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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 69.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE CHINCH BUG.

BY

F. M. WEBSTER,
In Charge of Cereal and Forage-Plant Insect Investigations.

Issued June 21, 1907.

WASHINGTON:
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1907.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., March 5, 1907.

Sir: I have the honor to transmit for publication the accompanying manuscript entitled "The Chinch Bug," by F. M. Webster, in charge of the cereal and forage-plant insect investigations of this Bureau. This is a thorough revision by Mr. Webster of his earlier account of this destructive pest published in 1898 as Bulletin No. 15, new series, of this office, and includes additional data based on observations made during the past eight or nine years. I recommend that it be published as Bulletin No. 69 of the Bureau of Entomology.

Respectfully,

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

Hon. James Wilson,
Secretary of Agriculture.

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ILLUSTRATIONS.

THE CHINCH BUG.

Few insects, and certainly no other species of the natural order to which this one belongs, have caused such enormous pecuniary losses as has the chinch bug, *Blissus leucopterus* Say. No other insect native to the Western Hemisphere has spread its devastating hordes over a wider area of country with more fatal effects to the staple grains of North America than has this one. But for the extreme susceptibility of the very young to destruction by drenching rains and to the less though not insignificant destructiveness during rainy seasons of the parasitic fungus, *Sporotrichum globuliferum* Speg., on both the adults and young, the practice of raising grain year after year on the same areas, as followed in the United States, would become altogether unprofitable. Some of this insect's own habits, emphasizing as they do the effects of meteorological conditions, are the most potent influences that serve to hold it within bounds, by giving its tendency to excessive increase a decidedly spasmodic character.

DISTRIBUTION.

The genus Blissus is widely distributed over the world, occurring in South Africa, Abyssinia, Algeria, Sicilia, southern Europe, northward at least to the sand dunes of central and northern Hungary, India, Japan, southern Russia, and in the Western Hemisphere in Buenos Aires, and from Panama and the Island of St. Vincent northward to middle California on the Pacific coast and Cape Breton on the Atlantic. When we come to understand that the Hemiptera of the world are far from being well known, and the faunas of South America and central Africa have as yet been hardly studied at all, we may well presume that future studies of the hemipterous insects of these countries may unite some of the different areas now known to be inhabited by the several species of this genus.

At present in the Old World this genus may be said to occur in the Ethiopian, Oriental, and Palæarctic life regions; while in the New World it ranges from the Neotropical region at Panama and St. Vincent into the Nearctic over the borders of the Boreal subregion in British America.

Our American species, *Blissus leucopterus* Say, the only one of the genus at present known in the Western Hemisphere, has been recorded from St. Vincent and Grenada, West Indies, by Uhler; Cuba, by Stål;

Volcan de Chiriqui, Bugaba, and San Feliz, Panama, by Champion; San Geronimo, Paso Antonio, Panzos, Champerico, and Rio Naranjo, Guatemala, by Champion; Lower Purissima, Lower California, by Uhler; Alameda, Cal., by Koebele; and in the vicinity of San Francisco, Cal., by both Uhler and Koebele; Orizaba, Mexico, by H. H. Smith; Tamaulipas, Mexico, by Uhler; Mesilla Park, N. Mex., by Cockerell; Florida, by Schwarz and Dr. J. C. Neal; Sydney, Cape Breton, by W. H. Harrington; Muskoka, Ontario, Canada, by E. P. Van Duzee, and Winnipeg, Manitoba, where a single specimen was collected by Dr. James Fletcher and given by him to Mr. Harrington, to whom I am indebted for information regarding its occurrence. Inland, in the United States, it may be said to be generally distributed from Texas to Manitoba. It is also very probable that its occurrence along the Pacific coast is much more extended than is at present known, as it has not been searched for to any extent in that region. (See map, fig. 1.)

HIBERNATION.

The chinch bug hibernates in the adult stage, and though there may be occasional exceptions, especially in the South, it has yet to be observed in very early spring in any other than the adult stage, at least in any locality north of Mexico. The writer observed pupæ in central Illinois apparently in hibernation in company with adults on November 11, but there is no proof that these survived the succeeding winter. In Tensas Parish, La., adults were abroad in considerable numbers during March, 1887, yet there was no indication of any young having wintered over. The adults were pairing and seemingly engaged in oviposition, precisely as is to be observed in the Northern States during May and June. No young were observed, as most certainly would have been the case had they occurred there, for observations were made in fields of young corn, where, had the young bugs been present even in very limited numbers, they would certainly not have escaped the rigid searching under and about the bases of the leaves of the young corn plants.

Doctor Howard[a] quotes Prof. G. F. Atkinson, at that time of Chapel Hill, N. C., as having observed half-grown chinch bugs on crab grass, about the 1st of October. The same authority also quotes Doctor Riley to the effect that many of the chinch bugs pair in the fall preparatory to seeking winter quarters, and also cites the fact that Mr. James O. Alwood observed them pairing in a field of uncut pearl millet, October 27, 1887, on the grounds of the Ohio Agricultural Experiment Station, then at Columbus, Ohio. Dr. Cyrus Thomas,[b] in speaking

[a] The Chinch Bug, by L. O. Howard; Report of the Commissioner of Agriculture for the year 1887, pp. 51–88.

[b] Bulletin No. 5, U. S. Entomological Commission, p. 13.

of the possibilities of an occasional third brood in southern Illinois and Kentucky, states that there were some evidences of this, but not

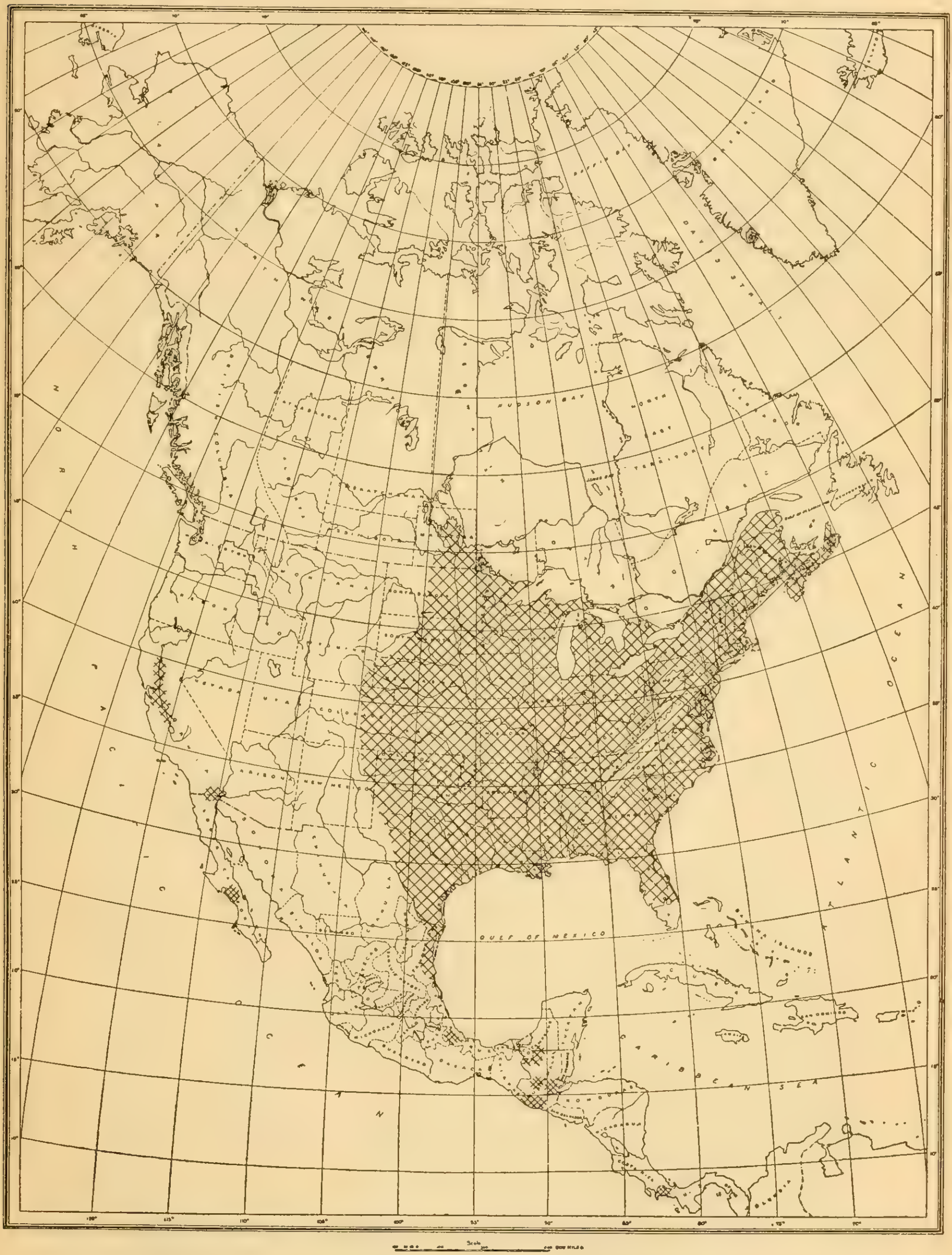

FIG. 1.—Map of North America showing distribution of the chinch bug. (Author's illustration.)

sufficient to justify him in asserting it as a fact or to satisfy him of its correctness.

It therefore seems probable that no young are produced as a result of the late pairing, at least until spring, and it has yet to be shown that the late appearing larvæ do not mature before the hibernating season sets in, or else die during the winter. When we come to consider the extreme susceptibility of the newly hatched chinch bug to wet weather, less perhaps in case of the short-winged form, it will be apparent that as we approach the Tropics the wet and dry seasons would tend to influence the breeding seasons, as those individuals that hatched before the close of the rainy season would be, in a measure at least, continually eliminated, while those that hatched so late as to be caught in the commencement of the rainy season would also be to an equal extent destroyed, and thus, by continually restricting the breeding period to certain months, establish a fixed law that would be adhered to even under the somewhat different conditions which occur farther to the northward. Unfortunately the date or dates on which the young were observed by Mr. Champion, on Volcan de Chiriqui, in Panama, are unknown to the writer, and it is impossible to say whether or not they were found during or near the dry season.

