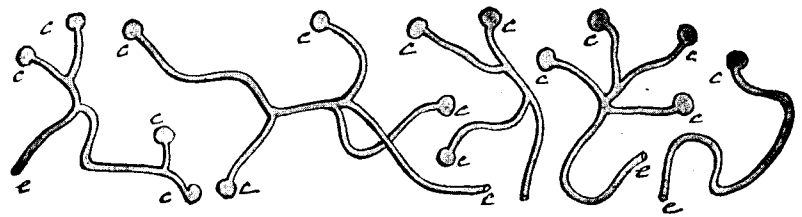

Fig. 55.—Burrows of *Sphecius speciosus: c, e, e*, main entrance; *c, c, c, c*, chambers for larvæ and their food. Greatly reduced (after Riley).

which he hoped to obtain the larvæ of the Cicada, from an oak which had been very thickly oviposited in, he found, after leaving the tree, that his head and clothes were covered with what seemed to be small red flies. The branches secured were kept in his office for several days and the little red flies appeared again in countless numbers. The examination of these flies under a microscope showed that they were minute Hymenoptera instead of Diptera, as he first supposed. He obtained very few larvæ of the Cicada from these shoots, and consequently inferred that practically all of the eggs had been parasitized by this insect. He states also that a neighbor of his trapped thousands of them in the soft paint which had been newly applied to his window shutters, and that by the middle of August this minute parasite was "everywhere in force."

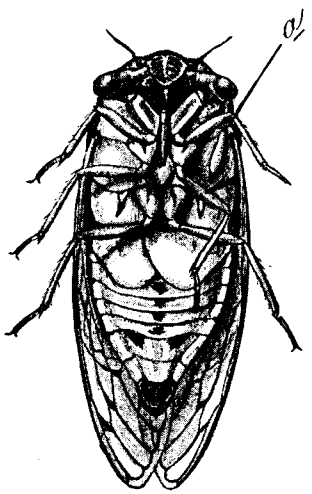

Fig. 56.—Adult Cicada with Sphecius egg attached at *a*. Natural size (after Riley).

What is probably the same insect (fig. 53) was reared in some egg-infested twigs collected by Mr. T. Pergande in Virginia in July, 1885. Doctor Howard has examined these specimens, and pronounces them to be a new species of a European genus not hitherto recorded from this continent, and has described them under the name *Lathromeris cicadæ*.[a] The life cycle of this minute parasite is evidently so short that it is possible for it to pass through two or three generations

[a] Canadian Entom., vol. 30, April, 1898, pp. 102, 103.

within the egg period of seven or eight weeks of the Cicada, and this accounts for its excessive multiplication, as described by Mr. Hartman, and probably makes it wherever it occurs one of the most efficient agencies in keeping the Cicada in check.

THE LARGER DIGGER WASP.

I have already referred to the probability of the larger digger wasp (*Sphecius speciosus* Dru.) preying on belated individuals of the periodical Cicada. That the bulk of the brood has disappeared, however, before this wasp becomes at all abundant has been often pointed out and is not to be questioned, and it is well known that the most of its work is with the later-appearing dog-day harvest fly (*Cicada tibicen* L.). With the assistance of Mr. Pergande and the writer, Professor Riley worked out the natural history of this wasp in detail in its relation to the dog-day harvest fly, and published a full illustrated account of the species.[a] Its life habits when it preys on the periodical Cicada are identical with its habits with the dog-day species or any other annual Cicada with which it may store its burrows. A brief account of the habits of this wasp is here reproduced, together with the figures illustrating its very curious and interesting life stages. (See figs. 54–60.)

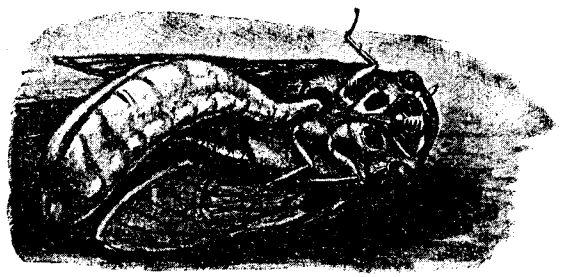

FIG. 57.—Cicada in burrow of Sphecius, with full-grown larva of latter feeding. Natural size (after Riley).

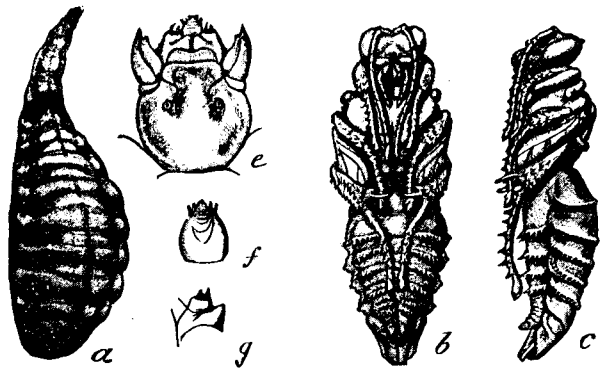

FIG. 58.—*Sphecius specciosus: a*, larva; *b*, pupa, from below; *c*, same, from side, natural size; *e*, head of larva; *f*, labium of same; *g*, maxilla of same. Enlarged (after Riley).

[a] Insect Life, Vol. IV, March, 1892, pp. 248–252.

This wasp and its near allies are the natural and perhaps the most destructive of the insect enemies of the adults of the different species of the Cicada, and their operations are often witnessed and are commented upon in print nearly every season. In fact, no more curious and interesting illustration of the wars which take place in the insect world is afforded than the sight of one of these wasps seizing its victim and silencing and paralyzing it with a sting, which, while throwing it into a comatose condition from which it never recovers and suspending or greatly reducing its vital functions, does not actually kill it, but leaves it an unresisting, living prey for the delicate wasp larva.

The fact that some tragedy is being enacted is often brought to the attention of the observer by the sudden cessation of the regular song note of the unsuspecting Cicada. The song ends in a sharp cry of distress, and if one is in position to witness the struggle the wasp may be seen grasping its victim and endeavoring to take flight, the quick thrust of its sting having almost immediately quieted the Cicada. Very often in the first struggle the wasp and the Cicada fall to the ground together, and it is necessary for the former laboriously to climb the tree again, dragging the Cicada with it, in order to take flight from an elevated point, the Cicada being usually much heavier than the wasp and bearing the latter slowly to the ground as it flies. For this reason it often becomes necessary for the wasp to carry the Cicada several times up into near-by trees, making repeated short flights before it reaches its burrow.

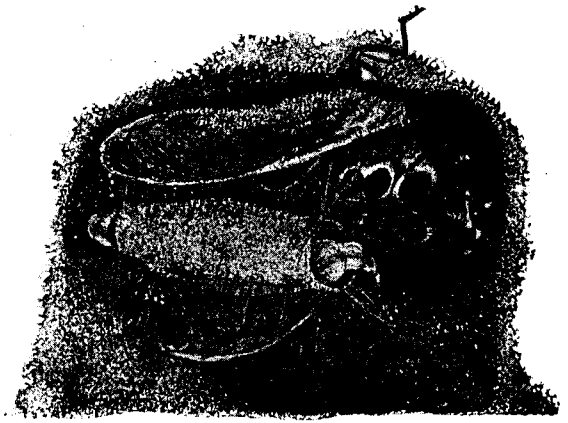

FIG. 59.—Larva of Sphecius spinning its cocoon. Natural size (after Riley).

The latter is excavated with great activity by the wasp, the drier and more elevated situations being usually chosen. The burrow ranges from 18 inches to 2 or 3 feet in length and has three or four or more branches of from 6 inches to a foot in length, each terminating in a little oval chamber. Within each of these chambers is stored a Cicada to which a single wasp egg is attached in such manner as to be covered and protected by one of the middle legs of the Cicada.

The parasitic larva on hatching merely protrudes its head and makes an opening into the body of its host at some suture where

entrance is easy, and slowly feeds on the soft, juicy interior. The larva remains outside of the Cicada throughout its life, but by means of its very extensile anterior segments, or neck, thrusts its small head throughout the interior of the Cicada and gradually exhausts the soft parts until the Cicada becomes a mere broken shell. The wasp larva increases in size very rapidly, ultimately attaining a length of 1½ to 2 inches. It is then nearly white in color, with the head and mouth parts remarkably well developed and the anterior segments narrowed and capable of very great extension. The whole transformation from the egg to the full-grown larva is comprised in a very brief period, the egg hatching after two or three days and the larval life not much exceeding a week.

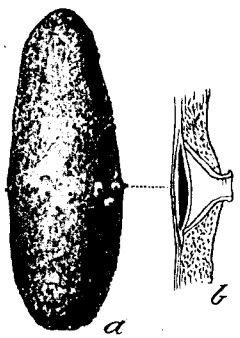

FIG. 60.—*a*, cocoon of Sphecius, natural size; *b*, enlarged section of pore. (After Riley.)

When fully grown the larva constructs a cocoon in a very peculiar manner. First a cylinder, open at both ends, is formed of earth with enough silk incorporated to form a rather dense and tough pod. When the cocoon is nearly completed the ends are capped, and the larva remains unchanged over winter and transforms to a pupa in the spring or early summer shortly before the appearance of the mature insect. About the center of the cocoon are a number of very curious structures which may serve as breathing pores until the larva has become accustomed to its new conditions, since they are ultimately sealed over, as represented in the illustration (fig. 60, *b*).

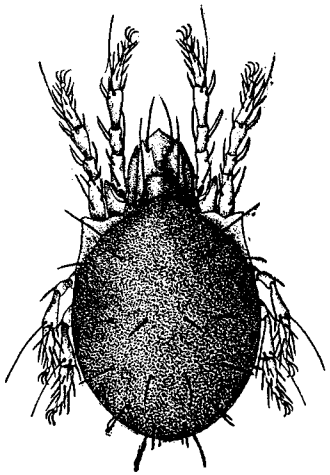

FIG. 61.—Mite egg parasite, *Oribatella* sp. (Author's illustration).

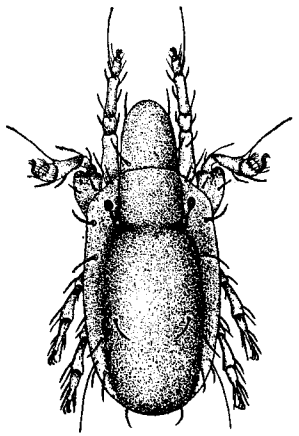

FIG. 62.—Mite egg parasite, *Oripoda elongata*. (Author's illustration).

Most of the fossorial wasps have habits very similar to this species, but many of the other genera provision their nests with the larvæ of Lepidoptera or with Orthoptera or sometimes with the larger spiders.

MITE PARASITES OF THE EGGS.

Of the mites found either preying on the eggs of the Cicada or associated with them in such manner as to suggest a predaceous habit, several represent species which are well known to subsist on soft-bodied insects or other animal food. An almost equal number, however, belong to a family of mites, the Oribatidæ, which, so far as the habits of the species are known, comprises, with few exceptions, strictly herbivorous mites, or such as subsist on vegetable decay. A few species, however, of this family possess mouth structures which indicate that they usually prey on other insects, and some of them are known to feed on decaying animal substances. In this country two species have been recorded as being true insect parasites, namely, *Nothrus ovivorus* Pack. and *Oribata aspidioti* Ashm., the former having been observed to suck the eggs of the canker-worm, and the latter to feed on scale insects in Florida. The types of these two species have not been preserved, and there is some doubt as to their correct reference.

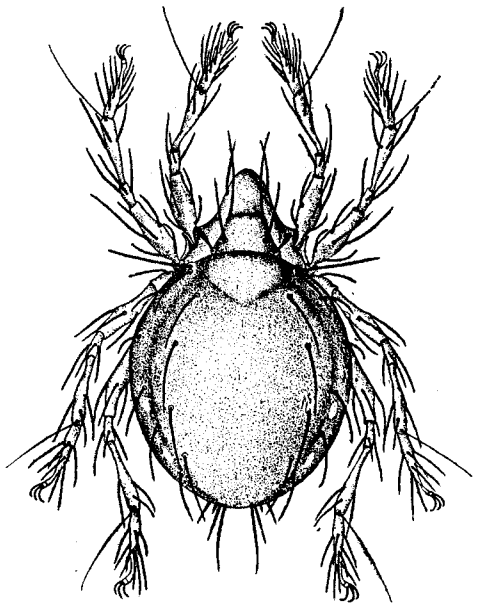

FIG. 63.—Mite egg parasite, *Oppia pilosa*. (Author's illustration).

All of the mites associated with the eggs of the Cicada, both those of doubtful and those of well-known predaceous habits, were invariably found in the egg slits, down among the woody fibers, where they could have little choice of food except that supplied by the Cicada eggs. In no case were the mites actually observed to be feeding on the eggs, but frequently the eggs were more or less shriveled and the contents extracted.

All of the mites referred to below have been examined for me by Mr. Nathan Banks, a specialist in this group, who has identified and described the material as far as its condition, as balsam mounts, permits. The accompanying illustrations are from very careful drawings

made several years since by Mr. Pergande, who collected several of the mites and mounted and made preliminary studies of the others. Much of the material was collected by Mr. E. W. Allis at Adrian, Mich., in 1885, the balance by Mr. Pergande in the District of Columbia and near-by Cicada districts in Virginia in the same year.

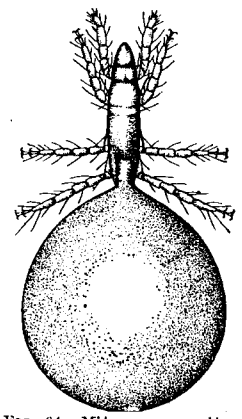

FIG. 64.—Mite egg parasite, *Pediculoides ventricosus*. (Author's illustration.)

THE ORIBATID MITES.

The members of the family Oribatidæ have the popular designation of "beetle mites," arising from their possessing a hard chitinous covering causing them to resemble minute beetles. Some six distinct species were found in the adult stage associated with the eggs of the Cicada, and several nymphal forms—the latter being often showily colored and the principal feeding stage of these mites.

The following are Mr. Banks's determinations of the oribatid material: (1) *Oribata* sp., collected by Mr. Pergande in the District of Columbia in July, 1885; (2) *Oribatella* sp. (fig. 61), collected by Mr. E. W. Allis at Adrian, Mich., in October, 1885; (3) *Oripoda elongata* Bks., MS. (fig. 62), collected with the last; (4) *Oppia pilosa* Bks. (fig. 63), also collected at Adrian, Mich.; (5) *Oribatula* sp., collected by Mr. Pergande in the District of Columbia and in Virginia in July, 1885; (6) Oribatid nymphs, collected with the last and possibly belonging to the same species; (7) *Hoplophora* sp., collected by Mr. Allis in Michigan in October, 1885.

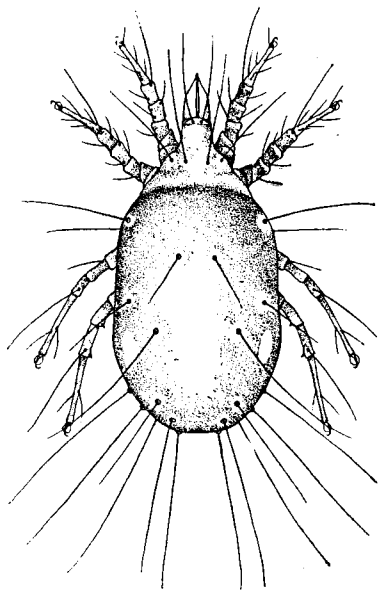

FIG. 65.—Mite egg parasite, *Tyroglyphus cocciphilus*. (Author's illustration.)

MISCELLANEOUS PREDACEOUS MITES.

The following mites have well-known predaceous habits and for the most part are miscellaneous feeders, subsisting on almost any available animal matter, such as soft-bodied insects, insect eggs, and various animal and also vegetable food products.

Perhaps the mite most commonly found with the eggs of the Cicada is *Pediculoides ventricosus* Newp. This species has a very general feeding habit and is often an active agent in the destruction of the eggs or young of insect pests. In breeding cages it is often a nuisance by destroying the smaller insects being kept under observation. The general form of the male and of the unimpregnated female of this mite is similar to that of the next species listed. The gravid female, however, develops an enormous globular extension from the tip of her abdomen, as illustrated in the accompanying figure (fig. 64).