In an article on the hibernation of the chinch bug, Mr. C. L. Marlatt [a] calls particular attention to the fact that in Kansas the chinch bug in autumn seeks the dense stools of some of the wild grasses in which to hibernate, and to such an extent did this occur that it was suggested as probably the normal hibernating habit of the species.

Before entering into a discussion of this matter, it will be well to present two communications received from the late Dr. J. C. Neal, at that time of Stillwater, Okla. As Doctor Neal was located in a section of the country where, in many cases, civilization had not influenced to such a marked degree the natural insect fauna, the author applied to him to secure some exact information in regard to the chinch bug under such conditions. The correspondence, however, was terminated suddenly by Doctor Neal's death. The two letters here given are among the last he ever penned. They are of a somewhat general nature, and will be referred to later in this discussion.

OKLAHOMA AGRICULTURAL AND MECHANICAL COLLEGE,
Stillwater, Okla., October 31, 1895.

MY DEAR SIR: Yours of the 28th just received. Last year was the first wheat year in most of the new additions to this Territory, and from all sections the cry was for infection, as "the bugs are ruining us." I received letters from every county in the strip and in the western sections. The most damage was done in the extreme southern range of counties, and near Okarche (see map, fig. 10) the damage was excessive. I do not think there is a single acre in this or Indian Territory that is not saturated, so to speak, with the chinch bug. You may put this whole area down as within the infested boundary line. My belief is that the increase of country roads, the decrease of March fires, the shiftless habits of the vast majority of our farmers in allowing volunteer

[a] Insect Life, Vol. VII, pp. 232–234, 1894.

wheat and oats to grow and wheat lands to remain fallow, and the planting of new and better grass crops than the tough blue-stem, are direct causes of what I believe a decided increase of this insect in Oklahoma during the last five years. It would be amusing, if it were not so pathetic, to read the many letters I get, something in this wise: "I planted wheat on sod land; the chinch bugs destroyed it so badly that in February I plowed it up and sowed oats; this, too, went the same way; I then planted corn, and when it was a foot high the little bugs came by the millions and destroyed that; I then planted the land to Kafir corn, and that will be ruined if you can not help me." What could I do for such a man? Had the bugs laid out a programme for their daily sustenance, no better commissary-general could have been obtained for them than he was, and I had to write him that his plan was the worst one possible for him, and the best for the bugs, and that the only suggestion I could make, from the bugs' standpoint and for their benefit, would be to plant wheat again so that they could have something for the coming winter's food. In his case it was a series of fatal mistakes from ignorance of the habits of the bugs.

Another thing which I believe adds materially to the increase of these pests is the complete destruction of the prairie chickens, the decimation of partridges, and the thinning out of all kinds of smaller birds, such as the cow blackbirds, bank sparrows, martins, larks, and other prairie birds. This section is full of reckless boys and men who kill everything that flies, good, bad, and indifferent, "for fun."

Some years ago I went out on the Cherokee Strip, miles away from human habitation, and saw some of the small birds—larks and killdees—busily picking in the young grass, in early spring, and upon examination found these places swarming with chinch bugs sucking the juices of the blue-stem grass.

Almost any time in the winter when the weather is warm one can find chinch bugs, and I have witnessed two "flights" of these insects and determined them. I should be glad to answer any more specific questions at any time.

With regards, I remain,

J. C. Neal.

The second letter is a short note in reply to the author's question regarding the grasses fed upon by the chinch bug, their hibernating habits, and developments:

Stillwater, Okla., *November 20, 1895.*

Dear Professor Webster: In reply to your postal, I would say that I do not know, but will at once make observations and report at my earliest chance.

My belief is that the bugs attack all the grass family except the Cenchrus, and that only is exempt on account of its bitter taste, which effectually shields it from insects, as far as I have seen, both in this section and in Florida.

I will take the matter in hand at as early a date as possible and write you progress and results.

Very respectfully, J. C. Neal.

It is reasonable to infer from these letters that the chinch bug wintered over about the stools of grass, and that the birds were observed to attack them there in early spring, as the statement is made that later, when the young corn was a foot high, the little bugs came by the million. This condition of affairs may be considered in connection with the statements of Dr. Asa Fitch,[a] regarding his observations

[a] Second Report on Noxious, Beneficial, and Other Insects of New York, p. 283.

in Illinois in the autumn of 1854, when in passing over the northern part of the State he found the ground in some places, in the midst of extensive prairies, covered and swarming with chinch bugs, reminding him, as he says, "of the appearance presented on parting the hair on a calf that has been poorly wintered, where the skin is found literally alive with vermin." Further along in his report (p. 290) he states that "so late as the forepart of October I met several of these insects in the pupa state, and some of these I do not doubt would pass the winter in that state, and therefore would not deposit their eggs until the following spring." That he did not find these pupæ in New York is shown by his statement on page 287 of the same report, to the effect that he had "met with but three specimens in New York, occurring on willows in the spring of 1847 and May 12, 1851." As shown farther on in this bulletin, there is no proof that these pupæ did not develop to adults before winter, or die before spring, and the conditions indicated would almost presuppose that hibernation would take place on the prairies where the insects were observed by Doctors Fitch and Neal. From personal recollection the writer knows that the section of Illinois to which Doctor Fitch refers was, at the time mentioned, but thinly populated, and there were still very extensive tracts of the original prairie grasses miles distant from woodlands.

In an interesting note by Mr. E. A. Schwarz [a] on the hibernation of the chinch bug, given in discussing Mr. Marlatt's paper, previously mentioned, attention is called to the fact that the hibernation of the chinch bug had been observed by him, in its maritime home, in the vicinity of Fortress Monroe, Va., which locality he had been in the habit of visiting for a number of years, during the first warm days of spring. The maritime flora and fauna are here late to awake, and most insects peculiar to the seacoast can still be found in their winter quarters by the end of April. By pulling up any good-sized stool of grass and beating it out on the smooth surface of the sand or over a cloth a multitude of various insects are sure to be found, and among them always plenty of chinch bugs. These stools of grass not only serve as winter quarters, but in summer the chinch bugs crawl into them during the daytime to protect themselves from the fierce rays of the sun.

In the timothy meadows of northeastern Ohio the writer has witnessed cases where the chinch bugs had commenced their operations along one side, worked part way across the field, killing the timothy as they advanced, and continued their depredations the following year precisely where they suspended work the autumn before, the long-winged individuals only migrating in the intervening time.

[a] Insect Life, Vol. VII, pp. 420–422, 1895.

In southwestern Maine, where this short-winged form has occurred in more or less destructive numbers for upward of forty years, and where it affects timothy in the same manner as in Ohio, both long and short winged individuals, the latter in the majority, hibernate under dead leaves, brush heaps, and similar débris in and about the fields where they have ravaged the timothy. They do not appear to select only the drier portions of such fields, but are found also literally swarming about the clumps of rushes (Juncus) that grow in the low spots. Some of these low places become submerged in winter by rains and melting snows, and the hibernating bugs are washed out and killed.[a] Possibly others not observed might have remained among the living timothy, as it is further stated that many hibernating individuals were to be found among the leaves of clover bordering on spots of timothy that had been killed out by them during the preceding summer.

That the short-winged or maritime form must hibernate in or in very close proximity to the field it infests goes without saying, and it would appear that but for the cultivation of timothy it would have become diffused inland from the coast less rapidly, if at all. It is doubtful if this inland diffusion began until the country became settled by the white man and timothy began to be grown by him as a forage crop—a situation that would be coexistent with a diminution in the number and extent of prairie and forest fires.

West of the Allegheny Mountains we encounter this short-winged maritime form only in western Pennsylvania, northern Ohio, southern Michigan, extreme northern Indiana, and equally extreme northern Illinois. The writer once found a single short-winged individual in southern Ohio, and a single individual that may or may not belong to this species has been recorded from New Mexico by Prof. T. D. A. Cockerell.

Except as indicated in the preceding paragraph, over this whole country the long-winged form is the only one known, and its habits are almost as unlike those of the maritime form as they would be were the latter a different insect. Timothy culture has never extended to the Gulf coast, and the extensive growing of the crop over this whole western country is of recent date, coexistent with the advent of the white man. Here, therefore, timothy is not attacked by chinch bugs.

The inland or long-winged form inhabits largely a prairie country, and it would appear that, as these prairies were annually burned over during the hibernating season, the form that became the most scattered prior to hibernation would be likely to stand the best chance of surviving. It seems to the writer that the wings of the chinch

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[a] Nineteenth Ann. Rept. Maine Agric. Exp. Sta., 1903, pp. 41–52.

bug might have been, in early days in the Mississippi Valley, kept up to a high standard of development by the necessity of such an escape from prairie fires and not by the presence of *Sporotrichum globuliferum*, as suggested by Professor Sajó in his paper, a translation of which is included herein under the heading, "Habits of the European species, *Blissus doriæ* Ferr."

As mentioned farther on, the advance of civilization having revolutionized the face of the country, there has come a corresponding change in the hibernating habits of the chinch bug. This insect must now seek shelter in the limited patches of timber that are left in the sections that were once entirely wooded and in the matted grass along fences and roadsides, but especially among the fallen leaves and rubbish that usually accumulate along Osage orange hedges. Brush piles, old haycocks, strawstacks, and, in Ohio, at any rate, shocks of corn fodder left standing in the fields through the winter, all harbor chinch bugs during the hibernating season.