Another predaceous mite, not at all uncommon, in the egg slits of the Cicada, both in the District of Columbia and in Michigan, is *Tyroglyphus cocciphilus* Bks. (fig. 65), very near *T. longior* Gerv., which species it very closely resembles. The species named is a widely distributed one and frequently occurs also in breeding cages, and often becomes very troublesome from its presence in enormous numbers on various food substances in the larder. A smaller species of the same genus was found with the Cicada eggs, but the material is not in good enough condition to make its identification possible.

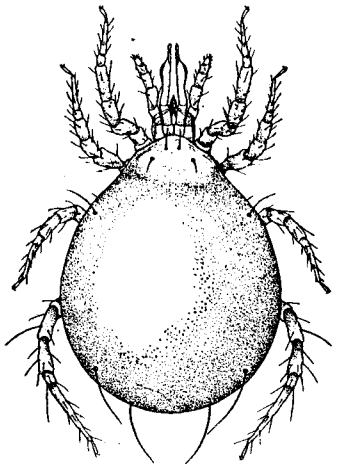

FIG. 66.—Mite egg parasite, *Iphis ovalis*. (Author's illustration.)

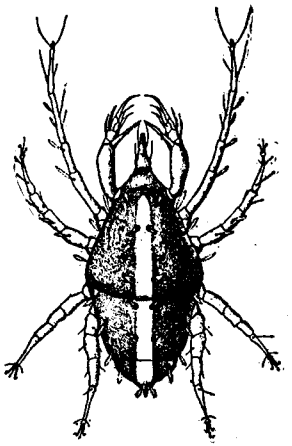

FIG. 67.—*Cheyletus* sp., mite egg parasite of Cicada. (Author's illustration.)

A species belonging to the family Gamasidæ was found by Mr. Allis associated with the eggs of the Cicada (fig. 66). It is apparently an undescribed species and is certainly distinct from the half dozen known from North America. Mr. Banks has suggested for it the name *Iphis ovalis*. The family to which it belongs includes true insect parasites which either live free or attached to their hosts, and there is little doubt but that this mite was attracted by the Cicada eggs.

Two mites, one belonging to the genus Cheyletus (fig. 67) and the other to the genus Bdella (fig. 68), were found associated with the eggs of the Cicada in Virginia in July, 1885. Both of these mites seem to be undescribed, but the material is not in good enough condition to warrant their description. Both genera are known to be carnivorous, and the specimens secured had doubtless been preying on the Cicada eggs.

THE VERTEBRATE ENEMIES.

Under this heading I will supplement merely the general statements given elsewhere on the destruction of the Cicada by birds, mammals, etc., by quoting the observations of Mr. A. W. Butler, who devoted considerable attention to the natural enemies of the Cicada in 1885 in southeastern Indiana. His lists and notes, which follow, could be much extended and, if all the enemies of the Cicada were known, would doubtless include all the insectivorous birds and mammals occurring within the range of this insect. He says:

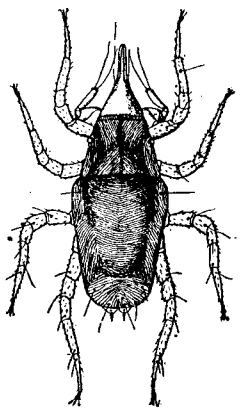

FIG. 68.—*Bdella* sp., mite parasite of eggs of Cicada. Greatly enlarged (author's illustration).

[a] Among birds the English sparrow, *Passer domesticus* (Linn.), is perhaps its greatest enemy. Within one week from the date of the appearance of the Cicada in Brookville not one could be found, and I doubt if a single specimen was permitted to deposit its eggs, owing to the persistent warfare waged by this garrulous sparrow.

Of native birds the robin, *Merula migratoria* (Linn.); blackbird, *Quiscalus quiscula æneus* (Ridg.); catbird, *Galeoscoptes carolinensis* (Linn.); red-headed woodpecker, *Melanerpes erythrocephalus* (Linn.); flicker, *Colaptes auratus luteus* Bangs; towhee, *Pipilo erythrophthalmus* (Linn.), and orchard oriole, *Icterus spurius* (Linn.) were their greatest enemies. Food of every other sort appeared to be neglected in order that they might feast for a limited period upon the easily captured Cicada.

Of other birds examined, the following contained Cicada remains: Brown thrasher, *Toxostoma rufum* (Linn.); Baltimore oriole, *Icterus galbula* (Linn.); scarlet tanager, *Piranga erythromelas* Vieill.; blue-gray gnatcatcher, *Polioptila cærulea* (Linn.); worm-eating warbler, *Helmitherus vermivorus* (Gmel.); purple martin, *Progne subis* (Linn.); wood pewee, *Horizopus virens* (Linn.); wood thrush, *Hylocichla mustelina* (Gmel.); yellow-throated vireo, *Lanivireo flavifrons* (Viell.); cardinal grosbeak, *Cardinalis cardinalis* (Linn.); tufted titmouse, *Bæolophus bicolor* (Linn.); Carolina chickadee, *Penthestes carolinensis* (Aud.); chipping sparrow, *Spizella socialis* (Wilson); downy woodpecker, *Dryobates pubescens medianus* (Swains); crested flycatcher, *Myiarchus crinitus* (Linn.); indigo bird, *Passerina cyanea* (Linn.); cow bird, *Molothrus ater* (Bodd.); white-bellied nuthatch, *Sitta carolinensis* Lath.; yellow-billed cuckoo, *Coccyzus americanus* (Linn.); black-billed cuckoo, *C. erythrophthalmus* (Wilson); American goldfinch, *Astragalinus tristis* (Linn.); crow, *Corvus brachyrhynchos* Brehm, and cedar bird, *Ampelis cedrorum* (Vieill.).

But two specimens of all the birds examined showed no evidence of cicada-eating. These were the cerulean warbler, *Dendroica cerulea* (Wilson), and the warbling vireo, *Vireosylva gilva* (Vieill.). Most birds eat only the softer parts, but some species—the robin, brown thrasher, towhee, and a few others—eat also the wings and legs, and even occasionally the head.

I found fox squirrels, *Sciurus rufiventer* Geoffroy, eating them, the young showing greater fondness for this food than did their parents. The ground squirrel, or chipmunk, *Tamias striatus* Baird, was very fond of them. I have seen this mammal climb to the highest limbs of an apple tree seeking cicadas.

When cicadas fell into our streams many of them became the prey of various species of fish. Our fishermen complained of their inability to get fish to take the hook while they were feeding upon this new food. The remains of this insect were found in black bass, *Micropterus salmoides* Henshall; blue catfish, *Ichthælurus punctatus* Jordan, and white sucker, *Catostomus teres* Le S.

Rev. D. R. Moore, a valued fellow-worker, found two species of snails, *Mesodon exoleta* Binn., and *M. elevata* Say, feeding upon dead Cicadas. This fact was a great surprise to me. But few instances were recorded of digger wasps killing these insects. *Stizus grandis* Say [a] was the only species observed. Aside from the enemies mentioned above, there were many others to which I could not direct my attention. In general, it may be said that beetles, spiders, and other insect enemies prey upon them incessantly, while parasitic flies, scavenger beetles, and ants destroy great numbers of their dead bodies.

[a] The nomenclature of the birds and mammals mentioned in this extract has been revised for this bulletin by Mr. Harry C. Oberholser, of the Bureau of Biological Survey, U. S. Department of Agriculture.

THE FUNGOUS DISEASE OF THE ADULTS.

The peculiar fungous disease of the adult cicadas was noticed by Dr. Joseph Leidy in the Proceedings of the Philadelphia Academy of Sciences for 1851, page 235, and has since been described as *Massospora cicadina* by Prof. C. H. Peck.[b] Mr. W. T. Hartman, of West Chester, Pa., speaking of the occurrence of this fungus in 1851, says:

> The posterior part of the abdomen in a large number of male locusts was filled by a greenish fungus. * * * The abdomen of the infected males was usually inflated, dry, and brittle, and totally dead while the insect was yet flying about. Upon breaking off the hind part of the abdomen, the dust-like spores would fly as from a small puffball.

One male specimen, received in 1868 from Pennsylvania, was affected by the same or a similar fungus, the internal parts of the abdomen being converted into what appeared to be a brown mold. R. H. Warder, of Cleves, Ohio, in speaking of this mold, says:

> I found that in many cases the male organs of generation remained so firmly attached to the female during copulation that the male could only disengage himself by breaking away and leaving one or two posterior joints attached to the female, and it is these mutilated males which I found affected by the peculiar fungus mentioned, and therefore conclude that the dry rot might be the result of the broken membranes.

[a] Synonymous with *Sphecius speciosus* Drury.

[b] Thirty-first Rept. N. Y. State Museum Nat. Hist., 1879, p. 44.

It is well established, however, that both males and females are affected by this disease, the former, however, in the greatest numbers, and that it is by no means confined to injured individuals.

Professor Peck describes this disease in general terms as follows:

> The fungus develops itself in the abdomen of the insect, and consists almost wholly of a mass of pale-yellowish or clay-colored spores, which to the naked eye has the appearance of a lump of whitish clay. The insects attacked by it become sluggish and averse to flight, so that they can easily be taken by hand. After a time some of the posterior rings of the abdomen fall away, revealing the fungus within. Strange as it may seem, the insect may, and sometimes does, live for a time in this condition. Though it is not killed at once, it is manifestly incapacitated for propagation, and therefore the fungus may be said to prevent to some extent the injury that would otherwise be done to the trees by these insects in the deposition of their eggs. For the same reason, the insects of the next generation must be less numerous than they otherwise would be, so that the fungus may be regarded as a beneficial one. In Columbia County the disease prevailed to a considerable extent. Along the line of the railroad between Catskill and Livingston stations many dead cicadas were found, not a few of which were filled by the fungoid mass.[a]

Professor Peck was not able to satisfy himself as to the time when the Cicada is attacked by this fungus, suggesting the possibility of its having entered the ground with the larva and slowly developed with its host, or perhaps entering the body of the pupa at the moment that it emerges from the ground, with the third possibility of its developing annually in the cicadas which appear every year, and becoming much more abundant, and therefore noticeable, in the years of the appearance of the great swarms of periodical cicadas. The latter supposition is unquestionably the correct explanation. Mr. A. W. Butler refers to this disease at some length in his notes on the Cicada in southern Indiana in 1885, and is of the opinion that nearly all of the male cicadas which are not killed by birds and other enemies ultimately succumb to this disease.

REMEDIES AND PREVENTIVES.

THE GENERAL CHARACTER OF THE PROBLEM.

In discussing this subject it is well to be again reminded that the fears aroused by the presence of this insect when in great numbers are unquestionably out of all proportion to the real damage likely to be done. While they are most abundant in old and undisturbed forest tracts and confine their work for the most part to forest trees, it is true also that in parks and lawns, especially such as contain trees of the original forest growth or their natural and immediate successors, the cicadas sometimes appear in scarcely diminished numbers. This is true also of orchards located on cleared lands or in the vicinity of standing forests, and under such circumstances instances of serious or fatal results to cherished plants or fruit trees are not uncommon.

[a] Loc. cit., pp. 19,20.

Notwithstanding the occasional instances of serious injury by the Cicada, it is probably still true that there is no other important injurious insect in this country that is responsible for so little serious damage in proportion to the fears aroused, and yet every recurrence of this insect calls forth the most anxious demands for means of control or extermination. The exploitation of the facts concerning this insect is, therefore, more to allay such fears, and to supply the desire for information concerning it which its presence always arouses, than from the necessity of detailing elaborate precautionary measures.

It is, nevertheless, important to know what may be done in the way of protection and control whenever occasion arises to make such action necessary, as for the protection of young fruit trees which are especially exposed to injury or trees and shrubs over limited areas, as in parks and lawns.

Precautionary operations are necessarily against the adults chiefly, as being the authors of the greater damage. Against the larvæ and pupæ in their subterranean life it is hardly worth while to take any action unless it be deemed desirable to attempt to exterminate a brood within a given territory or bit of woodland, in which case the remedies commonly employed against other subterranean insects, such as the Phylloxera or other root lice, will serve for this insect equally well, especially in the first year or two of its existence.

The prevention of injury from the Cicada includes, therefore, (1) methods of destroying the emerged insects, either mechanically or by insecticide applications; (2) applications to the plant to prevent oviposition; (3) certain precautionary measures which may be taken to lessen injury; and (4) operations to destroy the larval and pupal stages in the soil.

MEANS OF DESTROYING THE EMERGED PUPÆ AND ADULTS.

Collection of Adults.

In some instances the hand collection of the insects is feasible and will prevent damage. This method necessitates the continual driving of the insects from the plants by fighting or collecting them in umbrellas or bags in the early morning or late evening when they are somewhat torpid and sluggish. If undertaken at the first appearance of the Cicada and repeated each day, the work of control will be facilitated by the fact that most of the insects will be on the young trees or shrubbery or on the lower branches of larger trees and within comparatively easy reach.

An instance of this kind of work is recorded by Mr. Abner Hoopes, of West Chester, Pa.[a] The work reported was for the protection of nursery stock on the edge of woods from the attack of Brood X in

[a] Entomological News, Vol. XVIII, March, 1907, pp. 108, 109.

1902. There were 240,000 peach trees in the field to be protected, and seven men were kept at work in this field for over two weeks, and by actual count it was found that these men killed more than 1,000 cicadas each per day by hand collecting. Seventy thousand cicadas were collected in this field alone, and other men were employed in the smaller fields, so that Mr. Hoopes feels sure that at least 100,000 were killed altogether. In spite of this work, however, a loss of 12,000 trees was sustained out of the 240,000.

Destruction with Insecticides.

The various treatments aiming at the destruction of the insects themselves have yielded satisfactory results, but to have any practical value it is necessary to continue them daily or as long as the insects issue in any numbers. On a large scale, therefore, or over a considerable territory, in the presence of immense swarms, work of this sort will be ordinarily out of the question. The recommendations apply particularly, therefore, to small areas or orchards. Such work may be directed against the Cicada the moment it emerges from the ground, while still in the pupal stage, but perhaps more readily and successfully against the insect after it has shed its pupal skin and is still soft and comparatively helpless, and with less ease, but still with some degree of effectiveness, after it has hardened and begun its aerial duties.

Of the many substances experimented with few proved to be of much value, the best results being obtained with (1) pyrethrum or insect powder, using it both in the dry form and as an aqueous solution; (2) kerosene emulsions; and (3) solutions of various acids. These substances either effected the immediate death of the insect, or attained this end indirectly by preventing its transformation from the pupal to the adult stage; in other words, rendering the last molt impossible.

Pyrethrum powder is a perfectly satisfactory destroyer of the newly transformed and soft cicadas, and has considerable efficacy against the mature and hardened individuals. The best results are obtained in the morning, before the insects have gained full strength to ascend and while the plants are still wet with dew. The powder may be puffed on the insects while clinging to shrubbery or on the lower branches of the larger trees.

Pyrethrum powder is absolutely worthless against the pupæ, which even when thoroughly coated with it, will often succeed in casting off their powdered skins and escape uninjured. The winged insects are, however, very sensitive to the powder, and after an application soon show signs of uneasiness and in the course of a few hours fall helpless to the ground, where, though they may continue to have the power of motion for a day or more, a fatal termination is almost sure to follow.

The pyrethrum and water mixture is prepared by stirring up as much of the powder as the water will hold in suspension, or a little milk may be added to increase the holding power of the water. The results obtained with pyrethrum in water against the transformed insects are as satisfactory as with the dry powder, with the additional advantage of its being possible to throw the water by force pumps to parts of the plant where it would be difficult to place the powder. Against the pupæ, the water solution is more effective than the powder, but is less so than kerosene emulsion.

Kerosene emulsion, as an application for destroying the emerged pupæ and adults, is used in very strong solution, or at a strength ranging from one part of the emulsion to one of water up to a dilution of the emulsion with eight parts of water. The greater strengths were more immediate in their effects, but even with the more diluted washes very satisfactory results have been obtained. The emulsion at once stops all molting or transformation. Applied to the partly transformed insects, the soft wings harden into shapeless masses, and while occasional individuals may survive the treatment for two days or more, the application is usually fatal in the end. The treated pupæ are unable to transform to the adult stage and they eventually die or are devoured by their natural enemies. The death of the mature and hardened insect is caused by closing its breathing pores with the oily mixture, and in the case of the partly expanded or soft, immature individuals by the caustic effect it has on the forming wings and soft body.

The experiments with acids demonstrated also that exuviation may be prevented by spraying the newly emerged pupa with a 2 per cent solution of carbolic acid or a 15 per cent solution of acetic acid.

Applications to Prevent Oviposition.

All the early experiments with washes or other applications to prevent oviposition proved unavailing except such protections as could be applied to small trees or shrubs, such as covering them with netting. Professor Riley in 1868, and later, at his instance, Dr. W. S. Barnard, tested a number of repellent substances, such as kerosene emulsion, various oils, and carbolic-acid solutions, all pungent and disagreeably smelling substances, with results either unsatisfactory or of negative value.

In the occurrence in 1902 of Brood X some indications were obtained showing the possible protective value of lime washes. Mr. Slingerland reports that spraying a heavy coat of whitewash on the trees will keep the locusts away to some extent when there are other trees in the neighborhood. He states that the reason for this seems to be that the insects do not like to sit on a white surface. The

females will, however, oviposit on whitewashed twigs if there is no other place for them.

The experience reported by Mr. W. B. Alwood[a] would seem to indicate that the injury from the Cicada in orchards is prevented by the use of Bordeaux mixture. The cicadas appeared in full force in a young orchard which had been sprayed with this mixture, but practically all migrated elsewhere without ovipositing in the trees. Other orchards near the one referred to by Mr. Alwood were badly punctured. In view of this experience it may be that Bordeaux mixture or the lime-sulphur wash will prove a valuable preventive of injury from this insect.

Precautionary Measures.

In view of the difficulty of controlling this insect on a large scale after it has once emerged, it is well to adopt any precautionary measures that may tend to lessen or distribute the injury. The advent of all the large and well-recorded broods is commonly heralded in advance in the local papers by State entomologists or other persons who take interest in such recurrences. Forewarned in this way, much injury and loss may be avoided by neglecting all pruning operations during the winter and spring prior to the expected appearance of the Cicada in order to offer a larger twig growth and distribute by this means the damage over a greater surface. Another precaution, when a Cicada year is expected, is to defer the planting of orchards, especially in the vicinity of old orchards or forest land, until the danger is past. The same advice applies to budding or grafting operations in the fall and spring prior to the Cicada's appearance. Much disappointment arising from injury to orchards or valuable nursery stock may thus be avoided. Vigorous young trees will, it is true, often recover in three or four years from the effects of a loss of or injury to a considerable percentage of their branches, but it is difficult to overcome the unsymmetrical appearance which will commonly result from the indiscriminate pruning caused by the work of this insect, and the gnarled and scarified branches will long bear testimony to the industry of the female insect.

Much of the injury occasioned by the cutting of the twigs by the female Cicada in depositing her eggs can be remedied by subsequent proper treatment of the wounded plant. In the case of old trees, the main object to be secured is the rapid healing of the wounds and the prevention of their being used as points of secondary attack by other insects. The worst injured limbs in such trees should be cut out, so that all the vigor of the plant may be directed to the remaining wood. Any treatment also, as of thorough cultivation or the use of fertilizers, which will give the plant a more vigorous growth, will hasten the healing process. With young trees the worst affected branches should be removed, and the less injured ones protected from other insects while they are healing by coating the wounded parts with grafting wax or a moderately hard soap. These protective coverings should be renewed at least once a year, preferably in the spring, until the wounds are entirely healed over. In the case of a badly injured tree that has been recently budded or grafted, it may be well to cut it back nearly to the bud or graft, so that an entirely new top may be made.

[a] Proc. 15th Ann. Mtg. Assn. Economic Entomologists, Bul. 40, Bur. Ent., p. 75.

Means against the Cicada in its Underground Life.

While it is probably true, as we have already stated, that the Cicada in its underground life does not work any serious injury to plants on account of the very insignificant amount of nutriment which it annually draws from the rootlets, nevertheless in exceptional cases, where the ground is suspected of being very thickly populated with the larvæ and pupæ of this insect, it may be deemed desirable to undertake their extermination. This may be accomplished, as suggested, by using the remedies ordinarily employed against other subterranean insects, such as the Phylloxera and the apple root-aphis, with this difference, that the poisons will have to be introduced more deeply into the soil unless applied in the first or second year after the larvæ have begun their development.

If taken in time, the number of the larvæ in the soil may be greatly reduced by cutting off the branches of the trees which have been thickly oviposited in, thus preventing the hatching of the eggs. It will rarely, however, be possible to so completely eliminate the eggs from the tree as to prevent the entrance of the larvæ into the soil in considerable numbers.

Of the means employed against subterranean insects two are especially suitable for the destruction of the larvæ and pupæ of the Cicada—namely, bisulphid of carbon injected into the ground and tobacco dust incorporated in the soil.

Tobacco dust has a manurial value and is not at all injurious to plants. Its value against Cicada larvæ is purely theoretical, but there is little doubt but that if it can be incorporated in the soil some distance below the surface—namely, by first removing 6 inches or more of the top soil—it will effect the destruction of many of the delicate larvæ and pupæ of the cicadas. This dust is a waste product of tobacco factories and costs about 1 cent per pound, and is worth nearly its cost as a fertilizer.

Bisulphid of carbon, the popular French remedy for the grape root-aphis, will undoubtedly prove an efficient means against the Cicada in

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its underground life. It will be necessary, however, except in the first year or two of the existence of the larvæ, to inject it to a depth of at least 12 inches below the surface. It should not be introduced into the soil closer to the crown of young plants than 1½ feet, and not more than an ounce of the chemical should be introduced into each hole, which should be immediately closed. An injection should be made to about every square yard of surface. The bisulphid rapidly evaporates and penetrates throughout the soil, and is very deadly to insects. It is highly inflammable, and should not, therefore, be poured from one vessel to another near a fire. It may be introduced into the soil by means of injecting machines. This treatment is not expensive, and will be valuable for orchards, small groves, or private grounds.

THE PERIODICAL CICADA IN LITERATURE.

As would naturally be inferred of an insect as interesting as the periodical Cicada, the writings which have been devoted to it from the time of its first coming to the attention of the colonists to the present have been most voluminous in number and extent; much of this literature, however, is of a fugitive character and scattered through publications not now obtainable.

The earliest published account of the periodical Cicada which has come under my own observation was brought to my attention by Prof. E. A. Andrews, of the Johns Hopkins University, Baltimore, Md. It is contained in Volume I, No. 8, page 137, of the Philosophical Transactions of the Royal Society of London, published January 8, 1666, and is reported, unsigned, by the "publisher," Henry Oldenburg. The portion of the communication relating to the Cicada is quoted below:

SOME OBSERVATIONS OF SWARMS OF STRANGE INSECTS AND THE MISCHIEFS DONE BY THEM.

A great Observer, who hath lived long in *New England*, did, upon occasion, relate to a Friend of his in *London*, where he lately was, That some few years since there was such a Swarm of a certain sort of Insects in that *English* Colony, that for the space of 200 Miles they poyson'd and destroyed all the Trees of the Country; there being found innumerable little holes in the ground, out of which those Insects broke forth in the form of *Maggots*, which turned into *Flyes* that had a kind of tail or sting, which they stuck into the tree, and thereby envenomed and killed it. * * *

The rest of the article referred to a plague of locusts (grasshoppers) in Russia, with which the Cicada is confused. The brood referred to here is very likely No. XIV, which appeared in 1651. No other brood coincides with this narrative and No. XIV not very closely, but as the quotation states the relation was "upon occasion," and was "some few years since," there is ample warrant for assigning the account to the brood of fifteen years before.

Prior to the discovery of the above record the earliest published account known was that referred to in Bulletin 14 (new series) of the Division of Entomology, page 112, given in a work entitled "New England's Memoriall," by Nathaniel Moreton, printed at Cambridge, Mass., in 1669. I was unable to get the work cited, but an account seen by me was a quotation from it published in an editorial note to an article on the "Locust of North America," in Barton's Medical and Physical Journal of 1804. The brood referred to by Moreton is undoubtedly the same one referred to above, but the occurrence of seventeen years previous. Moreton, publishing of an event happening thirty-six years after it occurred, evidently made a mistake of one year, the occurrence not being 1633, as stated by him, but 1634. We have records of this brood in New England from 1787 to 1906. The records, if any were made of it after 1651 and prior to 1787, have not been discovered.[a]

The quotation from Moreton referred to follows:

Speaking of a sickness which, in 1633, carried off many of the whites and Indians, in and near to Plimouth [Plymouth], in Massachusetts, he says, "It is to be observed, that the Spring before this Sickness, there was a numerous company of *Flies*, which, were like for bigness unto *Wasps* or *Bumble-Bees*, they came out of little holes in the ground, and did eat up the green things, and made such a constant yelling noise as made all the woods ring of them, and ready to deaf the hearers; they were not any of them heard or seen by the *English* in the Country before this time: But the *Indians* told them that sickness would follow, and so it did, very hot in the months of *June*, *July* and *August* of that Summer," viz. 1633. He says, "Toward Winter the sickness ceased;" and that it was "a kinde of a pestilent Feaver."—New England's Memoriall, &c., pp. 90 and 91.

The fact noted, namely, that the native Indians associated the recurrences of this insect with pestilential diseases, is interesting, as showing that the Cicada had probably long been under observation by them and had exerted a vivid influence on their imaginations.

One of the earliest references on this continent to the periodical Cicada is recorded in Steadman's Library of American Literature, volume 1, pages 462–463. It is from the writings of an individual signing himself "T. M.," supposed to have been Thomas Matthews, son of Samuel Matthews, governor of Virginia. It was written in 1705, and refers to three prodigies which are said to have appeared in that country about the year 1675,[b] and which, from the attending disasters, were looked upon as ominous presages. One of these was the appearance of a large comet; another, the flight of enormous flocks of pigeons; and the last, relating evidently to the periodical Cicada, as follows:

The third strange appearance was swarms of flies about an inch long and as big as the tip of a man's little finger, rising out of spigot holes in the earth, which eat the

[a] See Proc. Ent. Soc. Wash., v, pp. 126–127, February, 1903.

[b] There is no recorded brood which could have appeared in 1675, and the year meant is probably either 1673 or 1676, both of which were cicada years.

new-sprouted leaves from the tops of the trees without other harm, and in a month left us.[a]

The next reference to this insect is in a journal, dated 1715, left by the Rev. Andreas Sandel, rector of the Swedish congregation at Philadelphia. It is important as giving the first reference to the use by the native Indians of the cicadas as an article of diet, and has been recently published in the Pennsylvania Magazine of History and Biography. The note is as follows:

May 9 [1715].—In company with several English clergymen, Mr. Talbot, Guerney, and Clubb,[b] I went up to Radnor, where we laid the corner stone of a church.

In this month some singular flies came out of the ground; the English call them locusts. When they left the ground holes could be seen everywhere in the roads, and especially in the woods. They were then encased in shells, out of which they crawled. It seemed most wonderful how being covered with the shell they were able to burrow their way in the hard ground. When they began to fly they made a peculiar noise, and being found in great multitudes all over the country, their noise made the cow bells inaudible in the woods. They were also destructive, making slits in the bark of the trees, where they deposited their worms, which withered the branches. Swine and poultry ate them; but what was more astonishing, when they first appeared some of the people split them open and ate them, holding them to be of the same kind as those to have been eaten by John the Baptist. These locusts lasted not longer than up to June 10, and disappeared in the woods.

Specimens of this insect for scientific study were first carried to the Old World by Pehr Kalm, a pupil of Linné, who was sent to America by the Swedish Government and traveled extensively in the colonies between 1748 and 1751. The account of his travels, published in Stockholm between 1753 and 1761, contains much interesting information relative to the common insects of this country at that early period, and gives a brief statement of the habits of the periodical Cicada. While this work was being printed, Pehr Kalm published a more detailed account of the species in the Swedish Transactions for 1756 (pp. 101–116). The account given in his travels (English edition, 1771, Vol. II, p. 6), is as follows:

There are a kind of *locusts* which about every seventeenth year come hither in incredible numbers. They come out of the ground in the middle of *May*, an make, for six weeks together, such a noise in the trees and woods that two persons that meet in such places, can not understand each other, unless they speak louder than the locusts can chirp. During that time, they make, with the sting in their tail, holes in the soft bark of the little branches on the trees, by which means these branches are ruined. They do no other harm to the trees or other plants. In the interval between the years when they are so numerous, they are only seen or heard single in the woods.

[a] See Webster, Insect Life, Vol. II, p. 161.

[b] Rev. John Clubb, a Welshman, for some time was schoolmaster in Philadelphia, and also assisted Rev. Evan Evans. He also preached to the Welsh settlers at Radnor and vicinity, and became rector of Holy Trinity Church, Oxford. He died in December of 1715. (The Pennsylvania Magazine of History and Biography, Vol. XXX, October, 1906, pp. 448, 449.)

The original scientific description of the species by Linné, based on material collected by Kalm, followed in 1758.[a] Fabricius afterwards described the species in two or three of his works under the name *Tettigonia septendecim*, reviving one of the old generic names of Aristotle for this class of insects, but Latreille, Lamarck, and subsequent authors retained Linné's name.

In his monographic work on the Cicadas of the world, 1788, Caspar Stoll gives a figure and a short description of *Cicada septendecim*.

Some popular accounts of the species closely followed Linné's description. Under the title, "Some observations on the Cicada of North America," Peter Collinson, esq., of London, England, gave a rather full account of the insect as then known, assigning fourteen or fifteen years as its life period, and published a plate illustrating the adult insect and a twig lacerated by the female.[b] Shortly thereafter appeared an article in Dodsley's Annual Register (1767, p. 103), entitled, "Observations on Cicada or Locust of North America, which appears periodically once in sixteen or seventeen years, by Moses Bartram, 1766, communicated by the ingenious Peter Collinson."

References to the periodical Cicada in American literature began to be more abundant toward the end of the eighteenth century and in the beginning of the nineteenth, Thomas Say, in 1817, referring to "numerous accounts of it in our public prints." Most of these, however, were unimportant notices and are now lost or not easily accessible.

The most interesting contribution to the American literature of the Cicada of this period, comprising two papers with valuable editorial notes, is contained in the Barton Medical and Physical Journal of 1804, already cited. The first title reads: "Some particulars concerning the locust of North America. Written at Nazareth, in Pennsylvania, Aug. 27th, 1793. Communicated to the Editor, by the Reverend Mr. Charles Reichel, of Nazareth." The paper gives a number of dates of occurrence in Pennsylvania and some interesting notes on the habits of the Cicada—some errors in which are corrected in a note by the editor, who announces that he has "for several years, devoted a great deal of attention to the natural history of this insect" and "designs to publish an extensive memoir on the subject," which, however, he seems never to have done.

The second paper (pp. 56–59) reads: "Additional Observations on the Cicada Septendecim. By the late Mr. John Bartram. From a MS. in the possession of the Editor." The older paper indicated in this title I have not seen, but it is evidently included in an account of travels by Bartram in Pennsylvania and Canada, printed in London in 1751. Under the title quoted are notes on the appearance

[a] Systema Naturæ, tenth edition, 1758, p. 435.

[b] Philos. Trans. 1764, vol. 54, pp. 65-69.

of a brood in the neighborhood of Philadelphia in 1749, which began to emerge May 10, but "in the latter end of April * * * came so near the surface of the ground, that the hogs rooted up the ground for a foot deep, all about the hedges and fences, under trees in search of them." There follow quite accurate notes on oviposition. The editor concludes the article by the citation from Moreton which has been already quoted.

Thomas Say, the father of American entomology, has one brief communication on the periodical Cicada, in which he criticises the use of the name "locust," and gives references to earlier literature and a brief note on habits.[a]

Another interesting communication of about the same period is by Dr. J. F. Davis,[b] in which the author controverts the "14 or 15" year period suggested by Collinson and quotes two letters, one from the Hon. Judge Peters, of Belmont, Pa., and the other from Myers Fisher, esq., of Philadelphia, to substantiate the 17-year period. Referring to the noise of this Cicada, Judge Peters says:

> One of your Spa-fields meetings can give you a faint idea of their incessant and unmusical cheering and noise. If Hogarth had known these locusts, he would have placed them about the ears of his enraged musician. Knife-grinders, ballad singers, etc., would have been lost in their din.

Mr. Fisher gives a very accurate, though brief, statement of the life cycle of the species (if his belief that they occur at great depths be excepted), and adds the very significant statement that "there is reason to believe that they appear every year in some part or other of the United States, with the complete period of 17 years between every local appearance."