The fact that the insect hibernates in matted bluegrass along roadsides and fences has been called in question by Professor Forbes and by Mr. Marlatt, the former in his first report as State entomologist of Illinois (p. 37) and the latter in Insect Life (Vol. VII, p. 232), but notwithstanding this, in some parts of Ohio, in Indiana, and Illinois they do hibernate in just such places and can be found there, especially during the winter and early spring following a season of abundance, but the investigator must know how to search for them. The writer has found them late in the fall collected under rails, half buried in soil and dead grass, and in northern Illinois, while searching for other insects in early spring, he was sure to find them in varying numbers with small Carabidæ, Staphylinidæ, and other early appearing insects, on the under side of boards laid down in grassy places, though no amount of searching the grass itself would have revealed their presence.

In the timothy meadows of northeastern Ohio the percentage of long-winged individuals is always much greater in fall than in June, showing that some, at least, hibernate there and migrate to the cultivated fields in spring. In Maine, in the case of the maritime form, of 565 bugs collected in hibernation in October, 1902, only 60 had long wings.[a] In Kansas, where Mr. Marlatt made his observations, there was still too much prairie, and the species was doubtless still adhering to its ancient habits of hibernation. In southern Ohio the author has found it attacking the wheat in May, in small isolated spots over the fields, while there was nothing in the least to imply an invasion from outside, but the wheat had been sown in the fall among corn, and later the cornstalks cut off and shocked, remaining in this condition until the following spring. This occurred so frequently that

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[a] 19th Rept. Maine Agric. Exp. Sta., 1903, p. 48.

there seemed no room to doubt that the attacks had been caused by adults wintering over in the corn fodder, and that these left their winter quarters in spring to feed and breed on the grain growing nearest at hand.

Prof. Herbert Osborn,[a] in giving a summary of his observations on the chinch bug in Iowa in 1894, states that "In a great majority of cases, 90 per cent or more, the infested fields were directly adjacent to hedges or thickets or belts of timber, and in 75 per cent Osage orange hedges were the most available shelter. In about 13 per cent of the cases the evidence showed hibernation in grass and weeds, and in some of these cases there could scarcely be a doubt that the hibernating bugs were protected by a heavy growth of grass or weeds and that they moved from these directly into the adjacent grain fields." Prof. Lawrence Bruner had previously called attention to the fact that the chinch bug hibernated in great numbers about Osage orange hedges in Nebraska. Doctor Lugger, in Minneseta, gives the following as offering shelter to the bugs during winter: "Rubbish of all kinds, but chiefly that of hedges, wind-breaks, and along the edges of woods, as well as corn fodder, logs, and even loose bark and stones."

While drenching rains are beyond all possible doubt fatal to the newly hatched young, the adult bugs seem to be almost proof against either wet or cold weather. It is doubtless true that very many individuals die in their winter quarters, and in fact the writer has found these dead in considerable numbers in some instances during early spring, but it seems at least doubtful if either cold or wet would entirely account for this fatality. It would seem that somewhere and at some period in the past this hibernation has been more for protection from natural enemies than against the elements, though of course there might have been other reasons not discernible under a changed environment. The pupa hides away to molt, though it does not appear that this course is followed in the earlier stages, and the reasons for this are not at all clear. That the adult is able to withstand combined cold and wet weather is amply proved by the observations of several people. Dr. Hy. Shimer, in Illinois, found that those which were in corn husks filled with ice, even the chinch bugs themselves being inclosed in the crystallized element, were able to run about when they were thawed out, apparently unaffected by a temperature that had varied from 15° to 20° below zero Fahr. It seemed that when exposed to the sweeping prairie winds at that temperature, with no protecting cover, they perished. Mr. G. A. Waters, in the Farmers' Review for October 19, 1887, relates that a bunch of fodder that had fallen into a ditch washed out near a corn

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[a] Chinch Bug Observations in Iowa in 1894, Insect Life, Vol. VII, pp. 230-232.

shock by heavy rains became covered with water that stood over it long enough for a sheet of ice to form. When the water had subsided the corn was husked and a number of chinch bugs were found among the ears, where they had been immersed for a week or more; yet on being exposed to the warm sun they began to crawl about in a lively manner.

The Maine Agricultural Experiment Station some years ago[a] carried out a series of experiments with the maritime form to determine the effect of freezing. Ten long-winged and 6 short-winged bugs were frozen in an open box for fifteen hours. Upon thawing out 2 gave no signs of life. After being kept for nine hours at a temperature of 65° the 14 surviving bugs were refrozen for fifteen hours and then thawed out, when 5 long-winged and 3 short-winged revived. After nine hours at a temperature of 65° they were frozen a third time for fifteen hours, during which time the minimum temperature sank to 16° below zero. When thawed out all revived, but during the following nine hours at 65° temperature the 3 short-winged bugs and 2 of the long-winged ones died. The remaining 3 long-winged were then frozen a fourth time for fifteen hours, after which none revived.

In summarizing the results of these experiments, 25 in number, it was found that complete submersion in water, even for a considerable period, is not necessarily fatal. Freezing during submersion in water is almost surely fatal. Freezing while exposed to dry atmosphere is generally fatal. Freezing in a moisture-laden atmosphere is only occasionally fatal. It will be observed, however, that not all of these results would necessarily follow corresponding experiments with the inland long-winged form.

SPRING, SUMMER, AND AUTUMN MIGRATIONS.

If there is an ample supply of proper food close at hand the chinch bug simply crawls from its hibernating place, but if it is in the timothy meadows of northeastern Ohio it does nothing but continue its ravages where it left off the autumn before, except some of the long-winged form, which very evidently fly to the wheat and corn fields. In wheat fields—unless the migration has been from an adjoining field, in which case the attack is made along the edge nearest thereto—the females do not seem to forsake their gregarious habits entirely, as they do not scatter out evenly over the entire field, but appear to locate in colonies, and when the young hatch and begin to attack the growing grain their presence is first disclosed by small whitening patches, which increase in dimensions as the young become older and more numerous. In low-lying fields these whitening patches more

[a] Nineteenth Rept. Maine Agric. Exp. Sta., 1903, p. 48.

commonly appear on the back furrows or on any slight elevations that occur in the field. But on higher and level ground the whitening areas are observed scattered over the entire field, and constantly widening until the whole field appears to ripen prematurely and crinkle down. When the migration is accomplished by crawling, the females seem to spread only enough to afford food for the young until the latter are able to make their own way from place to place. The young remain clustered on the plant about which they were hatched until this has been drained of sap, when they make their way, almost in a body, to a second plant, and in this way an attack will be pushed forward day after day.

In the spring the chinch bug probably lingers about its winter quarters until a favorable day for migration occurs. Transfer a typical Indian summer day to early May, and perhaps raise the temperature a few degrees, and you have a day during which chinch bugs may be seen on the wing, crawling along on fences, or at rest on the tops of fence posts as if taking observations, and in reality, as the writer has come to believe, to catch the scent of wheat or corn fields. It is on just such a day as this that *Aphodius serval* Say will be observed posted in precisely the same way, opening and closing the leaves of its antennæ, evidently to catch the scent of the fresh droppings of animals. The same movements characterize *Aphodius inquinatus* Hbst. during the Indian summer days of autumn. The writer has also observed the plum curculio, *Conotrachelus nenuphar* Hbst., acting in precisely the same way in late autumn.

While discussing the subject of chinch-bug migrations, it may be best to state here that there is a second flight of chinch bugs in summer after the majority have become fully developed, and not as soon as the individual reaches the adult stage, as Professor Sajö has found to be the case with the European species, *Blissus doriæ* Ferr. A migration by flight takes place in the fall, usually during the period of Indian summer. The magnitude of such migrations depends in the spring on the number of individuals that have been in hibernation, and in the summer and fall entirely on the abundance of the species during the current year. If there has been no great abundance during the spring the summer flight will not be likely to attract attention. During the invasion of 1896 in Ohio an individual alighted on the writer's hand while he was riding on a street car in the heart of the city of Columbus. A heavy storm of rain has much influence in scattering the bugs in midsummer, and just preceding a heavy rain the writer has noted the fully developed adults very abundant on Indian corn plants, while immediately after the storm there would be very few to be found. As these storms were not always accompanied by high winds, it is probable that it is the rainfall that scatters the insects.

In timothy meadows where the original attack has begun along one side and gradually extended inward, the line of separation between the entirely dead grass and that uninjured is frequently not over a yard in width, and within this narrow, irregular strip we may have the dead and brown, the yellowing indicating more or less serious injury, and the perfectly healthy green of unattacked plants. This many-colored border may change but little in the space of a week or ten days, except to advance very materially, leaving the grass completely dead or dried up, while the clover plants are uninjured. This indicates that the females, after leaving their places of hibernation, do not spread out over any large area, but to a certain degree maintain their gregarious habits. The author believes that these habits have been shaped by some past environment in which the species has been placed for a long period of time, as, for illustration, the inhabiting of bunches or tufts of grass more or less isolated from each other.

To what extent pairing takes place in these places of hibernation before the insects make their way to the cultivated crops is a matter of considerable uncertainty. From his own observations the writer is inclined to believe that only a very insignificant minority follow this course.

In his "Wanderings of Insects" Prof. Karl Sajö has called attention to the influence of electrical storms in the dispersal of insects, and it is quite possible that adult chinch bugs may be thus affected by the heavy thunder that usually accompanies these storms, during which they seem to disappear from corn plants on which they had previously congregated.

OVIPOSITION.

According to most writers the eggs are deposited either about or below the surface of the ground, among the roots of the grass or grain. It is more than likely that the place varies with the conditions, as the eggs are not infrequently found above ground about the bases of the plants, and even upon the leaves, though we have never found them there, but have often found them under the sheath of grasses. It would seem, then, that the eggs require a cool, damp, but not a wet location.