Dr. S. P. Hildreth, of Marietta, Ohio, made two very valuable contributions on the Cicada to the American Journal of Science and Arts (1826 and 1830), which are much more accurate than any of the earlier papers and too long to be quoted in this place. In the second of these papers he calls attention to the existence of the small form of Cicada, and gives a colored plate representing five views of the adult insect. Doctor Hildreth published a third paper also in 1847.[c]

The first account of this insect to be issued as a separate work is the memoir of Prof. Nathaniel Potter, of Baltimore, Md., entitled "Notes on the Locusts," etc., written in 1834 and privately published in 1839. This pamphlet of twenty-nine pages and one colored plate, representing the insect in both sexes and also the early stages, together with the nature of its work on twigs, and anatomical details, was the chief source of information for the account published by Harris in his "Insects Injurious to Vegetation," and while containing some wrong

[a] Mem. Phila. Soc. Prom. Agric., 1818, v. 4, p. 225.
[b] Jour. Sci. and Arts Roy. Inst., 1819, v. 6, pp. 372–374.
[c] Loc. cit., ser. 2, vol. 3, pp. 216–218.

inferences, gives with remarkable accuracy and detail observations on practically all of the features of the insect's life history and habits which are open to easy study, not only in its underground existence but throughout its transformation and aerial life. Professor Potter was evidently fully aware, not only of the two distinct sizes or varieties of the Cicada but also of the depth to which the larvæ penetrate and the fact of their forming roofs or turrets over their burrows some time before the period of their emergence—a record which has been hitherto overlooked and the credit for this discovery assigned to a much later period.

In speaking thus most favorably of Professor Potter's memoir it must not be forgotten that probably much of the actual observation and study upon which it is based are due to the research of Dr. Gideon B. Smith, of Baltimore, Md., who is given full credit in one of the introductory paragraphs, in these words:

> As our professional avocations would not permit us to devote our whole time to the pursuit, it became necessary to call in the aid of a colleague whose knowledge of entomology and industry could be relied upon. These qualifications were found and well exemplified in Mr. Gideon B. Smith. Should our labors reflect any light on so obscure a subject, the credit is equally due to him.

These two men were the first to make a careful and at all complete study of the periodical Cicada, Professor Potter's interest in the subject dating, he says, from 1783, and great credit is due them, and especially to Doctor Smith, whose later work will be subsequently considered.

Several brief accounts of the Cicada appeared in American and foreign publications about this time, adding nothing, however, to the facts already obtained, the most notable perhaps being the account by J. O. Westwood in his "Classification of Insects,"[a] in which he refers to the literature and habits of the species very briefly.

The next step of real importance was the discovery of a 13-year southern brood by Dr. D. L. Phares, of Woodville, Miss., and the publication of the fact in 1845 in the Woodville Republican.

Both before and after this time Doctor Phares was in communication with Dr. Gideon B. Smith, referred to above, whom he evidently ultimately convinced of the truth of the 13-year period for the southern broods.

Doctor Smith continued for many years the work which he had begun as the colleague of Professor Potter, keeping his notes in the form of a rather voluminous manuscript, which was first prepared, he states, in 1834, the date signed to Professor Potter's memoir. Doctor Smith twice entirely rewrote and revised his manuscript, the title-page of the last copy reading as follows:

> The American Locust *Cicada septendecim*, et *tredecim*. Embracing the natural history and habits of the insect in its perfect state and while underground, with

[a] 1839–40, Vol. II, p. 426.

drawings of its several organs and the perfect insects, the egg and the young taken from life, with a register of the places and time of its appearance in every part of the United States, by Gideon B. Smith, M. D. Originally written in 1834, transcribed with additions 1851, and rewritten with additions and illustrations in February, 1857, in the sixty-fourth year of my age.—G. B. S.

This manuscript is substantially the paper by Professor Potter revised, with much interesting matter added and particularly a register of some 21 broods in many colonies, in which are separated the two tribes, one of seventeen years, represented by fourteen broods and the other thirteen years, represented by seven broods. Doctor Smith's classification of the broods under these two tribes undoubtedly resulted from his correspondence with Doctor Phares and perhaps other observers residing in the South. Most unfortunately, Doctor Smith failed to publish this very interesting manuscript and therefore never received due credit for the valuable work which he accomplished.

Townend Glover used this manuscript to some extent in his article on the Cicada in the Report of the U. S. Department of Agriculture for 1867 (1868), referring to Doctor Smith as having devoted much time to studying the habits of the Cicada, and as the best authority on the subject in the Middle States, and particularly as holding that there are two tribes "differing only from each other in the period of their lives, the northern being seventeen years, and the other, or southern tribe, requiring only thirteen years in which they perform their transformations." The use of Doctor Smith's manuscript afterwards by Professor Riley, as will be subsequently noted, was not of such character as to bring into prominence the real value of Doctor Smith's contribution to science. Two minor notes only were published by Doctor Smith. The first is his Scientific American note of March 22, 1851, which was afterwards communicated by Mr. Spence to the London Entomological Society.[a] In this note Doctor Smith briefly reviews and sums up the results of his seventeen years' study of this insect, and states that he has located thirty different locust districts, occupying fourteen of the seventeen years. Since he does not mention the 13-year race he was evidently unaware of its existence as late as 1851. The second is a brief note in the Country Gentleman for May, 1869, in which he mentions both races.

From this time on until the important publications by Walsh and Riley a number of articles on the Cicada appeared, some of them of considerable interest and value, and notably those by Miss Magaretta H. Morris, of Germantown, Pa., on the habits, times of appearance, and ravages occasioned by this insect, and by Prof. Joseph Leidy on the fungous disease attacking the species.[b] Dr. J. C. Fisher, in 1851,

[a] Proc. Ent. Soc. London, April 7, 1851, Vol. I, pp. 80, 81.

[b] Described by C. H. Peck as *Massospora cicadina* in 31st Rept. N. Y. State Mus. Nat. Hist., 1879, pp. 19, 20, and 44.

described as a distinct species *Cicada cassinii*, the small form referred to by several of the earlier authors, and to this paper were appended comparative notes on the habits of the two forms by John Cassin.[a] About this time, 1851–52, also appeared the very complete account by Doctor Harris in his "Insects of New England," and also some anatomical studies of the sexual system and musical apparatus by Dr. W. I. Burnett. In 1856 Dr. Asa Fitch, in his first report on the insects of New York, gives an extended account of the periodical Cicada, classifying or listing some nine broods, but not adding otherwise particularly to the knowledge of the insect. Several accounts of the species followed, including the notice of a 13-year brood, which Doctor Phares claims to have published in the Republican of Woodville, Miss., May 5, 1858, under the title "*Cicada tredecim*"—the earliest published suggestion of this name for the 13-year race. None of the other communications, including papers and notices by Fitch, Walsh, Glover, and Cook, is of great importance, if we except the reference by Glover to Smith already noted.

The next step of real importance was the publication by Walsh and Riley in the first volume of the American Entomologist of a very full and illustrated editorial account, in which the 13-year species is characterized and the 13-year period for the southern broods is fully established and a register of some sixteen broods is given. Professor Riley in his First Missouri Report reproduces this article with the additions to the broods derived chiefly from the manuscript memoir by Doctor Smith, which had been in the meantime communicated to him by Dr. J. G. Morris, of Baltimore, Md. In this paper Professor Riley revised and renumbered the broods, increasing their number to twenty-two. Professor Riley's classification of the broods, and the details of the life history and habits of the insect, as given by Walsh and Riley in the American Entomologist, and later by Riley in his report, have been accepted as the chief source of information since.

From the date of these articles until 1885 the additions to the literature are chiefly of records bearing on the distribution of the broods, furnished notably by Rathvon, McCutcheon, Riley, Le Baron, Glover, Phares, Packard, Lintner, and many others.

The recurrence in 1885 of the great Brood X of the 17-year race, in conjunction with the very important 13-year Brood XXIII, gave again a great stimulus to the study of this insect. Professor Riley published in June, 1885, as Bulletin No. 8 (old series) of the Division of Entomology, an account of both races with a very full chronology of all the known broods. These data were repeated in part, with important additions, in the Report of the Department for that year, published in 1886. Other general articles were published by Doctor

[a] Proc. Acad. Nat. Sci. Phila. 1851, Vol. V, pp. 273–275.

Lintner and many others. The output of literature on the periodical Cicada since 1885, if one takes the daily press notices and articles into account, has been enormous and particularly in the special Cicada years. This has resulted from the fact that as the dates for the appearances of all the broods are now well understood, the recurrences have been foretold and looked forward to, thus vastly increasing the popular interest. The new information gained has related chiefly to facts of distribution. Some interesting data have been given, however, on the subject of the peculiar huts or turrets, which are sometimes constructed by the emerging pupæ, and some anatomical studies have been made.

For a description of these and other papers the reader is referred to the bibliography of the writings on the periodical Cicada which is appended. The important papers from the earliest times to the present are listed, omitting much of the ephemeral and less valuable matter which added little or nothing to the knowledge of the habits and distribution of the species.

BIBLIOGRAPHY OF THE PERIODICAL CICADA.

[Chronologically arranged.]

1666. [Oldenburg, Henry, "publisher"].—"Some observations of Swarms of Strange Insects and the Mischiefs done by them." <Philos. Trans. London, Vol. I, No. 8, p. 137.
Includes first reference to periodical Cicada (Brood XIV).

1669. Moreton, Nathaniel.—"New England's Memoriall." <Cambridge, 1669.
Refers to a "kinde of pestilent feaver" fatal to whites and Indians in season of 1633 (1634?) ascribed by the Indians to the "flies," which appeared that year and which are briefly described.

1705. Matthews, Thomas (?).—Steadman's Lib. Am. Lit., Vol. I, pp. 462, 463 (1887).
Quotes the writings of 1705 of "T. M.," supposed to refer to Thomas Matthews, describing the occurrence of a swarm of cicadas as one of three prodigies appearing about 1675. (See pp. 147–148.)

1715. Sandel, Andreas.—Mitchell and Miller's Medical Repository, Vol. IV, p. 71. (Abstract.) (Memorandum dated 1715.) (See 1906.)
Refers to the use of the cicadas as food by the Indians.

1756. Kalm, Pehr.—Beskrifning pa et slagts Gras-Hoppor, uti Norra Americas (*Cicada septendecim*). <Vetensk. Acad. Handl. 17, pp. 101–116—German Translation 1767, t. 26, pp. 130–143.

1753–61. Kalm, Pehr.—Travels in North America. Vol. II, p. 6.
Gives a brief account of the species, which is said to come about every 17th year.

1758. Linné, C.—Systema Naturæ, 10th Edit., p. 436.
Original description of the species.

1764. Collinson, Peter.—Some observations on the Cicada of North America. <Philos. Trans. Lond., vol. 54, pp. 65–69, 1 pl.

1767. Bartram, Moses.—"Dodsley's Annual Register," p. 103.
Account in letter to Peter Collinson, London, England.

1775. Fabricius, J. C.—Syst. Ent., p. 679, No. 6; Ins., II, 1781, p. 319, No. 6; Mant. Ins., II, 1787, p. 266, No. 9.
Described as *Tettigonia septendecim*.

1788. Stoll, Caspar.—"Der Cicaden," etc.
Gives a figure and short description of *Cicada septendecim*.

1804. Reichel, Rev. Charles.—Some particulars concerning the locust of North America. <Barton Med. and Phys. Journal, Vol. I, p. 52, ff.

1804. Bartram, John.—Additional observations on *Cicada septendecim*. From a MS. in the possession of the editor. <Barton Med. and Phys. Journ., Vol. I, pp. 56–59. (Earlier paper prob. 1751, Miscl. in Travels in Pa. and Can. Lond., Sept., 1751.)

1818. Say, T.—Mem. Philad. Soc. Prom. Agric., vol. 4, p. 225.
Refers to earlier literature and gives brief note on habits.

1819. Davis, J. F.—On the *Cicada septendecim*. <Journ. Sci. and Arts Roy. Inst., vol. 6, pp. 372–374.
Criticises paper of Collinson; quotes letters by Hon. Judge Peters and Myers Fisher to substantiate the 17-year period.

1826. Hildreth, S. P.—Am. Journ. Sci. and Arts, vol. 10, pp. 327–329.
Habits and appearances detailed with considerable accuracy.

1828. Hildreth, S. P.—Ueber die americanische Cicada (*Cicada septendecim*). <Fror. Not., Bd. 22, No. 426, pp. 33–35.

1828. Booth, Jesse.—Ueber die *Cicada septendecim*. <Fror. Not., Bd. 22, No. 468, pp. 84–87.

1830. Hildreth, S. P.—Notices and observations on the American Cicada or locust. <Am. Journ. Sci. and Arts, vol. 18, pp. 47–50.
Characters, habits, and appearances; refers also to existence of small forms.

1832. Hildreth, S. P.—Ueber *Cicada septendecim*. <Isis, 1832, pp. 1059, 1060.

1837. Children, J. G.—Proc. Ent. Soc. London, vol. 1, p. xxx.
Exhibited specimens of the different stages and read extract from a letter from Doctor Harlan, of Philadelphia, giving a brief statement on habits, 17-year brood, etc.

1839. Potter, Nathaniel.—Notes on the *Locusta septentrionalis americanæ decim septima*. <Baltimore, J. Robinson, 27 pp., 1 pl.
History, habits, descriptions, and figures of *Cicada septendecim*.

1839–40. Westwood, J. O.—Classification of insects, II, p. 4.
Brief account of species and reference to the literature.

1843. Morton, S. G., and others.—*Cicada septendecim*, discussion and extracts from minutes in reference to. <Proc. Acad. Nat. Sci., Phila., Vol. I, pp. 277–280, June.
Notes on various broods of periodical Cicada.

1845. Phares, Dr. D. L.—Woodville, Miss., Republican, May 17.
Published fact of a 13-year brood in Mississippi.

1846. Forsley, C. G.—On the *Cicada septendecim* in 1835 in Louisiana. <Proc. Bost. Soc. Nat. Hist., vol. 2, p. 162.
Gives habits and distribution.

1846. Morris, M. H.—Proc. Acad. Nat. Sci. Phila., vol. 3, pp. 132–134.
Ravages, habits, and the times of appearance at various places.

1847. Morris, M. H.—Apple and pear trees destroyed by the locust. <Am. Agric., March, vol. 6, pp. 86, 87.
Ravages, habits, and transformations.

1847. Hildreth, S. P.—*Cicada septendecim* in 1846. <Am. Journ. Sci. and Arts, March, ser. 2, vol. 3, pp. 216–218, 1–2; Ann. and Mag. Nat. Hist., vol. 20, pp. 136–138.
Habits in Ohio.

1847. Morris, M. H.—Proc. Acad. Nat. Sci. Phila., vol. 3, pp. 190, 191.
Ravages of the larvæ; enemies.

1847. Hildreth, S. P.—Die Siebzehnjahr-locust (*Cicada septendecim*). <Fror. Not., Bd. 3, No. 60, pp. 241–245.

1848. Hildreth, S. P.—Détail sur les moeurs de la *Cicada septendecim*. <Institut, XVI, No. 744, pp. 107, 108.

1848. MORRIS, M. H.—Destruction of fruit trees by the seventeen-year locust. <Am. Agric., September, vol. 7, p. 279.
Notes on injuries to forest and fruit trees by the larvæ.

1851. SMITH, Dr. GIDEON B.—On the American locust (*Cicada septendecim*). <Scientific American, March 22; presented by Spence in Proc. Lond. Ent. Soc. (n. s.), Vol. I, 1851, pp. 80, 81.
Reviews his work; states that he has located thirty locust districts, occupying fourteen of the seventeen years; 13-year race not mentioned.

1851. SPENCE, R. H.—Proc. Ent. Soc. Lond. (n. s.), Vol. I, pp. 103, 104.
Letter on the Cicada in Maryland in 1851.

1851. LEIDY, J.—Proc. Acad. Nat. Sci. Phila., Vol. V, p. 235.
Characters of the spores of a fungus affecting the Cicada.

1851. FISHER, Dr. J. C.—Proc. Acad. Nat. Sci. Phila., Vol. V, pp. 272, 273.
Description of *Cicada cassinii* as a new species hitherto confounded with *C. septendecim.*

1851. CASSIN, JOHN.—Notes on the above species of *Cicada* (*C. cassinii*), and on the *Cicada septendecim* Linn. <Proc. Acad. Nat. Sci. Phila., September, Vol. V, pp. 273–275.
Characters and habits of *Cicada septendecim* and of *Cicada cassinii* compared.