EGG PERIOD AND NUMBER OF EGGS DEPOSITED BY EACH FEMALE.

Doctor Shimer states that each female deposits 500 eggs, scattering them over a period of from ten days to three weeks, and as the adult develops in fifty-seven to sixty days after the eggs are deposited, or about forty-two days after hatching, it will be seen that some of the earliest hatched young are well along toward full development by the time the last eggs are being deposited. According to Doctor Riley, the eggs hatch, on the average, in two weeks.

In a series of breeding-cage experiments Prof. W. G. Johnson found that each female deposited from 98 to 237 eggs, the egg period lasting from eighteen to twenty-one days, and the period of oviposition covering from thirty-eight to forty-two days. Forbes also records in his Fifth Report (p. 44) experiments showing that the period of incubation may cover from twelve to twenty-two days. (See Forbes's 19th Report, pp. 177–183.) It must be remembered, however, that Professor Johnson had but six females employed in his experiments and that these were necessarily under an artificial environment.

DESCRIPTIONS OF THE DIFFERENT STAGES OF DEVELOPMENT.

The following descriptions of the egg and various stages of the young bugs are taken from Riley's Seventh Missouri Report, while that of the adult is from the original by Thomas Say, as published in his American Entomology (Vol. I, p. 329, Le Conte Ed.):

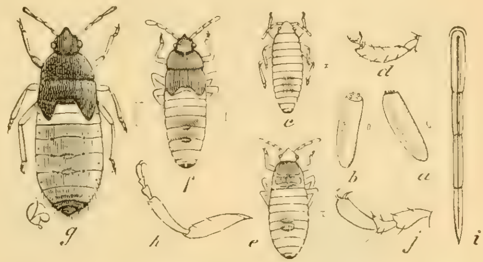


FIG. 2.—*Blissus leucopterus:* *a*, *b*, eggs; *c*, newly hatched larva; *d*, its tarsus; *e*, larva after first molt; *f*, same after second molt; *g*, pupa; the natural sizes indicated at sides; *h*, enlarged leg of perfect bug; *j*, tarsus of same, still more enlarged; *i*, proboscis or beak, enlarged. (From Riley.)

The egg.—Average length 0.03 inch, elongate-oval, the diameter scarcely ⅕ the length. The top squarely docked and surmounted with four small rounded tubercles near the center. Color, when newly laid, pale or whitish, and translucent, acquiring with age an amber color, and finally showing the red parts of the embryo, and especially the eyes toward tubercled end. The size increases somewhat after deposition, and will sometimes reach near 0.04 inch in length. (Fig. 2, *a*, *b*.)

Larval stages.—The newly hatched larva is pale yellow, with simply an orange stain on the middle of the three larger abdominal joints. The form scarcely differs from that of the mature bug, being but slightly more elongate; but the tarsi have but two joints and the head is relatively broader and more rounded, while the joints of body are subequal, the prothoracic joint being but slightly longer than any of the rest. The red color soon pervades the whole body, except the first two abdominal joints, which remain yellowish, and the members, which remain pale.

After the first molt the red is quite bright vermilion, contrasting strongly with the pale band across the middle of the body, the prothoracic joint is relatively longer, and the metathoracic shorter. The head and prothorax are dusky and coriaceous, and two broad marks on mesothorax, two smaller ones on metathorax, two on the fourth and fifth abdominal sutures, and one at tip of abdomen are generally visible, but sometimes obsolete; the third and fourth joints of antennæ are dusky, but the legs still pale. After the second molt the head and thorax are quite dusky and the abdomen duller red, but the pale transverse band is still distinct; the wing pads become apparent, the members are more dusky, there is a dark-red shade on the fourth and fifth abdominal joints, and, ventrally, a distinct circular dusky spot, covering the last three joints. (Fig. 2, *c, d, e, f.*)

The pupa.—In the pupa all the coriaceous parts are brown-black, the wing-pads extend almost across the two pale abdominal joints which are now more dingy, while the general color of the abdomen is dingy gray; the body above is slightly pubescent, the members are colored as in the mature bug, the three-jointed tarsus is foreshadowed, and the dark horny spots at tip of abdomen, both above and below, are larger. (Fig. 2, *g.*)

The adult.—Blackish, hemelytra white with a black spot.

Inhabits Virginia.

Body long, blackish, with numerous hairs. Antennæ, rather short hairs; second joint yellowish, longer than the third; ultimate joint rather longer than the second, thickest; thorax tinged with cinereous before, with the basal edge piceous; hemelytra white, with a blackish oval spot on the lateral middle; rostrum and feet honey-yellow; thighs a little dilated.

Length less than three-twentieths of an inch.

I took a single specimen on the Eastern Shore of Virginia.

The whiteness of the hemelytra, in which is a blackish spot strongly contrasted, distinguishes this species readily.

To the foregoing description of the adult Dr. Asa Fitch, in his second report on the Insects of New York, adds brief descriptions of nine varieties, all, with but one exception, being based upon slight variations in color, some, perhaps, being due to immaturity, the single exception being the short-winged inland form, of which variations from the nearly wingless to fully winged are shown in figures 3 and 4.

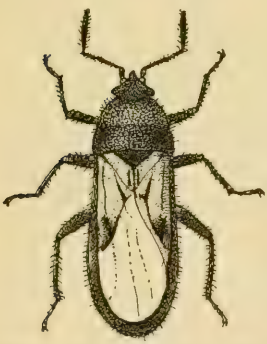


FIG. 3.—*Blissus leucopterus:* adult of long-winged form. Much enlarged (original).

Leaving, then, out of consideration the color varieties as arranged by Doctor Fitch, we have a long-winged form (fig. 3) in which individuals from the eastern portion of the country differ from those found in the West by being more hairy and robust, as pointed out by Mr. Van Duzee, and a short-winged form (fig. 4), found along the seacoast, and in the North Atlantic Coast region, extending inland as far as the country adjacent to the Great Lakes.

DEVELOPMENT AND HABITS OF THE YOUNG.

The newly hatched young are very active, and the first to appear may be observed with their progenitors about the bases of wheat, corn, or grass plants, and later all stages are seen mingling together, having little appearance of belonging to the same species, so greatly do they vary in size and color in their several stages of development.

As a rule the bugs confine themselves to the lower portion of the plants attacked, but may later push their way upward, especially if the lower portion becomes tough and woody, finally covering the plants in patches, as seen in figure 5, where they are shown on a stalk of young corn. Mr. E. A. Schwarz relates a curious exception to this habit in Florida upon sand oats, *Uniola paniculata*, where the entire development of the insect is undergone upon the highest part of this tall plant and not close to the bottom. Mr. Schwarz has given as a probable reason for this the fact that strong winds are continually blowing the fine, sharp sand through among the lower parts of the plants, rendering it nearly or quite impossible for the bugs to remain in that situation, thus forcing them to seek their sustenance farther up the plants. While figure 5 gives a good representation of the appearance of a corn plant when the chinch bugs are present in excessive numbers, yet the writer has invariably found that these bugs much prefer a stalk that has been blown down by the wind or partly broken off by the plow and left lying nearly flat upon the ground.

In timothy meadows the very young are to be found only by pulling away the soil from about the bulbous roots and drawing down

FIG. 4.—*Blissus leucopterus:* adults of short-winged form. Much enlarged (original).

the dead sheaths that usually envelop them. An observer may even pull up a tuft of grass entire, and yet, unless he examines in this way closely, may overlook them, so snugly are they thus ensconced among the roots. If driven to forsake a tuft of grass the young bugs move to another and crawl downward, and are soon to be found as snugly settled as before. It is only when they are older and well advanced toward maturity that they work to any extent above ground, and even then only in cases where they are present in great numbers. Singularly enough, where infested meadows are plowed up and planted with corn the females seem to ignore the young corn plants and select the occasional stray clumps of timothy that cultivation has failed to destroy and deposit their eggs about these, so that later the young may be swarming about these last, while hardly one is to be found about the young corn. This is precisely the opposite of what is observed farther west.

Although living externally on their food plants, and notwithstanding the fact that the young may attack the bases or even the roots of some of these, the species is essentially an external feeder, and appears while thus engaged almost totally indifferent to possible attacks of natural enemies. When not feeding, however, there is at times a tendency to hide away under the sheaths of young corn or beneath clods of earth or bunches of coarse stable manure, where this has been recently applied and left more or less exposed on the surface of the ground. The writer has noted this in cases where neither an uncomfortable temperature nor wet weather necessitated protection.

As has been shown in the description of the larval stages, there are four molts between the egg and the adult state. Just how the molting larvæ act we have never been able to determine; neither have we witnessed pupation, but a fully developed pupa that is ready to molt is easily distinguished by its larger size and more tightly fitting skin, which is almost shining white on the median ventral surface of the abdomen. It now hides itself away, seemingly preferring to get under the sheaths of grasses or grains; but if these are not convenient it will crawl under loose clods, or even into crevices in the ground. While thus hidden away the pupa skin splits along the back and the fully developed adult makes its way out, leaving the empty skin behind. These last are very frequently mistaken for dead chinch bugs, and, when moldy, the farmer is very likely to suppose that they are bugs which have been killed by the fungus *Sporotrichum globuliferum*, if this has been applied in the fields.

On first emerging from the pupa the adult is generally of a dull pink color, except the wings, which are white, exclusive of the veins; these being of the same pinkish hue as the body. In a short time these colors change to the normal ones of the species, but during the breeding season these newly developed adults may be observed crawling about with the young of all stages as well as the maturely colored adults.

If this development has been taking place in a wheat field and the grain is harvested at this time, or if from any other cause the food supply becomes suddenly exhausted, all sizes of larvæ with pupæ and adults will start off on foot to hunt for a fresh supply. Though many individuals may now have become fully developed, and, so far as can be determined, possess wings entirely fitted for active service, nevertheless they will crawl along a dusty road or across freshly plowed fields in company with their less fortunate fellows, seemingly never for a moment supposing that they can span the intervening space by flight. The writer is totally unable to account for this phenomenon in the species at this time, the disinclination to use the wings being so wholly unlike the habits of *B. doriæ*, as shown by the careful and painstaking observations of Professor Sajö in Hungary. Again, the seeming desire on the part of the pupæ to secrete themselves while transforming to adults does not at all coincide with the idea of a supposed immunity from attacks of natural enemies. Surely our species of Blissus has not always lived where natural enemies were as few as they are with us at the present time. Even where we have both the long-winged and short-winged forms occurring together in timothy meadows there is no such haste exhibited on the part of the former to escape from the companionship of the latter, as observed by Professor Sajö. We know, however, that our species certainly does enjoy a considerable immunity from natural enemies, though its conspicuous colors in both the larval and adult stages contrast very strongly with those of its usual food plants and its presence is still further advertised by its strangely persistent gregarious habits. We have come to suppose the species to be, in part at least, protected from attack by its vile odor, and so, indeed, it may be in the United States, but the writer fully believes that somewhere in its southern habitat it will be found to have one or more enemies, like the ant, *Eciton hamatum* Fab., of Central America, for illustration. Our native ants, however, will seldom attack even the young.

NUMBER OF GENERATIONS ANNUALLY.

Over the most of its area of habitation in North America, at least, the chinch bug is two brooded, though in northeastern Ohio the writer has totally failed to detect the second brood, or, in fact, to perceive any indications that a second brood occurs; but this will be referred to later. As previously shown, there is not sufficient proof at hand to warrant the statement that there is, even in the far South, a partial third brood. It is probable that the number of broods of this species annually has been primarily decided in its home in the tropical regions by the wet and dry seasons occurring there, and that we have in the North these same broods occurring at slightly different periods under the influence of a change from wet and dry to hot and cold seasons.

Belt, in his Naturalist in Nicaragua, has the following to say with regard to the seasons on the northeastern side of that country: "The rains set in in May and continue with occasional intermissions until the following January, when the dry season of a little more than three months begins" (p. 103). "The heaviest rains fall in July and August, and at those times the brooks are greatly swollen." "In September, October, and November there are breaks of fine weather, sometimes lasting for a fortnight, but December is generally a very wet month, the rains extending far into January, so that it is not until February that the roads begin to dry up" (p. 104). It seems that possibly we have here the key to the secret of the number of broods annually of the chinch bug. That this insect may be able to adapt itself still further to changed latitude and environments and become single brooded is not at all impossible. As illustrating the ease with which insects, at least some of them, can change their habits to correspond with their environment, we have in South Australia the following facts regarding the codling moth, *Carpocapsa pomonella* L., of which, though being still double brooded, "the winter caterpillars hatch into moths irregularly from the beginning of October until the middle of November and deposit their eggs accordingly, giving rise to a succession of young caterpillars until the beginning of December. About the third week in December the first moths of the second brood begin to appear and deposit eggs, and members of this second generation of moths continue hatching and egg laying until the end of February."[a]

The author's notes on the chinch bug in northeastern Ohio are as follows: Very young larvæ, with what appeared to be their progenitors, were observed at Jefferson, Ashtabula County, within 11 miles of the shores of Lake Erie, June 16, 1893, there being no advanced larvæ among them. On August 27, 1896, a few miles south, at West Andover, in the same county, only adults were observed in two days' search, though some of these showed by their color that they had but recently passed the pupal stage. In this latter locality, May 7, 1897, the sexes were pairing, but no young were present so far as could be observed, while to the south and west of this locality, June 8 and 9, precisely the same conditions obtained as to the bugs, no young appearing at this time. Quite copious rains might have destroyed the young, but within 15 miles of these localities, on July 14 of this year, larvæ were found after first molt and stages intervening between these and the adults. Near Youngstown, on October 3, 1897, only adults were present, pairing was not in progress, and the insect was not pairing in Ashtabula County on August 27, 1896. June 9, 1898, only two very young larvæ could be found at Salem, about 15 miles southwest of Youngstown.

Up to October 17, 1898, no young of a second brood had been observed, though careful search had been made from time to time in the fields and meadows of northeastern Ohio, and a large number of adults which developed in July and August, and since kept in confinement, had not only not reproduced, but had shown no disposition whatever to pair. On the other hand, in southwestern Ohio, in the vicinity of Cincinnati, on September 24, where the species occurred in abundance, fully 75 per cent were pupæ, the remainder being made up of larvæ, some of them quite young, and adults in about equal

[a] George Quinn, in Journal of Agriculture and Industry, South Australia, Vol. I, p. 112.

proportions, some of the latter showing by their immature colors that they had but just passed the pupal stage.

Hatching is not fully in progress in the Northeast before the 25th of June, only an occasional individual having passed the first molt before the 10th of July. In the light of the information that has been gained by these observations, the occurrence of a second brood of young in northeastern Ohio is doubtful.

The late Dr. J. A. Lintner, in his studies of the outbreak of this insect in New York State in 1882 and 1883, seems to have relied much on the published habits of the species farther west—as, indeed, the writer has himself done until recently—and made no exact studies of the species at that time; and in his annual report, where the outbreak is discussed, no absolute proof of the existence of a second brood in New York is presented.[a] The occurrence of a second brood of young in northern Illinois, as indicated by Doctor Fitch, has always been considered as settled, and in a more northern latitude than northern Ohio, so that there must be some other influences besides latitude to account for the phenomenon. That the species has occupied this territory for many years is indicated by the observations of Mr. E. P. Van Duzee, of Buffalo, N. Y., who wrote that the insect was as abundant twenty-three years ago as at the present time, so that whatever effect on the insect the recent occupation of the country might have had, that effect has passed away and a condition of what we might call equilibrium now exists here.

On July 7, 1889, in the extreme northern part of Indiana, the writer found an abundance of young which had not yet molted for the first time. Dr. A. S. Packard records adults as pairing at Salem, Mass., June 17, 1871, as quoted by Doctor Lintner, while the latter gentleman[b] records the young as occurring in Lawrence County, N. Y., about June 5, 1883.

Hardly have the latest hatched young of the first brood developed to the adult before the young of the second brood begin to appear. In southern Ohio this is about the first week in August. Generally these young do little injury, because the wheat has long since been harvested and the corn is usually too far advanced and tough to offer a desirable source of food supply, except in cases where fields have been planted very late, and here the writer has known them to work considerable injury, especially in seasons of severe drought that prevented the rapid growth of the plants. Fall attacks on wheat are rare, and the injury is never of a serious nature, as it is usually the case that by the time the young wheat is large enough to invite attack the chinch bugs are searching for winter quarters.

[a] Second Report State Entomologist of New York, pp. 148–164, 1885.

[b] Loc. cit., pp. 158, 159, 164.

In the timothy meadows of northern and northeastern Ohio, however, the principal injury is done during August and September, and in favorable weather on into October. Now, if we allow sixty days for development from the egg, it would be September before the appearance of the adults of the brood to which these various young belonged. If all eggs were deposited immediately, it would be November before the adults of the second brood would begin to occur, a condition of affairs that has never been observed. As prevously shown in this bulletin, the first brood is fully developed in northeastern Ohio by the first of September, but there certainly is no indication that a second brood of young is developed during September and October. It would seem, then, that from northern Ohio through New York, New England, and probably to Nova Scotia the adults from the first brood of larvæ winter over, and that there is here but one annual brood.

DESTRUCTIVENESS LARGELY DUE TO GREGARIOUS HABITS.

Attention has been directed previously to the gregarious habits of the chinch bug, and we only refer to the phenomenon again because it is to this that its destructiveness is largely due. It is not the excessive numbers, but the persistency with which they will congregate *en masse* on limited areas, that renders their attacks so fruitful of injury. With an ample supply of food the young develop and leisurely diffuse themselves over the adjacent fields, and there are neither swarming flights nor migrations. In 1884, in northern Indiana, a small field of wheat was severely attacked by chinch bugs. At harvest there was every prospect of a migration from the field of wheat to an adjacent one of corn, and the bugs were present in sufficient numbers to have worked serious injury to the latter: but the wheat had grown up thinly on the ground, and there had sprung up among the grain a great deal of meadow foxtail grass, *Ixophorus* (*Setaria*) *glaucus*, and panic grass, *Panicum crus-galli*, and to these grasses the bugs transferred their attention, finishing their development thereon, and later, so far as could be determined, they scattered by flight out over the adjacent fields, working no further injury. Pedestrian migrations may continue for a fourth of a mile or even more, but on reaching a suitable food supply the tendency of the bugs is to congregate upon their food plants until these are literally covered with individuals varying in color from the black and white of the adults to the bright vermilion of the more advanced larvæ. (See fig. 5.) Whatever tendency there is exhibited toward a wider diffusion is confined to the adults, the others remaining and leaving in a body only when the plant on which they have congregated has been drained of its juices and has begun to wither, when they simply crawl to the nearest plants and again congregate upon these as before. In case the migration has been to a field of corn, if this is badly overgrown with either of the two grasses previously named, the bugs will collect upon the latter, and unless the corn plants are very small they will not as a rule attack them until the grass has been killed. Some farmers have gone so far as to claim that a benefit is derived from a certain abundance of chinch bugs, the statement being made that the bugs will kill out these grasses to an extent that nothing else will. It is clear that the acquisition of wings is not the signal for the adults to abandon the companionship of the larvæ and pupæ, yet they do gradually disappear from among them. It is possible that the disposition to pair does not exist until the individual has reached a certain age beyond seeming maturity, and that it is not until the passion for mating has overcome their gregarious inclination that they are disposed to migrate. Or it may be that the phenomenon may be explained on the supposition that when the pairing season approaches the males scatter out in order to find females with which they are not akin, thus following out natural selection and preventing a continual interbreeding. Over the northern United States, at least, the injury in cultivated fields is done almost entirely by the young bugs, but in the timothy meadows the damage is due as much, if not more, to the depredations of the adults.