1851. BURNETT, Dr. W. J.—Proc. Bost. Soc. Nat. Hist., IV, p. 71 and p. 111.
Sexual system and musical apparatus; appearance in cleared lands.

1851. BURNETT, Dr. W. J.—Points in the economy of the 17-year locust (*Cicada septendecim*) bearing on the plural origin and special local creation of the species. <Proc. Am. Ass. Adv. Sci., 6th Meet., pp. 307–311.

1852. WILD, Ph.—Sur les moeurs de la *Cicada septendecim*. <Ann. Soc. Ent. France, 2d Ser. vol. 10., Bul., pp. XVIII, XIX.

1852. HARRIS, T. W.—Insects of New England, pp. 180–189; Ins. Inj. to Veget., 1860, pp. 206–217; do. Flint Edit., 1863, pp. 206–219.
General account of the species.

1852. EVANS, GURDON.—Insects injurious to vegetation. <Trans. N. Y. State Agric. Soc. for 1851, vol. 11, pp. 741–751.
Notes concerning various insects of Madison County, N. Y., including the 17-year Cicada.

1854. FITCH, A.—Report (on the noxious, beneficial, and other insects of the State of New York). <Trans. N. Y. State Agric. Soc. for 1854, vol. 14, pp. 742–753; 1st and 2d Repts., Albany, 1856, pp. 38–49.
Gives a general account of the species and enumerates nine broods.

1857. SMITH, Dr. GIDEON B.—The American locust, etc. <Last revision. February.
Unpublished manuscript used in part by Glover and Riley.

1858. PHARES, Dr. D. L.—Republican, Woodville, Miss., May 5.
Published a notice of the 13-year brood under the title "*Cicada tredecim.*"

1859. SMITH, Dr. G. B.—Country Gentleman, May 12, vol. 13, p. 308.
"Predicts the appearance of locusts the coming spring in Virginia, Maryland, North Carolina, Tennessee, Georgia, and Mississippi. They belong to the tribe of thirteen and seventeen year locusts." (13-year Brood XXIII and 17-year Brood I.)

1860. FITCH, A.—The Entomologist, No. 22—The 17-year Cicada. <The Country Gentleman, March 29, vol. 15, p. 210.
Remarks on popular names for insects; regularity of appearance of *Cicada septendecim;* necessity of ascertaining its distribution in order to predict its future visitations.

1861. STÅL, C.—Ann. Soc. Ent. France, 4th ser., Vol. I, September, p. 618.
Reference of *Cicada septendecim* to genus Tibicen Latr.

1862. HERRICK, E. C.—Uprising of the 17-year Cicada in New Haven County, Conn., in 1860. <Am. Journ. Arts and Sci., 2d ser., vol. 33, pp. 433, 434.

1865. RILEY, C. V.—Seventeen-year locust. <Prairie Farmer, August 19, vol. 32 (n. s., vol. 16), p. 127.
Agrees with S. P. G. in doubting that *Cicada septendecim* lives seventeen years immature, and gives reasons for his doubt.

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[a] Synonym of *Sphecius speciosus.*

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1894. RILEY, C. V.—Circular Div. Ent. U. S. Dept. Agric., May 5, pp. 4.
Gives distribution by counties of Broods XIX and II, and asks for confirmations.

1894. SLINGERLAND, M. V.—The periodical Cicada or locust. <The Farmer's Advocate, June 1, p. 225.
Brief account, and the broods that will appear in 1894.

1894. DAVIS, WM. T.—The 17-year locust on Staten Island. <Proc. Nat. Sci. Assn. Staten Isand, IV, No. 4, February 10, pp. 13–15.

1894. DAVIS, W. T.—The 17-year Cicada on Staten Island. <Journ. N. Y. Ent. Soc., II, No. 1, March, pp. 38, 39.
Records of cicadas observed since 1877.

1894. DAVIS, WM. T.—The harvest flies (Cicada) of Staten Island, N. Y. <Amer. Nat., Vol. 28, No. 328, April, pp. 363, 364.
Various notes on *Cicada tibicen* L., song, time of appearance, and capture, and on *C marginata* Say and *C. canicularis* Harr. Mere mention of the periodical Cicada.

1894. RILEY, C. V.—The periodical Cicada. <Rept. of Ent. in Ann. Rept. U. S. Dept. Agric., 1893, pp. 204, 205.
Records of broods for 1893.

1894. DAVIS, W. T.—The 17-year locust on Staten Island. <Amer. Nat., Vol. 28, No. 329, May, p. 452.
Cicada observed since 1877.

1894. SMITH, J. B.—The periodical Cicada. <Entom. News, May, Vol. V, p. 145.
Notice of the brood to appear in 1894, and the relation of the English sparrow to this insect.

1894. LINTNER, J. A.—The periodical Cicada, or the 17-year locust. <Circular, Albany, N. Y., June 19, p. 4.
Habits, turrets, questions regarding the present appearance.

1894. SLINGERLAND, M. V.—The periodical Cicada, or 17-year locust. <Rural New Yorker, July 28, p. 470; August 4, p. 488.
General popular account, habits, and broods.

1894. DAVIS, W. T.—The 17-year locust on Staten Island in 1894. <Proc. Nat. Sci. Assn. of Staten Island, Vol. IV, No. 9, September, pp. 33–35.

1894. SHUFELDT, R. W.—The 17-year Cicada and some of its allies. <Popular Science News, Vol. XXVIII, October 10, pp. 154, 155.

1894. LANDER, B.—Hut-building 17-year cicadas. <Sci. Amer., October 13.
Full account, with explanations and figure.

1894. SMITH, J. B.—Insect Life, Vol. VII, October, pp. 192–195.
Under "Notes of the year in New Jersey," gives distribution of Cicada in 1894 in that State.

1894. KROM, O. S.—The hut-building Cicada. <Sci. Amer., November 10, p. 295.
Criticises theories of Mr. Lander, and suggests other explanations.

1894. LANDER, B.—Cicada hut-builders. <Sci. Amer., November 24, p. 327.
Replies to Mr. Krom, and gives additional proof in support of his (Lander's) point of view.

1894. SMITH, J. B.—The periodical Cicada. <Rept. Entom., Ann. Rept. N. J. Agric. Exper. Sta., pp. 582–591, figs. 52–57.
General articles relating especially to Brood II in New Jersey; Cicada towers discussed.

1895. LANDER, BENJAMIN.—Domed burrows of *Cicada septendecim*. <Journ. N. Y. Ent. Soc., III, March 1, pp. 33–38, plate.

1895. LOVE, E. G.—Notes on the 17-year Cicada, *Cicada septendecim*. <Journal N. Y. Micros. Soc., XI, April 2, pp. 37–46, plate 49.
Original observations on structural details, the turrets, etc.

1895. MARLATT, C. L.—The Hemipterous mouth. <Proc. Ent. Soc. Wash., Vol. III, No. 4, pp. 241–249, June 22, figs. 21–23.
Detailed study of the hemipterous mouth from dissection of the periodical Cicada.

1895. LINTNER, J. A.—The 17-year locust in the State of New York in 1894. <10th Rept. Inj. and other Ins. N. Y. From 48th Rept. N. Y. State Mus. Nat. Hist., pp. 420–425, 2 figs.
Quotes circular (see above) and gives the results.

1895. MCCARTHY, G.—Bul. No. 120, N. Car. Agric. Exp. Sta., November.
Contains brief notice of Cicada.

1896. OSBORN, HERBERT.—Observations on the Cicadæ of Iowa. <Proc. Iowa Acad. Sci., III, 1895, pp. 194–203. *Cicada septendecim*.

1896. SLINGERLAND, M. V.—The apple crop and 17-year locusts. <Rural New Yorker, January 25, p. 53.
Doubts that the Cicada has any influence on the crop.

1896. HYATT, J. D.—*Cicada septendecim*: its mouth parts, and terminal armor. <Am. Mo. Mic. Journ., February 17, p. 46.
Mouth parts and ovipositor of the Cicada; method of oviposition (illus.).

1896. SLINGERLAND, M. V.—On what do 17-year Cicadas live? <Rural New Yorker, May 23, p. 351.
Food habits of Cicada.

1896. BRUNER, L.—Seventeen-year locusts. <Nebraska State Journal, June 19.

1896. SLINGERLAND, M. V.—Seventeen-year locusts not poisonous. <Rural New Yorker, July 11, p. 464.
Food habits of Cicada.

1897. SCHWARZ, E. A.—The periodical Cicada in 1897. <Cir. No. 22, s. s., Div. Ent., U. S. Dept. Agric., May, pp. 4.
Localities for Brood V, *septendecim*, and Brood XXII, *tredecim*, in 1897.

1897. WEBSTER, F. M.—The 17-year locust in Ohio. <Ohio Farmer, May 20, p. 40, 1 map.
Expected occurrence in the State.

1897. SLINGERLAND, M. V.—Do 17-year locusts damage fruit trees? <Rural New Yorker, July 3, p. 437.
Damage not of great importance.

1897. WEBSTER, F. M.—The San Jose scale and the periodical Cicada. <Newspaper bulletin, Ohio Agric. Exp. Sta., November, pp. 2.
Relates to Brood V in eastern Ohio.

1897. WEBSTER, F. M.—Brood XV [V] of *Cicada septendecim* in Ohio. <Can. Ent., October, pp. 225–229.
Distribution of Brood V in Ohio in 1897.

1897. WEBSTER, F. M.—The periodical Cicada, or so-called 17-year locust in Ohio. <Bul. No. 87, Ohio Agric. Exp. Sta., November, pp. 37–68, 11 figs.
Distribution in Ohio, habits, natural enemies, etc.

1898. HOPKINS, A. D.—The periodical Cicada in West Virginia. <Bul. No. 50, W. Va. Agric. Exp. Sta., January (April), pp. 46, 23 figs., 1 map, 4 pls.
A general account with detailed records of all broods in West Virginia.

1898. SCHWARZ, E. A.—The periodical Cicada in 1898. <Circular No. 30, s. s. Div. Ent., U. S. Dept. Agric., April, pp. 4.
Location of Brood XXIII, *tredecim*, and Brood VI, *septendecim*, in 1898.

1898. HOWARD, L. O.—A new egg-parasite of the periodical Cicada. <Can. Ent., Vol. XXX, pp. 102, 103, April.
Description of *Lathromeris cicadæ*, new species.

1898. LINTNER, J. A.—The periodical Cicada. <12th Ann. Rep. State Entom., New York, 1896. (May, 1898), pp. 272–289, Pls. IX-XIII.
Gives additions to bibliography, a general account of insects, with original observations on habits, and especially on the Cicada chambers, chiefly based on Brood II in 1894.

1898. MARLATT, C. L.—The periodical Cicada. An account of *Cicada septendecim*, its natural enemies and the means of preventing its injury, together with a summary of the distribution of the different broods. <Bul. U. S. Dept. Agric., Div. Ent. No. 14, n. s., 148 pp., 4 pls., 57 figs.
Habits, varieties, distribution, systematics, structure, development, enemies, and remedies.

1898. FORBES, S. A.—The seventeen-year Cicada. <Prairie Farmer, June 25, p. 9.

1898. SANDERSON, E. D.—Entomology. <Country Gentleman, July 21, pp. 573, 574, 1 fig.
Note on *Cicada tredecim*.

1898. DE VARIGNY, H.—La cigale de dix-sept ans. Histoire d'un insecte. <Rev. scient. (4) T. 10, pp. 353–365. *C. septendecim*.
A lengthy review, with extracts from Bulletin 14, n. s., Division of Entomology.

1898. SCHENKLING, SIEGMUND.—Die siebzehnjährige Cikade. <Die Natur, Jahrg. 47, pp. 447–451. *C. septendecim* nach Marlatt.

1898. HOPKINS, A. D.—Some notes on observations in West Virginia. <Bul. No. 17, n. s., Div. Ent., U. S. Dept. Agric., November, pp. 44–49.
Includes a reference to work on the periodical Cicada, and especially the relation of temperature to appearance.

1898. MARLATT, C. L.—A new nomenclature for the broods of the periodical Cicada. <Miscl. Results Work Div. Entom., Bul. U. S. Dept. Agric., Div. Ent., No. 18, n. s., pp. 52–58. *C. septendecim*.

1898. MARLATT, C. L.—A consideration of the validity of the old records bearing on the distribution of the broods of the periodical Cicada, with particular reference to the occurrence of Broods VI and XXIII in 1898. <Miscl. Results Work Div. Entom., Bul. U. S. Dept. Agric., Div. Ent., No. 18, n. s., pp. 59–78. *C. septendecim*.

1899. SAJO, KARL.—Die siebzehnjährige Cikade (*Cicada septendecim*). <Prometheus, Jahrg. 10, pp. 388–393, 401–406. 13 figs. (Z. T. nach C. L. Marlatt).
Account of habits and life history based largely on Bul. 14, n. s., U. S. Dept. Agric., Div. Entom.

1899. WEBSTER, F. M.—Distribution of Broods XXII [X], V [XIII], and VIII [XIV] of *Cicada septendecim* in Indiana. <Proc. Indiana Acad. Sci. 1899, pp. 225–227, 1 map.

1899. SMITH, J. B.—The periodical Cicada. <Report of the Entom. of the New Jersey Agric. Coll. Exp. Station for 1898, pp. 447–450, May 1.
New Jersey records of Brood VI, 1898, with map.

1899. LANDER, B.—Note on the seventeen-year Cicada. <Journ. N. Y. Ent. Soc., vii, pp. 212–214.
Notes on the Cicada huts—shallow soil believed to be cause.

1899. WEBSTER, F. M.—Entomology. <Ohio Farmer, August 31, p. 152.
Notes on *Cicada septendecim*.

1899. FELT, E. P.—Notes of the year for New York. <Country Gentleman, Sept. 14, p. 733.
Note on *Cicada septendecim*.

1899. FELT, E. P.—Notes of the year for New York. <Bul. No. 20, n. s., Div. Ent., U. S. Dept. Agric., November, p. 62.
Record for Brood VII in western New York, 1899.

1899. ALLEN, GRANT.—"The day of the cankerworm." <Strand Mag. Oct.
Relates chiefly to the periodical Cicada, with many illustrations from Bul. 14, n. s. (Div. Ent., U. S. Dept. Agric.), given as new! Reprint, Sci. Am. Sup., v. 49 (1900), pp. 20122–20124.

1900. FELT, E. P.—Fifteenth Report of the State Entomologist on the injurious and other insects of the State of New York. <Bul. N. Y. State Museum, vol. 6, No. 31, June, p. 544.
List of localities in western New York for Brood VII, 1899.

1900. WEBSTER, F. M.—The 17-year locust in Ohio. <Ohio Farmer, July 5.
Relating to Brood VIII in eastern Ohio.

1900. HOPKINS, A. D.—The periodical Cicada or seventeen-year locust in West Virginia. <Bul. No. 68, W. Va. Agric. Exp. Sta., September, pp. 259–330, 3 pls., 4 figs., 9 maps. A revision of Bul. 50.
A full account of the Cicada, with descriptions of all the broods occurring in West Virginia, with maps.

1900. LUGGER, O.—Bugs injurious to cultivated plants. <Bul. No. 69, Minn. Agric. Exp. Sta., December.
Periodical Cicada discussed, pp. 102–3. Illustrations. Does not occur in Minnesota.

1900. WEBSTER, F. M.—Notes on the occurrence of Brood XX [VIII] of the periodical Cicada, *Cicada septendecim*, in Ohio in 1900. <Entom. News, Vol. XI, December, pp. 638–640, 1 fig.
Report on Brood VIII in Ohio in 1900, with map.

1901. SLINGERLAND, M. V.—Work of the 17-year locust. <Rural New Yorker, October 12, p. 690.
Letter by "S. B." and not by Slingerland. Tied green rye straw around the trees and left two trees unprotected. It was several years before they fully recovered (the two trees). Says that trees that exude gum are not much harmed by the locust. Speaks of sparrows eating Cicada.

1901. JOHNSON, W. G.—Timely warning to fruit growers. <American Agriculturist, July 13, p. 32, 1 fig.
Notice of coming brood of seventeen-year Cicada.

1901. SLINGERLAND, M. V.—Seventeen-year locust. Watermelon bug. <Rural New Yorker, July 13, p. 484.
Letter and reply, N. Y.