FOOD PLANTS.

As to food plants, there can be no doubt that these consisted originally of the native grasses. This is amply proved by the observations of Fitch and Le Baron, in Illinois; Dr. J. C. Neal, in Florida and Oklahoma; Marlatt, in Kansas; Schwarz, in Florida; and by those of Mr. Henry G. Hubbard in the midst of the Colorado desert in California. Regarding this last statement, Mr. E. A. Schwarz wrote as follows:

> You may be interested to learn that chinch bugs were collected this year (1897) on March 28 by Mr. H. G. Hubbard, at Salton, in the midst of the Colorado desert of California. This locality is considerably below the ocean level, and represents an ancient extension of the Gulf of California. Even at the present time the Salton Basin is occasionally flooded, the water entering through New River, which runs from the mouth of the Colorado River into the Salton Basin. The specimens were taken on a species of coarse grass which is incrusted with a saline deposit.

No wonder that the chinch bug is accused of being a seashore species!

Of cultivated grasses, or such as occur in cultivated fields, probably *Ixophorus glaucus* and *Panicum crus-galli* are the favorites, though millet and Hungarian grass are apparently nearly as attractive. As early as 1845, in Illinois, Dr. William Le Baron, afterwards State entomologist, gave the food plants of the chinch bug as follows:

FIG. 5.—Corn plant two feet tall infested with chinch bugs. (Author's illustration.)

* * * "all kinds of grain, corn, and herd's-grass" (timothy).[a] But to this day in Illinois, as shown by the observations of Professor

[a] Prairie Farmer, December, 1845.

Forbes and the writer, the species will attack timothy only in cases where it is compelled to do so by reason of a lack of other food. In addition to the preceding, Doctor Howard gives broom corn, sorghum, chicken corn, Bermuda grass (*Capriola dactylon*), bluegrass (*Poa pratensis*), crab grass (*Syntherisma sanguinalis*), and bottle grass (*Ixophorus viridis*), and also states that in the rice fields near Savannah, Ga., in August, 1881, he observed the winged adults upon the heads. Prof. H. A. Morgan wrote that in 1897 it had become a serious enemy to "Providence" rice in Louisiana, where for two years it had seriously injured corn, and the writer was informed through other sources that it proved injurious to corn again in 1898. Adults have often been found collected in the silk of belated ears of corn in the fields in September, when all other parts of the plant had either become too old and tough to afford nourishment or else had been killed by the frosts of autumn. Prof. Lawrence Bruner has recorded the insect as feeding upon so-called wild buckwheat (*Polygonum dumetorum* or *P. convolvulus*).[a] The writer has never seen chinch bugs attack bluegrass (*Poa pratensis*), and has seldom witnessed them injuring oats, but on September 27, 1904, he observed larvæ, pupæ, and adults, the last all fully winged, attacking Arrhenatherum (oat grass) on the experiment farm of the University of Tennessee, at Knoxville. Over the western country the major portion of the damage done is to fields of wheat, barley, rye, and corn, the outbreak generally originating in wheat or barley fields and the bugs migrating at harvest to the corn-fields. (See fig. 5.) In the eastern part of the country, where the timothy meadows are the most seriously infested, this is not the case, and here the migrations are as likely to be to the timothy meadows as to the fields of corn, where both are equally within reach. Besides, everything indicates that a very large proportion of the adults may hibernate in these meadows, even making their way thereto in the autumn.

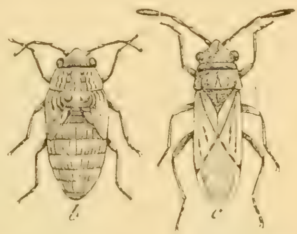


FIG. 6.—*Nysius angustatus*: *b*, pupa; *c*, mature bug. (From Riley.)

INSECTS THAT ARE MISTAKEN FOR CHINCH BUGS.

Messrs. Osborn and Mally[b] have given a list of twelve species of Hemiptera which have been mistaken with more or less frequency for the chinch bug, the list being as follows:

Nysius angustatus Uhl., the false chinch bug (fig. 6), is probably the most frequently mistaken for the true chinch bug, as it often

[a] Report Commissioner of Agriculture, 1887, pp. 57–58.

[b] Bul. No. 32, Iowa Agr. College Exp. Sta., pp. 363–385.

breeds in considerable numbers under purslane, amaranth, etc., and more than any other insect resembles the chinch bug. It is, however, of a light-gray color, which will always distinguish it from its more destructive fellow.

Ischnodemus falicus Say, or the long chinch bug, as it is sometimes called, is much larger and longer than the true chinch bug.

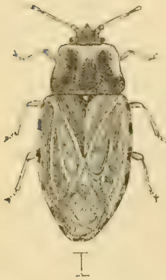


FIG. 7.—*Piesma cinerea.* (From Riley.)

Ischnorhynchus didymus Zett. is more robust, of a light-tawny color, with prominent, glassy wings.

Peliopelta abbreviata Uhl. is, next to the false chinch bug, probably the most often mistaken for the true insect, and especially is this true in localities where the brachypterous form of *Blissus leucopterus* abounds, viz, in timothy meadows. Its broader head and body, however, quickly enables one to distinguish it.

Geocoris fuliginosus Say, *G. borealis* Dallas, *G. bullatus* Say, and *G. limbatus* Stål, according to Osborn and Mally, have all been confused with the chinch bug in Iowa. These are all broader and flatter than the true chinch bug, the head being nearly as wide as the thorax.

Ligyrocoris sylvestris L. is larger than the true chinch bug, and its wings are quite dark instead of white.

Trapezonotus nebulosus Fall. is a trifle larger and its body is not so black as in the chinch bug.

Cymodema tabida Spin. is longer than the true chinch bug, of a light brown color, and the ends of the wings are glassy.

Triphleps insidiosus Say, or the insidious flower bug (fig. 15), as it is more commonly called, is another bogus chinch bug, though an enemy of the true pest, as previously stated.

Piesma cinerea Say, the ash-gray leaf bug (fig. 7), is often mistaken for the true chinch bug, though its form differs greatly from that of the latter. It is often quite abundant, but not in grain fields or meadows.

FIG. 8.—*Corimelæna pulicaria.* (From Riley.)

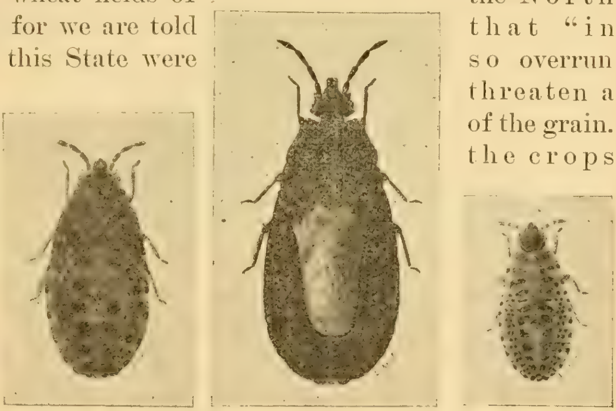
Corimelæna pulicaria Germ., the flealike negro bug (fig. 8), has been confused with the chinch bug; though it does not in the least resemble the latter, either in form or color, and its confusion is probably to be accounted for by the fact of its being occasionally found in wheat fields in considerable numbers.

Brachyrhynchus granulatus Say (fig. 9) has been mistaken for the chinch bug in Ohio, and in a way that was somewhat amusing. Farmers in southern Ohio, during the winter of 1896–97, were burning over the woodlands with a view to destroying the hibernating insects, when there came several discouraging reports to the effect that such a course would be ineffective, as the bugs were wintering in the tops of trees, especially where the tops were dead, under the bark and often from 50 to 75 feet from the ground. This was a piece of astounding information, to the writer at least, and it was only after securing specimens that he was able to solve the mystery. This insect, in all stages of development except the egg, hibernates under loose bark. It is broader and much flatter than the true chinch bug, but the wings are white and the body black.

The object in calling attention to these bogus chinch bugs is to prevent their confusion with the true *Blissus leucopterus*, as in some cases people finding them and supposing them to be the true pest are likely to become panic stricken and often destroy property unnecessarily, so notorious has the name "chinch bug" become in the United States.

LOSSES CAUSED BY CHINCH BUGS.

It would appear that this pest first made its presence known by its ravages in the wheat fields of the North Carolina farmers; for we are told that "in 1785 the fields in this State were so overrun with them as to threaten a total destruction of the grain. And at length the crops were so destroyed in some districts that farmers were obliged to abandon the sowing of wheat. It was four or five years that they continued so numerous at this time."[a]



a b c

FIG. 9.—*Brachyrhynchus granulatus: a*, early nymph; *b*, adult; *c*, late nymph. All enlarged (original).

In the year 1809, as stated by Mr. J. W. Jefferys,[b] the chinch bug again became destructive in North Carolina to such an extent that in Orange County farmers were obliged to suspend the sowing of wheat for two years. In 1839[c] the pest again became destructive in the Carolinas and in Virginia, where the bugs migrated from the wheat fields at harvest to the corn, and in 1840 there was a similar outbreak, and both wheat and corn were seriously injured. In all of these cases, however, there is no recorded estimate of the actual financial losses resulting from the attacks of the chinch bug. According-

[a] Webster on Pestilence, Vol. I, p. 279. Not seen. Quoted from Fitch.

[b] Albany Cultivator, first series, Vol. VI, p. 201.

[c] The Cultivator, Vol. VI, p. 103.

ing to Le Baron, during the years from 1845 to 1850 the insect ravaged over Illinois and portions of Indiana and Wisconsin, and in 1854 and 1855 it again worked serious injury in northern Illinois. The writer's earliest recollection of the chinch bug and its ravages in the grain fields of the settlers on the prairies dates from this last outbreak. Mr. B. D. Walsh estimated the loss to the farmers of Illinois in 1850 at $4,000,000, or $4.70 to every man, woman, and child living in the State. The earlier outbreaks, though the occasion of smaller money loss, were even more disastrous; for the destruction of the grain crops in those pioneer days not only took away all cash profits, but also deprived the early settlers of their very living, and in some cases reduced them to starvation.

In 1863, 1864, and 1865 the insect was again destructive in Illinois and other Western States, its ravages being especially severe in 1864, when we have another attempt at computation of the financial loss. Dr. Henry Shimer, of Mount Carroll, Ill., who had carefully studied the chinch bug, estimated that "three-fourths of the wheat and one-half of the corn crop were destroyed by the pest throughout many extensive districts, comprising almost the entire Northwest." In criticising the doctor regarding another point, Messrs. Walsh and Riley, in The American Entomologist (Vol. I, p. 197, 1869), admit that the estimate was "a reasonable one," and, taking it as a basis, with the actual cash price per bushel, computed the loss at about 30,000,000 bushels of wheat and 138,000,000 bushels of corn, with a total value of both amounting to over $73,000,000. Of course all computations of this sort are necessarily only approximately correct, but there is more likelihood of an under than an over estimate in this case.

There was a serious outbreak of the chinch bug in the West again, in the year 1868, and again in 1871, but in 1874 the ravages were both widespread and enormous. Doctor LeBaron computed the loss in 1871 in seven States, viz, Iowa, Missouri, Illinois, Kansas, Nebraska, Wisconsin, and Indiana, at $30,000,000.[a] Doctor Riley computed the loss in Missouri alone in the year 1874 at $19,000,000, and added the statement that for the area covered by Doctor LeBaron's estimates in 1871 the loss in 1874 might safely be put down as double, or upward of $60,000,000.[b] Dr. Cyrus Thomas, however, estimates the loss to the whole country for the same year at upward of $100,000,000.[c]

The next serious outbreak of the chinch bug of which we have the losses resulting therefrom computed, occurred in 1887, and covered more or less territory in the States of Kentucky, Ohio, Indiana,

[a] Second Report State Entomologist of Illinois, p. 144.

[b] Seventh Report State Entomologist of Missouri, pp. 24–25

[c] Bulletin No. 5, U. S. Entomological Commission, p. 7.

Illinois, Wisconsin, Minnesota, Iowa, Missouri, and Kansas. In this case the damage was estimated by the United States statistician, Mr. J. R. Dodge, at $60,000,000, the heaviest losses occurring in Illinois, Iowa, Missouri, and Kansas.[d] This gives us as the estimated loss in the thirty-eight years, 1850 to 1887, both inclusive, the enormous sum of $267,000,000.

There was a serious outbreak in Kansas, Iowa, Minnesota, and Illinois, having its beginning probably as early as 1892, but reaching its maximum severity, as in Ohio, in 1896. The loss in Ohio during the years 1894, 1895, 1896, and 1897 could not have fallen far short of $2,000,000. The farmers of this State in many cases were entirely

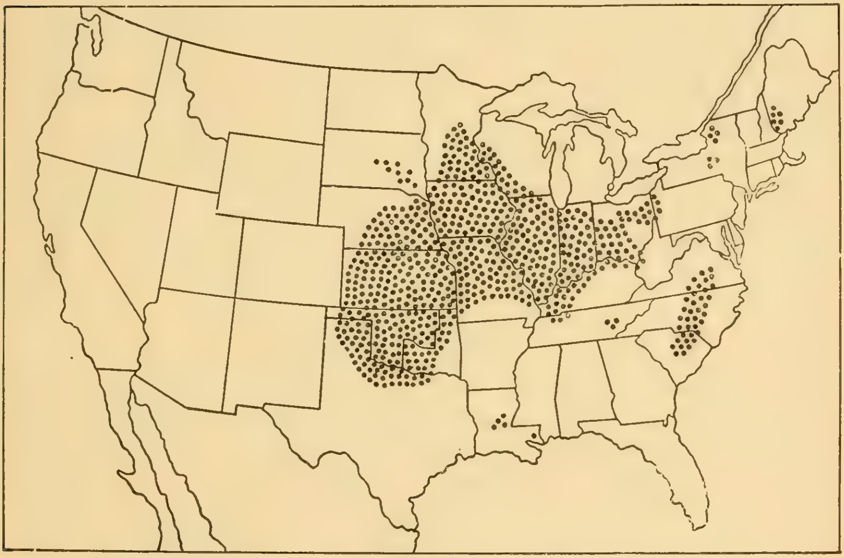


FIG. 10.—Map showing areas in the United States over which the chinch bug occurs in greatest abundance and may at any time become destructive. (Original.)

unfamiliar with the chinch bug and its ravages, and therefore were unable to account for the damage that it worked in their fields until some time after. This was especially true of the timothy meadows in the northeastern part of the State; so that there were probably many fields, both of grass and of grain, that suffered seriously, and, in fact, in some cases were ruined by the chinch bug without the owners being aware of the cause. For this reason, while the computed loss appears large, it seems to me to be entirely reasonable. Of the losses occasioned in other States during the years above indicated no definite computations are available, but they were severe, and must have amounted to millions of dollars. If we could have careful estimates of the loss during the last fifteen years, it would in all probability

[d] Report of U. S. Commissioner of Agriculture, 1887, p. 56.

swell the amount to considerably in excess of $330,000,000 for the period from 1850 to 1906. Within the last ten years the insect has become more injurious in Oklahoma, western Kansas, and northern Texas, localities not included in these estimates, and although the spring rains serve to destroy the young bugs, outbreaks in northern Texas and Oklahoma are not rare in fields of wheat, corn, and barley. If the indirect losses were to be added, the amount would indeed be enormous. During the outbreak in Ohio at least two farmers became discouraged, and, thinking that the loss of their crops by the attack of chinch bugs would result in their financial ruin, in their despondency they sought relief in suicide.

When we take into consideration that the financial losses as above estimated have not fallen upon the entire nation, but almost without exception upon the nine States previously named (see fig. 10), it will be seen that this diminutive insect constitutes a formidable enemy to the agriculturist of these States. In fact, small as it is, this pest has cost the people of these nine States a sum of money which, a few years ago, would have defrayed the entire expense of the National Government for a whole year. Fire excepted, there is probably no other factor that has caused such an enormous financial loss within the same period over the same area of country.

NATURAL CHECKS.

All adverse natural influences affecting the chinch bug will be treated under this head, with the exception of animal and vegetable foes, which are considered here as natural enemies.

INFLUENCE OF PRECIPITATION ON THE CHINCH BUG.

There is probably no more potent factor in restraining the increase in numbers of this species than is to be found in meteorological influences consequent upon rain. The fact has long been known that the years of greatest abundance of the chinch bug were preceded by a series of years during which there had been a deficiency in the rainfall over the area of country devastated by this species. In fact, it has in a general way come to be understood that dry seasons are favorable and wet seasons unfavorable for the development of the chinch bug, though the details of the phenomenon have never been very carefully and elaborately worked out. The entomological and meteorological records of the past have, however, clearly shown that the amount of the annual rainfall is not a safe guide in this problem. Chinch bugs have occurred in excessive numbers during years of heavy precipitation.

The term "wet season," so frequently used in this connection, is an indefinite one, but if the term "season" be restricted to the period of time intervening between the vernal and autumnal equinoxes we shall have more definite grounds upon which to base our studies of meteorological influences. Thus applied, the terms "wet" and "dry" seasons would include within them the two breeding periods of the chinch bug, at least largely so, north of latitude 30° N. But the history of this species has shown that there may be an excess of rainfall during this critical period and that still a sufficient number of insects may develop to work serious injury over considerable areas of coun-

FIG. 11.—Map showing distribution of chinch bug in Ohio in 1896. (Author's illustration.)

try. This is due to two, and perhaps more, causes. In the first place, an unusually heavy rainfall at long intervals, while bringing up the total for a given period, may have but little effect in reducing the number of chinch bugs, while a much less amount of precipitation coming at short intervals and in the midst of the hatching season would cause a far greater mortality among the young. And, in the second place, the precipitation may come at the beginning or even before the commencement of this breeding season or just at the close thereof, thus enabling the major portion of the young to reach a period in their development wherein they are little, if at all, susceptible to the effects of drenching rains. This was clearly illustrated in southern Ohio during the spring of 1896, and again in 1897. Throughout southern Ohio, in 1896, between latitude 38° 30′ and 39° 40′, as the reports of the United States Weather Bureau show, there

FIG. 12.—Map showing distribution of chinch bug in Ohio in 1907. (Author's illustration.)

had been but very little rain up to May 11, and no general rain until May 25. The effect upon the young bugs, judging from the destruction which they caused, would seem to have been to destroy only the latest to hatch, leaving the earlier developing young sufficiently advanced to withstand the effects of the later and heavier rains. The accompanying map (fig. 11) will show the areas over which chinch bugs were reported marked thus ☰, while the area seriously ravaged is indicated thus #, showing that the rain came too late in such a section to ward off an outbreak of the pest.

According to the Weather Bureau reports also, the distribution of rain in May, 1897, differed materially from that of the same month of 1896, in that in 1897 the major portion of the rain fell prior to the 15th, the remainder of the month being rather dry, the only general precipitation occurring on the 23d and 24th, with a much

FIG. 13.—Map showing distribution of chinch bug in Ohio in 1894. (Author's illustration.)

lighter rain on the 28th. But here again the amount was insufficient to ward off serious injury, as is indicated by map (fig. 12), the same symbols being used here as before. In this case it was probably the latter portion of the brood that survived, as a personal inspection of the country early in the month failed to reveal the presence of young bugs, though they were certainly present in abundance at a corresponding period of the preceding year.