1901. FERNALD, C. H., & H. T. FERNALD.—Report of the entomologists. <Thirteenth Annual Report, Hatch Exp. Sta., Mass., January, p. 86.
Brief notes on Marthas Vineyard swarm (Brood VIII) in 1900; as much in evidence as ever.

1901. WEBSTER, F. M.—Report of the committee on entomology. <Ann. Rept. Ohio State Hort. Soc. f. 1900, pp. 1, 2, 7 pls., 2 figs.
Report on Brood VIII.

1901. FELT, E. P.—Seventeen-year Cicada. <Country Gentleman, November 7, p. 902.

1901. HOPKINS, A. D.—Circular of warning. <W. Va. Agric. Exp. Sta., Oct. 15, 1 p., 1 map.
Relating to the 1902 swarm of the periodical Cicada.

1901. SANDERSON, E. D.—Three orchard pests. <Bul. No. 53, Delaware Agric. Exp. Sta., January, 1902 (Dec., 1901), pp. 13–19.
Includes an illustrated account of *Cicada septendecim* L., pp. 13–19, with special reference to Brood X, 1902, in Delaware.

1902. FELT, E. P.—Spraying for Cicada. <Country Gentleman, March 13, p. 219.
Mechanical oil emulsions not advised.

1902. HUNTER, W. D.—The periodical Cicada in 1902. <Circ. No. 44, s. s., Div. Ent., U. S. Dept. Agric., March 13, pp. 4.
An inquiring circular sent out for Brood X, 1902.

1902. SLINGERLAND, M. V.—Whitewash for 17-year locusts. <Rural New Yorker, March 15, p. 189.
Heavy coat of whitewash on trees fairly protective.

1902. LOWE, V. H.—Miscellaneous notes on injurious insects. <Bul. No. 212, New York State Agric. Exp. Sta., April, pp. 1–15, pls. I–IV on Cicada.
Contains an advance warning of Brood X of the periodical Cicada, with some good photographs.

1902. MARLATT, C. L.—A new nomenclature for the broods of the periodical Cicada. <Cir. No. 45, s. s., Div. Ent., U. S. Dept. Agric., pp. 8, May 1.

1902. ALWOOD, W. B.—What to do with locusts. <Rural New Yorker, May 17, p 351.

1902. HOPKINS, A. D.—What to do with locusts. <Rural New Yorker, May 17, p. 351.

1902. HOOPES, ABNER.—Entom. News, XVIII, Mch., pp. 108, 109.
Record of hand collecting in nursery; June 18, 1902. Brood X.

1902. QUAINTANCE, A. L.—The seventeen-year locusts; how the adults feed. <Rural New Yorker, July 26, p. 511.

1902. OSBORN, H.—Insects affecting forest trees. <Proc. Columbus Hortic. Soc., vol. 17, September, pp. 79–92.

1902. QUAINTANCE, A. L.—On the feeding habits of the periodical Cicada. Bul. No. 37, n. s., Div. Entom., U. S. Dept. Agric., November, pp. 90–94. 3 figs.
First careful observation demonstrating feeding of adult cicadas.

1902. OSBORN, H.—Some notable insect occurrences in Ohio for the first half of 1902. <Bul. No. 37, n. s., Div. Entom., U. S. Dept. Agric., November.
Brief reference (p. 116) to periodical Cicada, Brood X, 1902, in Ohio.

1902. SANDERSON, E. D.—Notes from Delaware. <Bul. No. 37, n. s., Div. Entom., U. S. Dept. Agric., November.
Brief record for Delaware for Brood X, 1902 (p. 101).

1902. QUAINTANCE, A. L.—The periodical Cicada or seventeen-year locust. <Bul. No. 87, Maryland Agric. Exp. Sta., November, pp. 65–116; 2 pls., 17 figs.
Full account of Brood X, 1902, in Maryland, with valuable new observations on habits, etc., and map.

1902. OSBORN, HERBERT.—A statistical study of variations in the periodical Cicada. <The Ohio Nat., III, Dec., pp. 323–326.
A careful study of the *cassinii* form.

1902. OSBORN, HERBERT.—Statistical study of variation in the periodical Cicada. <(Amer. Assoc.) Science, new series, vol. 16, pp. 345, 346.
Synopsis of paper.

1902. SANDERSON, E. D.—Report of the entomologist: <Delaware Agric. Exp. Sta., Report 1902, pp. 137–139 (3 plates).
Brief notes on periodical Cicada in Delaware, Brood X, 1902.

1903. MARLATT, C. L.—Notes on the periodical Cicada in the District of Columbia in 1902. <Proc. Ent. Soc. Wash., vol. 5, pp. 124–126.

1903. MARLATT, C. L.—An early record of the periodical Cicada. <Proc. Ent. Soc. Wash., vol. 5, No. 2, pp. 126–7.
Author's extras published February 4, 1903.

1903. PETTIT, R. H.—Mosquitoes and other insects of the year 1902. <Special Bul. No. 17, Mich. Agric. Exp. Station, January.
Brief note on periodical Cicada (pp. 21, 22) with records for 1902, Brood X.

1903. SMITH, J. B.—Report of the entomological department for 1902. <New Jersey Agric. Exp. Sta., February.
Cicada septendecim, pp. 470–489—record of Brood X, with notes on other New Jersey broods and map of all broods occurring in the State.

1903. GARMAN, H.—Seventeen-year locusts in Kentucky. <Bul. No. 107, Kentucky Agr. Exp. Sta., pp. 81–100, 4 pls., 3 figs. (May 23).
General account. Special reference to Brood X, 1902; maps, 1902 and 1906.

1903. QUAINTANCE, A. L.—Entomological notes from Maryland. <Bul. No. 40, Div. Ent., U. S. Dept. Agric., August, p. 47, 1 map.
Includes reference to periodical Cicada, with map for Maryland of Brood X, 1902.

1903. ALWOOD, W. B.—A note on the oviposition of the seventeen-year locust (*Cicada septendecim* Linn.) <Bul. No. 40, Div. Ent., U. S. Dept. Agric., August, pp. 75, 76.
Indicates the possible repellent action of Bordeaux mixture, and gives list of 33 plants oviposited in.

1903. MEEK, W. J.—On the mouth parts of the Hemiptera. <Bul. Univ. Kansas, ii, pp. 257–277, pls. vii-xi. November.
A detailed anatomical study based on the periodical Cicada.

1903. BRITTON, W. E.—Third Report of the State Entomologist. <Report Conn. Agric. Exp. Sta. f. 1903, p. 214.
Brood XI, 1903, expected but no records obtained. (Was reported for Rhode Island.)

1903. FELT, E. P.—Eighteenth report of the State Entomologist on injurious and other insects of the State of New York. <Bul. 64, N. Y. State Museum, Albany, p. 113.
Brief report of Brood X, 1902, in New York.

1904. McCOOK, HENRY.—[The periodical Cicada.] <Harpers' Mag., June, 1904.

1905. GARMAN, H.—The seventeen-year locust will not appear in Kentucky this year (1905). <Kentucky Agr. Exp. Sta. Bul. 120, pp. 74–76. May.
Distribution of Broods XIV, 1906, and XIX, 1907, from Kentucky Bulletin 107.

1905. [SURFACE, H. A.]—The seventeen-year locust in Pennsylvania. <Penna. Dept. Agric. Mo. Bul. Div. Zool., vol. 3, No. 6 (Oct.), pp. 174, 175.
Advance warning of Brood XIV, 1906.

1906. MARLATT, C. L.—The periodical Cicada in 1906. <U. S. Dept. Agric., Bur. Ent. Cir. 74, pp. 5, figs. 3, Apr. 16.

1906. [SURFACE, H. A.]—The Cicada or seventeen-year locust in Pennsylvania. <Penna. Dept. Agric. Mo. Bul. Div. Zool., vol. 3, No. 12, pp. 369–377.
Various records of appearance in Pennsylvania.

1906. [SANDEL, Rev. ANDREAS.]—"Extracts from the Journal of." <Pa. Mag. of Hist. & Biog., Vol. XXX, Oct., pp. 448–449.

APPENDIX.

DR. GIDEON B. SMITH'S CHRONOLOGY OF THE PERIODICAL CICADA.

[From a copy, by Dr. J. G. Morris, of Doctor Smith's unpublished manuscript.]

It is proper to remark in relation to the districts in this tribe or division that there is some uncertainty in relation to some of them (as well as to those of the northern division) that have their borders on the great line that separates the two divisions, owing to the fact, remarked upon in another place in this work, that the districts often interlock, those of the northern running down into the territory of the southern and those of the southern running up into that of the northern division, sometimes for hundreds of miles. A remarkable instance of this will be found in the case of the southern Illinois district, which ascends to the north nearly three degrees of latitude above the regular line of division; and also to the lapping of one district over another on their respective boundaries, elsewhere noticed. The reader will therefore make due allowance for such errors as he may find in the dates of appearance.

REGISTER OF THE SOUTHERN TRIBE (THIRTEEN-YEAR LOCUSTS).

1842. *Illinois.*—In Washington, Jefferson, Franklin, Perry, Randolph, Monroe, St. Clair, Madison, Bond, Clinton, Edwards, Marion, and adjacent counties in the southern end of the State, in 1829, 1842, 1855, and again in 1868. Of this there is great doubt whether it belongs to the seventeen-year tribe, as is indicated by the following paragraph from the Baltimore Sun of June 13, 1859: "The locusts have made their appearance in Egypt, in southern Illinois, and cover woods and orchards in swarms."

1842. *Kentucky.*—Northwest corner of State, about Paducah and adjacent counties in the south, in 1829, 1842, 1855, and again in 1868.

1842. *Alabama.*—Russell and adjacent counties on the east side of Black Warrior River, in 1842, 1855, and again in 1868.

1842. *Louisiana.*—Morehouse Parish, Caddo, Claiborne, Washita, and adjacent parishes, in 1855, and again in 1868.

1842. *Arkansas.*—All the northern counties in 1842, 1855, 1868.

1842. *South Carolina.*—Chester district and all adjoining to the Georgia line and to North Carolina north[ward] in 1816, 1829, 1842, 1855, 1868.

1842. *Tennessee.*—Montgomery, Bedford, Williamson, Rutherford [and adjacent counties], in 1842, 1855, and again in 1868.

1842. *Georgia.*—Cherokee County in 1816, 1829, 1842, 1855, 1868.

1842. *North Carolina.*—Mecklenburg County in 1816, 1829, 1842, 1855, 1868.

1842. *Missouri.*—All southeast part in 1829, 1842, 1855, 1868.

1843. *Georgia.*—Habersham and Rabun(?) counties in 1843, 1856, 1869.

1843. *Georgia.*—Muscogee, Jasper, Greene, Washington, and adjacent counties in 1843, 1856, 1869.

1844. *Florida.*—Jackson, Gadsden, and Washington counties in 1844, 1855, 1870.

1845. *Mississippi.*—From the Mississippi River east to a ridge that divides the State north and south, 45 miles from the river, and north and south to the boundaries of the State, in 1806, 1819, 1832, 1845, 1858.

1845. *Louisiana.*—East and West Feliciana in 1806, 1819, 1832, 1845, 1858.

1846. *Georgia.*—Gwinnett, Dekalb, and Newton counties in 1846, 1859.

1846. *Tennessee.*—Northern part in 1846, and again in 1859.

1846. *Mississippi.*—All the east of the State, from the ridge 45 miles from the river on the west to the east boundary, in 1820, 1833, 1846, 1859.

1849. *Texas.*—Appeared in some parts in vast numbers; unable to get any particulars. If true, will appear again in 1862.

1854. *Georgia.*—Cherokee County, northern part, in 1828, 1841, 1854, 1867.

1855. *North Carolina.*—Buncombe and McDowell counties in 1855.

[N. B.—Doubtful whether this is a southern or northern district. They appeared in 1855, at all events, and will again in 1868 or 1872.]

1859. *Louisiana.*—Carroll Parish, May 1.

1859. *Arkansas.*—Phillips County, May 10.

1859. *Tennessee.*—About Memphis.

REGISTER OF THE NORTHERN TRIBE (SEVENTEEN-YEAR LOCUSTS).

1842. The locust appeared in North Carolina from Raleigh to near Petersburg, in Virginia, and will appear again in 1859.

1842. They appeared in the valley of Virginia from the Blue Ridge on the east, the Potomac River on the north, to the Tennessee and North Carolina lines on the south, and several counties in the west, in 1808, 1825, 1842, and will appear again in 1859.

1842. *Illinois.*—About Alton, and again in 1859.

1842. *Maryland.*—Southern part of St. Mary County, dividing the county about midway east and west. Appeared there in 1825, 1842, and again in 1859.

1842. *North Carolina.*—Rowan, Davie, Cabarrus, Iredell, and adjacent counties in 1825, 1842, and will appear again in 1859.

1842. *Indiana.*—Sullivan and Knox counties in 1859.

1843. *New York* and *Connecticut* from Long Island Sound, west side of Connecticut River, north on both sides of the Hudson River to Washington County, N. Y., and west to Montgomery County on the Mohawk River. Appeared there in 1809, 1826, 1843, and will again in 1860.

1843. *Michigan.*—Kalamazoo; appeared in 1843, and will again in 1860.

1843. *Indiana.*—Dearborn County; will again in 1860.

1843. *North Carolina.*—Caldwell(??), Rockingham, Stokes, Guilford, Rowan, Surry, and adjacent counties; appeared in 1792, 1809, 1826, 1843, and will again in 1860.

1843. *Pennsylvania.*—Bounded by Peters Mountain on the south, Mahonlago (?) Mountain on the north, and extending from the Susquehanna to the Delaware River; appeared there in 1843, and will in 1860.

1843. *New Jersey.*—Whole State, in 1775, 1792, 1809, 1826, 1843, and again in 1860.

1843. *Maryland.*—From Anne Arundel County to the north part of St. Mary, from the Potomac to the Chesapeake Bay, in 1809, 1826, 1843, 1860.

1844. *Illinois.*—In Warren County, and will again in 1861.

1844. *Iowa.*—In various parts, and will again in 1861.

1845. *Missouri.*—All the western part of the State from Saline County west, as far as heard from, north to the boundary of the State and south to Arkansas in 1845, and will again in 1862.

1846. *Ohio.*—Eastern part, extending west to Scioto River and Sandusky on Lake Erie, extending over twelve counties in 1829, 1846, and again in 1863.

1846. *Virginia.*—Southeastern part in 1829, 1846, and will in 1863.

1846. *Virginia.*—Lewis County, in 1795, 1812, 1829, 1846, and will in 1863.

1847. About Wheeling, in Virginia, in 1830, and will again in 1847, 1864.

1848. *New York.*—In Monroe, Livingston, Madison, and adjacent counties in 1797, 1814, 1831, 1848, and will in 1865.

1849. *Pennsylvania.*—In Armstrong, Clarion, Jefferson, Chemung, Huntingdon, Cambria, Indiana, Butler, Mercer, Beaver, and in nearly all the western counties in 1832, 1849, and will in 1866.

1849. *Ohio.*—In Mahoning, Carroll, Trumbull, Columbiana, and adjacent counties, especially in Columbiana in 1812, 1829, 1846, the eastern district lapping over this in that county; appeared in this district in 1815, 1832, 1849, and will in 1866.

1850. *Virginia.*—County (?) and adjacent territory in 1833, 1850, and will in 1867.[a]

1851. *Maryland, Pennsylvania, Delaware, Virginia.*—Beginning at Germantown, Pa.; south to the middle of Delaware; west through the eastern shore of Maryland, upper part of Anne Arundel; west through the District of Columbia, Loudoun County, Va., where it laps over the south Virginia district from the Potomac to Loudoun County some 10 to 20 miles in width, and [in] this strip of territory they appear every eighth and ninth year. Thence the line extends through the northern counties of Virginia and Maryland to the Savage Mountain, and thence along the southern tier of counties in Pennsylvania to Germantown. The whole territory embraced in these boundaries is occupied by the locusts. Appeared here in 1766, 1783, 1800, 1817, 1834, 1851, and will again in 1868.

1851. *Ohio.*—Cincinnati; Franklin, Columbus; Piqua, Miami County. This district extends into Indiana to New Albany, Madison, Indianapolis, to the Wabash River, Terre Haute, and to Louisville, Ky., in 1834, 1851; will again in 1868.

1852. *Massachusetts.*—Bristol County, Dearfield, Hampshire, and to Fall River in 1767, 1784, 1801, 1818, 1835, 1852, and will in 1869.

1853. *Ohio.*—Vinton County in 1853, and will in 1870.

1853. *Illinois.*—In Jo Daviess County, and will in 1870.

1854. *Illinois.*—In Winnebago, Menard County, and neighborhood in 1854; again in 1871.

1855. *Maryland.*—On the old Liberty Road leading to Carroll, and Adams County, Pa., and on the Winden (?) Mile Road extending to Carlisle, Pa., in 1838, 1855, and in 1872.

1855. *Kentucky.*—About Frankfort, Lexington, and Flemingsburg, extending to Meigs and Gallia counties, Ohio, in 1838, 1855, and in 1872.

1855. *Maryland.*—Eastern Shore from Cecil County to Worcester in 1838, 1855, and in 1872.

1855. *Massachusetts.*—Barnstable County, in 1770, 1787, 1804, 1821, 1838, 1855, and in 1872.

1855. *Virginia.*—Kanawha County, extending only 15 miles each way, in 1838, 1855, and in 1872.

1855. *North Carolina.*—In Buncombe and McDowell counties in 1855; again in 1872. [N. B.—There is some doubt whether this district is not a 13-year district. The locusts appeared there in 1855, at all events.]

[a] This evidently refers to Brood IX, which is known from many counties in Virginia (see pp. 49–50).

[NOTE ON THE SMITH REGISTER.—An examination of the above register of appearances, prepared by Dr. Gideon B. Smith, at once indicates the painstaking care which Doctor Smith must have devoted to the subject, and surprises one with the accuracy and completeness of the records. All of the important broods known until recently are designated more or less completely in Doctor Smith's register, namely, the seven 13-year broods and the fourteen 17-year broods mentioned in Bulletin 14.

Taking the records in the order in which they are given in Doctor Smith's register, and beginning with the 13-year race, it will be seen that the localities listed after 1842 and 1855 refer to Brood XIX, after 1843 to Brood XX, and similarly 1844 to Brood XXI, 1845 to Brood XXII, 1846 and 1859 to Brood XXIII, 1849 to Brood XXVI, and 1854 to Brood XVIII.

Comparing in the same way his register of the northern tribe, or 17-year race, it is seen that his localities listed after 1842 apply to Brood I, after 1843 to Brood II, and similarly 1844 to Brood III, 1845 to Brood IV, 1846 to Brood V, 1847 to Brood VI, 1848 to Brood VII, 1849 to Brood VIII, 1850 to Brood IX, 1851 to Brood X, 1852 to Brood XI, 1854 to Brood XIII, and 1855 to Brood XIV. The records given after 1853 are probably erroneous, as indicated in the discussion of my Brood XII (pp. 55–56).—C. L. M.]

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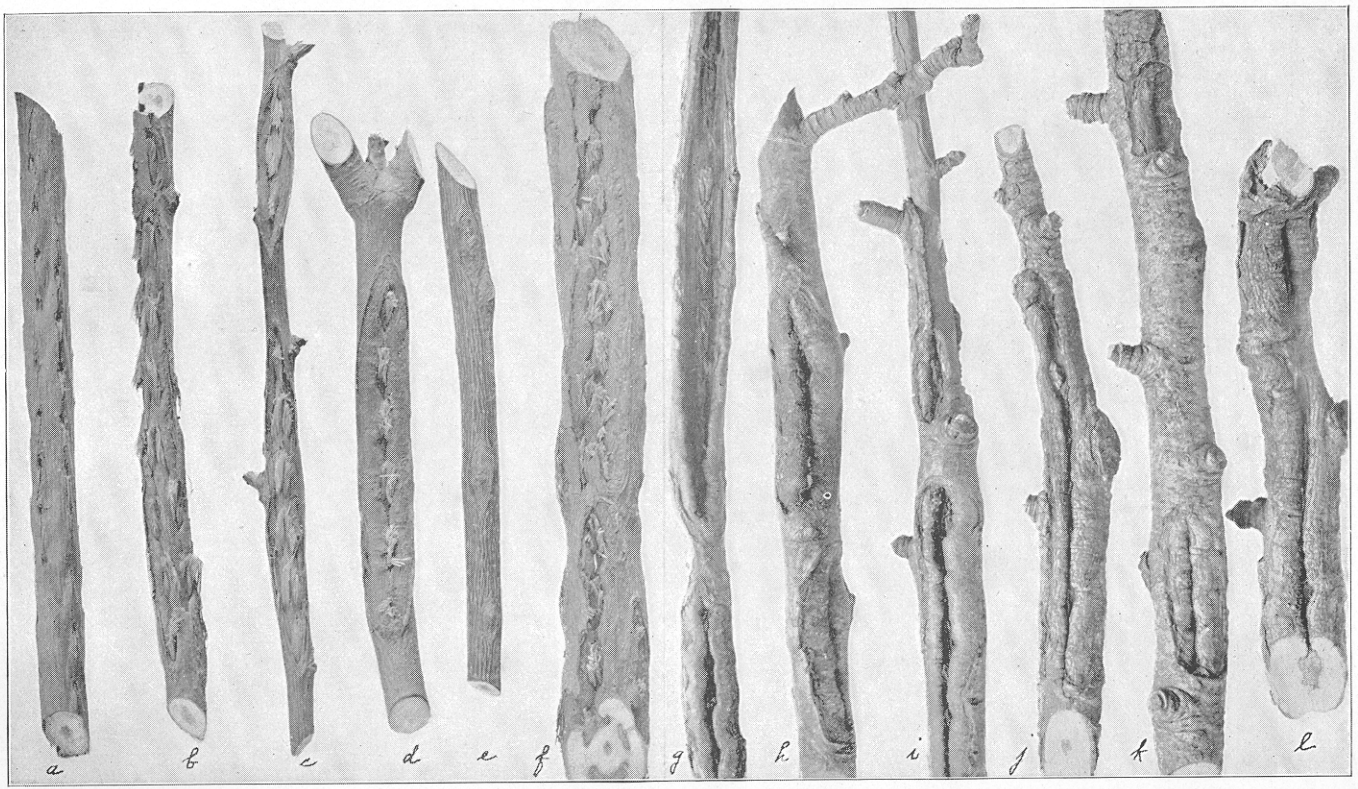
C. V. Riley, del L. Sullivan pinx.

A. HOEN & CO. BALTIMORE.

TRANSFORMATION OF PERIODICAL CICADA (TIBICEN SEPTENDECIM).



WORK OF THE PERIODICAL CICADA.

a, Fresh wounds in maple; *b*, *d*, *e*, and *f*, Condition four months later in maple; *e*, Wounds healed in one season; *c*, Three months' old scars in wild cherry, showing that the punctures may extend both toward the top and base of the twig; *g*, *h*, *i*, *j*, *k*, *l*, Cicada scars seventeen years old on terminal branches from old trees; *g*, *h*, *i*, Apple; *j*, *k*, *l*, Pear. (After Hopkins.)

As already noted, the gift of song is found in the male insect only, and the true sound apparatus consists of two small ear-like or shell-like inflated drums situated on the sides of the basal segment of the abdomen. These drums are caused to vibrate by the action of powerful muscles, and the sound is variously modified by adjacent smaller disks—the so-called "mirrors" or sounding boards—and issues as the peculiar note of the species, which once heard is never likely to be forgotten, or, if heard again, mistaken for that of some other insect. The true sound organs are entirely exposed in the periodical Cicada except for the covering afforded by the closed wings of the resting insect. In other cicadas these drums are usually protected by overlapping valves or expansion of the body wall.

The sounding drum, or "timbal," as Réaumur termed it, of the periodical Cicada is a tense, dry, crisp membrane numerously ribbed or plated with the convex surface turned outward. The ribs are chitinous thickenings or folds in the surface of the parchment-like drum, and strengthen the drum while perhaps rendering it at the same time more elastic. The sound is produced by the rapid vibration, or undulation, caused by the springing or snapping in and out of these corrugated drums. Two powerful muscles of very peculiar structure situated within the base of the abdomen set these drums in motion, producing the rattling so-called song of the Cicada, very much, as has been suggested, as sound is produced by pressing up and down the bottom of a tin pan which is somewhat bulged.

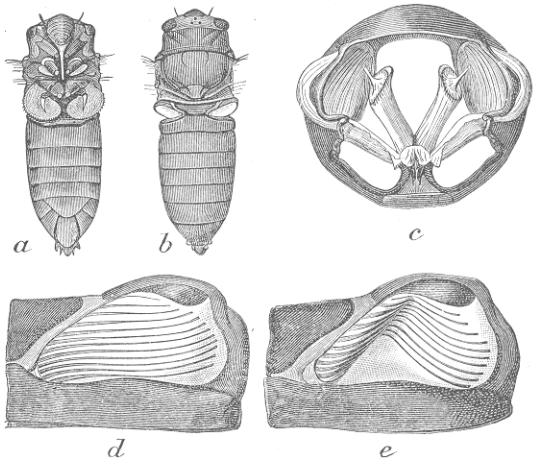
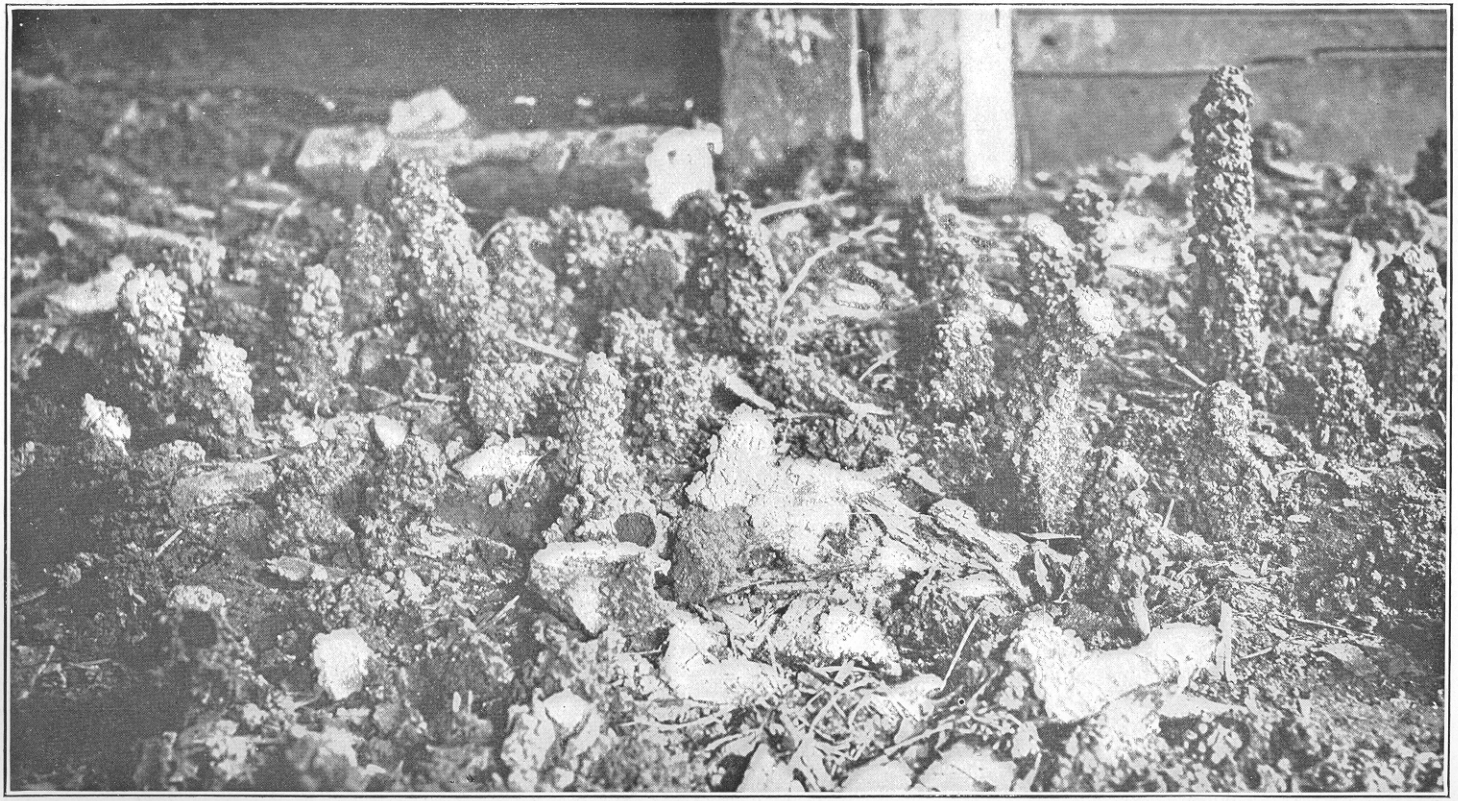


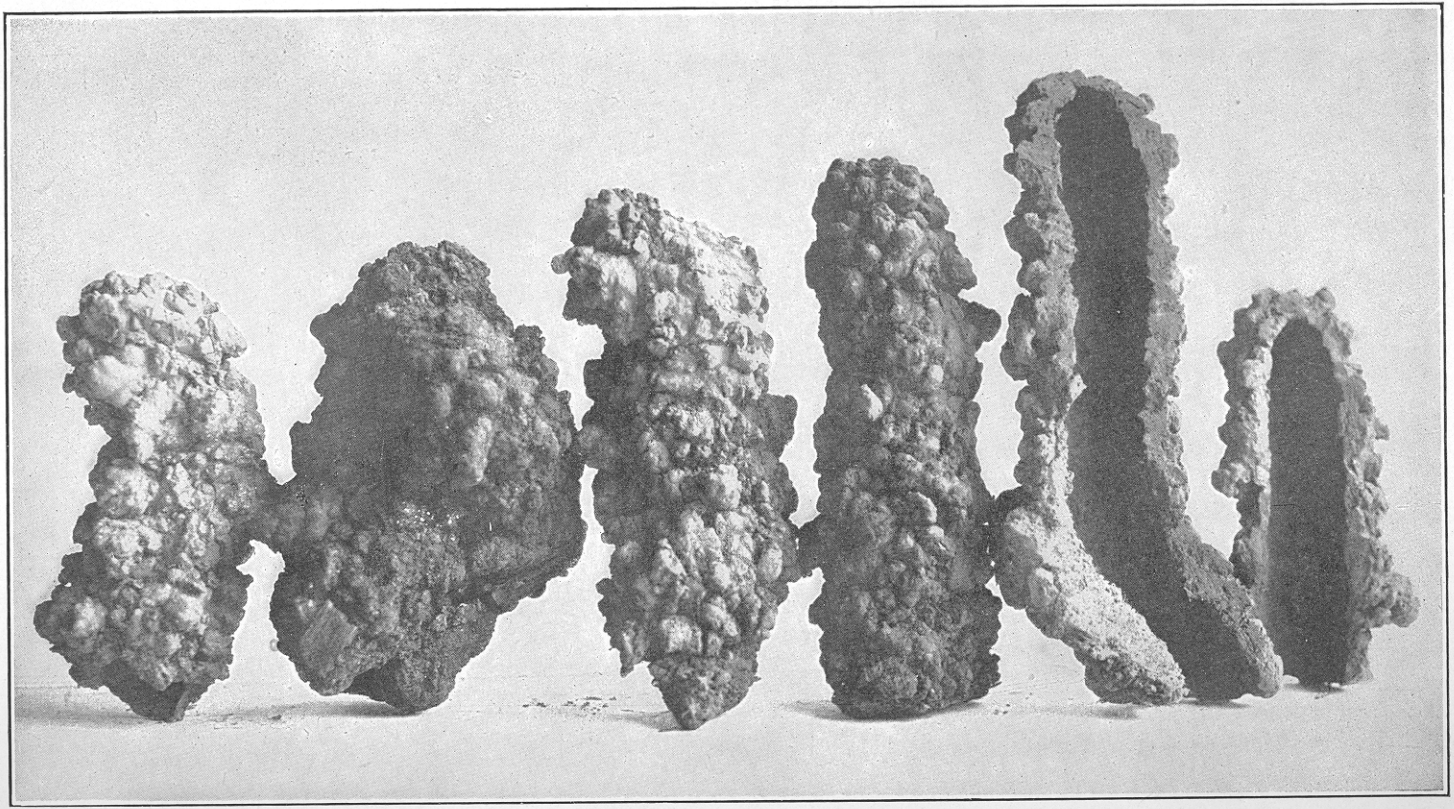
FIG. 38.—The musical apparatus of the periodical Cicada: *a*, view from beneath, showing the plates (light colored) covering the sounding disks; *b*, dorsal view, the timbals showing as light-colored areas; *c*, section at base of abdomen, showing attachment of large muscles to timbals; *d*, timbal greatly enlarged, in normal position; *e*, same drawn forcibly in by the action of one of the muscles, as in singing. (Author's illustration.)

Beneath each "timbal" in the base of the abdomen of the insect is a large sound or air chamber, and a third occurs in the thorax joining the first two. These are closed by the body walls and membranes, and the two abdominal ones beneath by the very peculiar "mirrors," or "spectacles"—the tense, mica-like membranes situated at the base of the abdomen and protected and covered by the semicircular rigid disks projecting from the thorax. These transparent

PHOTOGRAPH OF CHAMBERS OF THE PERIODICAL CICADA, GENERAL VIEW, TAKEN AT NEW BALTIMORE, N. Y., MAY, 1894. (AFTER LINTNER.)



PHOTOGRAPH OF CHAMBERS OF THE PERIODICAL CICADA IN WOODSHED, WASHINGTON, D. C., 1902. (ORIGINAL.)



PHOTOGRAPH OF CHAMBERS OF THE PERIODICAL CICADA, NATURAL SIZE, IN WOODSHED, WASHINGTON, D. C., 1902. (ORIGINAL.)

EMPTY PUPAL SHELLS OF THE PERIODICAL CICADA CLINGING TO LEAVES, BROOD X, 1902, WASHINGTON, D. C. REDUCED. (ORIGINAL.)

trunks was quite audible, particularly vigorous pupæ ascending the trees to the height of 30 feet.

Plate V, showing empty pupal shells clinging to leaves, still further illustrates the large number of these insects which often emerge.

As noted by Mr. Farmsley, of Louisville, Ky., the cicadas do not appear very numerously on tops of mountains within an infested area, but gradually decrease in numbers as one ascends, the greater scarcity being noticeable both to the eye and the ear, the rattling chorus growing less and less strong.

On the authority of Dr. Hopkins, the diminishing of the Cicada in numbers as one ascends to higher elevations is apparently not always true. Dr. Hopkins describes driving for a day through the Cicada district of West Virginia in 1897 on the occasion of the reappearance of the 17-year Brood V, and states that as he approached the eastern

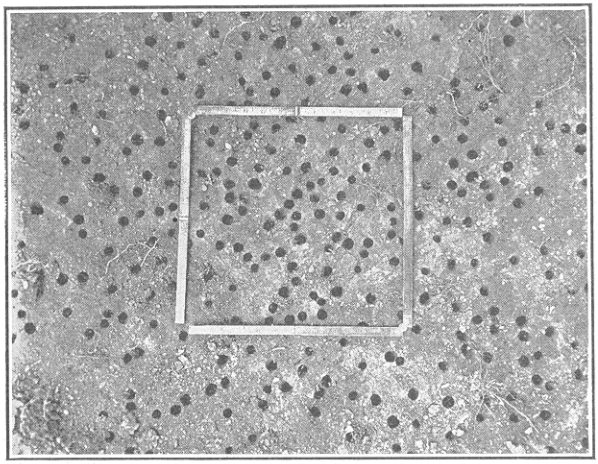
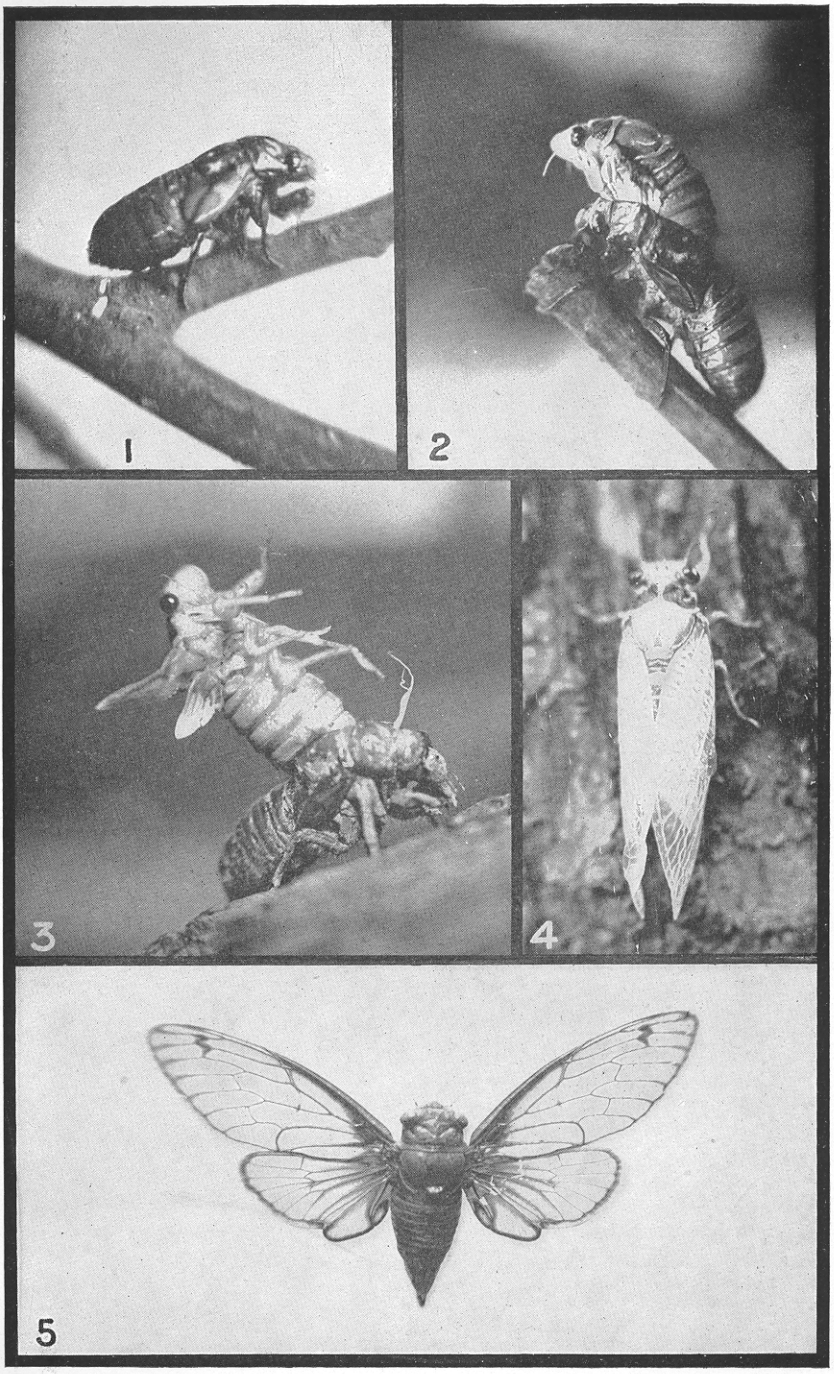


FIG. 40.—Exit holes of the periodical Cicada at surface of soil. The rule shows the large number of holes occurring, in this instance, in a square foot of ground

borders of Preston County the cicadas became more numerous, and as the mountain west of Cranesville was ascended the Cicada was found, at an elevation of 2,600 to 2,800 feet, to occur in far greater numbers than at any point previously traversed. The leaves and twigs of the trees were literally covered with the insects, and the twigs were bending from their weight. This point seems to have been the eastern border of the swarm, and a few rods farther up the cicadas became very scattered and soon ceased altogether.

They often also appear in greatest number in rather well-defined districts within the general range of the brood, or, in other words, are irregular in local distribution. This variation in abundance is due in some cases to differences in the character of the soil and in others, perhaps, to varying surface conditions, as of timber growth, etc. They prefer, apparently, white-oak groves, and are most abun-



THE TRANSFORMATION OF THE EMERGED PERIODICAL CICADA.

1.—Pupa ready for transformation. 2.—Adult beginning to issue from pupal shell. 3.—Adult nearly free from pupal shell. 4.—Freshly transformed adult, the coloring immature. 5.—Adult, several hours after transformation, the coloring mature. About natural size.

of the surrounding wood, there remains in the center of the twig a dead spot, and the white glistening egg shells of the escaping larvæ have been found in place six years after they have been inserted in the twig by the female Cicada.

Considerable danger follows the work of the Cicada, in that as long as the wounds remain open or as dead spots on the limbs they are not only a source of weakness in the case of winds, but they offer attractive situations for the attacks of various wood-boring insects. If left to themselves the limbs might entirely recover, except for the scars, but the borers gaining entrance through these spots complete the work

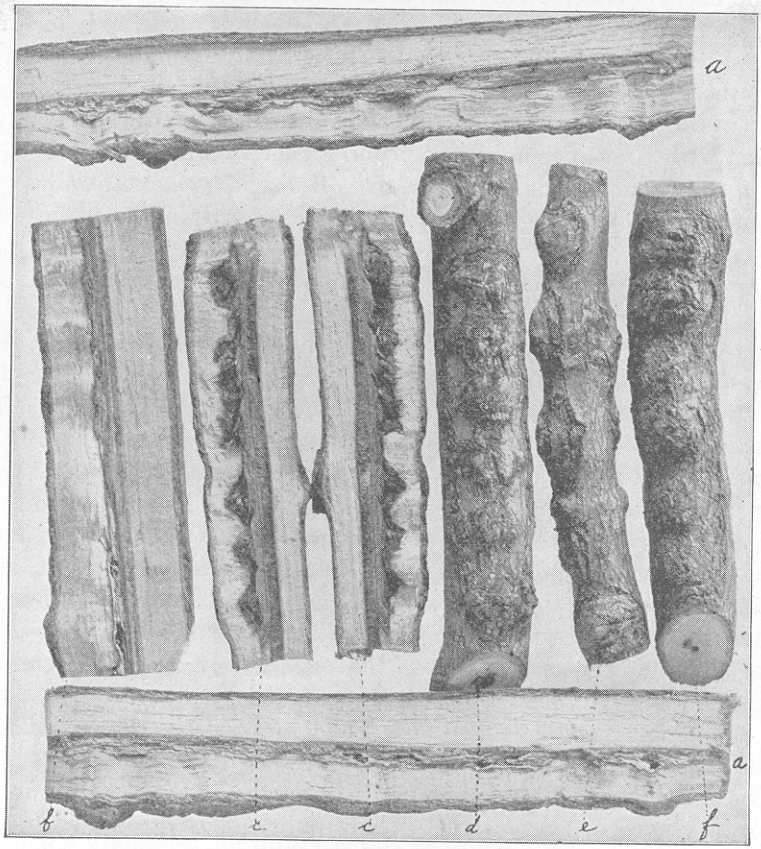


FIG. 43.—Periodical Cicada scars in hard-maple twigs after seventeen years. (Hopkins.)

of destruction which the Cicada began. Furthermore, such open wounds or pockets in the twigs of fruit trees Doctor Hopkins has shown to be favorite points of attack for the woolly aphis (*Schizoneura lanigera* Hausm.), the presence of which not only prevents the wounds from healing but causes additional abnormal growth, adding considerably to the injury to the branches, and making them more liable to the attacks of other insects.

within the egg period of seven or eight weeks of the Cicada, and this accounts for its excessive multiplication, as described by Mr. Hartman, and probably makes it wherever it occurs one of the most efficient agencies in keeping the Cicada in check.

THE LARGER DIGGER WASP.

I have already referred to the probability of the larger digger wasp (*Sphecius speciosus* Dru.) preying on belated individuals of the periodical Cicada. That the bulk of the brood has disappeared, however, before this wasp becomes at all abundant has been often pointed out and is not to be questioned, and it is well known that the most of its work is with the later-appearing dog-day harvest fly (*Cicada tibicen* L.). With the assistance of Mr. Pergande and the writer, Professor Riley worked out the natural history of this wasp in detail in its relation to the dog-day harvest fly, and published a full illustrated account of the species.[a] Its life habits when it preys on the periodical Cicada are identical with its habits with the dog-day species or any other annual Cicada with which it may store its burrows. A brief account of the habits of this wasp is here reproduced, together with the figures illustrating its very curious and interesting life stages. (See figs. 54–60.)

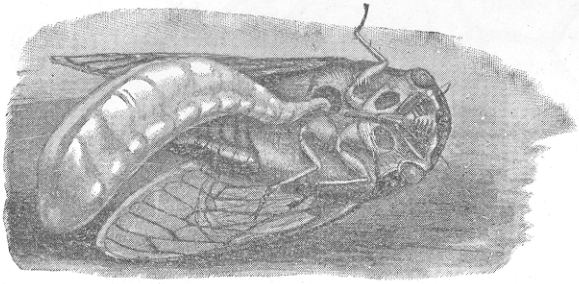


FIG. 57.—Cicada in burrow of Sphecius, with full-grown larva of latter feeding. Natural size (after Riley).

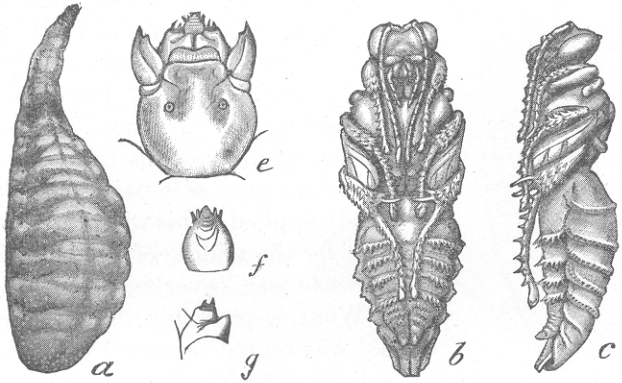


FIG. 58.—*Sphecius speciosus: a*, larva; *b*, pupa, from below; *c*, same, from side, natural size; *e*, head of larva; *f*, labium of same; *g*, maxilla of same. Enlarged (after Riley).

[a] Insect Life, Vol. IV, March, 1892, pp. 248–252.

This wasp and its near allies are the natural and perhaps the most destructive of the insect enemies of the adults of the different species of the Cicada, and their operations are often witnessed and are commented upon in print nearly every season. In fact, no more curious and interesting illustration of the wars which take place in the insect world is afforded than the sight of one of these wasps seizing its victim and silencing and paralyzing it with a sting, which, while throwing it into a comatose condition from which it never recovers and suspending or greatly reducing its vital functions, does not actually kill it, but leaves it an unresisting, living prey for the delicate wasp larva.

The fact that some tragedy is being enacted is often brought to the attention of the observer by the sudden cessation of the regular song note of the unsuspecting Cicada. The song ends in a sharp cry of distress, and if one is in position to witness the struggle the wasp may be seen grasping its victim and endeavoring to take flight, the quick thrust of its sting having almost immediately quieted the Cicada. Very often in the first struggle the wasp and the Cicada fall to the ground together, and it is necessary for the former laboriously to climb the tree again, dragging the Cicada with it, in order to take flight from an elevated point, the Cicada being usually much heavier than the wasp and bearing the latter slowly to the ground as it flies. For this reason it often becomes necessary for the wasp to carry the Cicada several times up into near-by trees, making repeated short flights before it reaches its burrow.

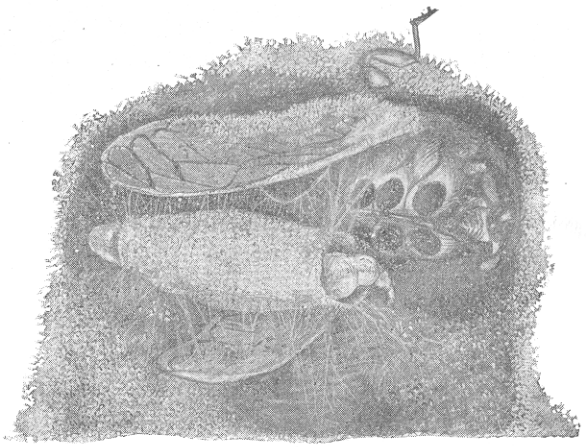


FIG. 59.—Larva of Sphecius spinning its cocoon. Natural size (after Riley).

The latter is excavated with great activity by the wasp, the drier and more elevated situations being usually chosen. The burrow ranges from 18 inches to 2 or 3 feet in length and has three or four or more branches of from 6 inches to a foot in length, each terminating in a little oval chamber. Within each of these chambers is stored a Cicada to which a single wasp egg is attached in such manner as to be covered and protected by one of the middle legs of the Cicada.

The parasitic larva on hatching merely protrudes its head and makes an opening into the body of its host at some suture where