That the amount and frequency of rain during the month of May has very much to do with the ravages of chinch bugs where sufficient numbers have wintered over to produce the requisite number of young, is further shown by the fact that in 1894 the only locality where serious ravages were committed was in Wyandot County, as shown on map (fig. 13), and this was one of the few areas in Ohio where the precipitation during that month was less than 3 inches.

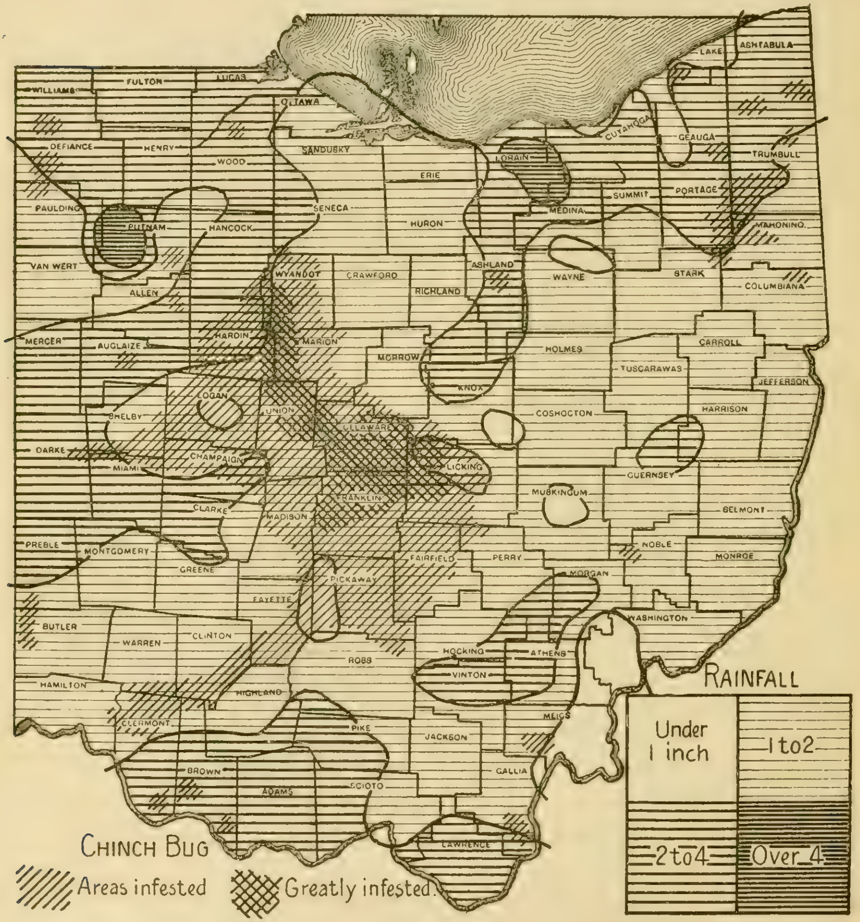


FIG. 14.—Map showing distribution of chinch bug in Ohio in 1895, and amount of precipitation over the State during May of the same year. (Author's illustration.)

Except over a circular area covering less than one-half of the county the amount of precipitation was 3 to 5 inches, and this area includes that ravaged by the chinch bugs during the following month.

Still more striking, however, is the relation between the two phenomena during the following year. The last of this series of maps (fig. 14) shows the area over which chinch bugs were reported and the area where their injuries were the most severe; also, by horizontal lines, the areas over which the amount of precipitation was the least. From this it will be observed that in all of the seriously affected area, and in nearly all of the area over which the pest was reported at all, the precipitation during the month of May, 1895, was from 1 to 2 inches, the extension of the point westward into Shelby County being especially interesting. It may be said with regard to the occurrences outside of this area of light precipitation that the exact localities were probably not indicated, as the information was secured from farmers, and their locations as indicated on the map were their post-office addresses, which might have been several miles away in any direction, and the isolated points of attack were often based upon one or two reports. If exact localities could have been obtained, and the precise area of precipitation indicated, the connection between the two phenomena would have been shown more correctly, and would probably have revealed an even greater uniformity than is now apparent. It must be understood, however, that in these calculations northeastern Ohio is excluded, and the writer believes that what is true of the rest of the State will be found to be equally correct as regarding territory occupying the same latitude westward to the limit of this area of distribution. While it is probable that the effect of precipitation during August would have a similar influence on the second brood of young, and, consequently, upon the number of adults which would go into winter quarters, yet a careful study of the two factors shows that meteorological conditions in August have a far less influence upon the following brood than do those of May.

Owing to causes which are as yet unknown to the writer the same laws do not apply to the northeastern part of Ohio and to what we have termed the west-bound tide of migration. Here, and as against the more or less short-winged form of chinch bug, meteorological conditions appear to exert a far less potent influence. What is true of meteorological conditions during May elsewhere in Ohio, seems to be partly true of June in the northeastern portion of the State, though there is not the evidence of the effect of precipitation here that we have elsewhere. Doctor Lintner, in his Second Report, while discussing the outbreak of the chinch bug in New York during 1882–83, calls attention to the fact that both in 1881 and 1882 there was an excess of precipitation. On page 158 of his report Doctor Lintner says that spring, summer, and autumn were exceptionally wet. In spring heavy and continued rains flooded meadows which, later, showed the effect of chinch-bug attack. Even at haying time while the bugs were young and, according to all accounts, easily killed by heavy rains, they persisted in multiplying and living despite the fact that rains were so frequent and severe that only a portion of the hay could be gathered in a proper condition. This was the state of affairs on July 5 when the hay was cut, and on October 10 Doctor Lintner stated that owing to continued rains grass was still lying in the fields and could not be gathered, while fields of oats remained unharvested. In all of the reports given of this outbreak it was stated that the damage was first observed in August or September, and it is believed that this will hold good as applied to northeastern Ohio.

As has been stated, the females oviposit as a rule at or just below the surface of the ground, and the young make their way upward in order to secure food. In case of cultivated grains this mode of procedure is absolutely imperative, as the bases of the plants are at that time too tough and woody to offer sufficient food. But in the case of timothy the conditions are entirely different, as the bulb of this plant, situated just below the surface of the ground and convenient to the place of oviposition, furnishes an ample supply of food without making it necessary for the young to crawl upward in order to secure it. Then, too, the surface of the ground in cultivated fields is nearly or quite free of dead leaves and stems, there being little but the vertical-growing plants to afford protection from the weather. In timothy meadows the surface of the ground is usually covered to the depth of an inch or more with dead and decaying stubble and leaves, and the top of the ground itself is often more or less loose and mellow in the immediate proximity to the bulbs of the plants. It would appear that we might here have a partial solution of the problem of the vital effects of precipitation on the young bugs. Besides, for aught we know, the progeny of this quite short-winged form may be better able to withstand naturally the effect of drenching rains than that of the east-bound long-winged form. We must recollect that in the one case the progenitors have worked their way over hot, arid plains as well as cool, damp prairies, while in the other case the tide of migration lay between the more elevated lands and the sandy beaches of the seashore where there was always a more or less near proximity to the ocean, until the tide of migration left the seashore and drifted westward over New York and onward into northeastern Ohio. (See map, fig. 17.)

This influence of precipitation on the young chinch bugs while in the act of hatching, and that of temperature upon the adults in winter, some illustrations of which have been included under the subject of hibernation, are the only cases where meteorological conditions appear to have a direct effect on this species. As previously shown, the temperature effects are, largely at least, unfavorable for such adults as may happen to be more or less unprotected during the hibernating season. Upon this point it might be well to suggest that this protection, which may be composed of leaves and dried grass, may be burned away in early winter and thus leave the insects without the expected protective covering, or this covering may be still further augmented by a mantle of snow, which, remaining for a more or less protracted period of time, counteracts the influences of temperature, and the latter then becomes a factor of secondary importance in the problem of life among chinch bugs. It is very doubtful if temperature is as vital in its effects as are the indirect influences of precipitation during the breeding season.

It has long been understood that the two species of entomogenous fungi, *Sporotrichum globuliferum* Speg. and *Entomophthora aphidis* Hoffm., both of which attack the chinch bug, require for their rapid development an atmosphere heavily charged with moisture, and that without this neither of these becomes sufficiently abundant to cause any serious mortality among the insect host, but this matter will receive attention in the discussion of these parasitic foes farther on.

INFLUENCE OF TEMPERATURE ON THE CHINCH BUG.

The writer would call attention here to a possible influence of temperature upon what he has termed the west-bound tide of migration. When the time arrives for the hibernating adults to leave their winter quarters and disperse over the fields prior to oviposition, if the weather should prove too severe they have but to remain in these quarters a while longer until more favorable weather. Thus, along the northern Atlantic coast the season is generally much later near the shore than it is a few miles inland, and Mr. Schwarz[a] has called attention to the influence which this phenomenon exerts upon the chinch bug. Now, this retardation amounts probably to about a month in spring, which would have a tendency to delay oviposition, especially among the short-winged females. If this were continued through a long period of time, consequent upon the slow movement of this tide of migration northward along the coast, it would hardly be surprising to find that this retarded activity in spring had become so characteristic as to be retained after this tide had swept to the westward, and resulted in the species being thus single brooded in the East, while it is double brooded in the east-bound tide of migration in the West. This effect of a long habitation along the shores of the northern Atlantic would be to some extent encouraged by the prolonged northern winter and the correspondingly shorter period during which the species could breed, and thus instead of the effects of the old environment becoming obliterated they might be continued, or, as in case of the fore-shortening of the wings, still further intensified. If the effect of this prolonged period

[a] Insect Life, Vol. VII, p. 422.

of hibernation has been to reduce the number of broods, then it will have to be considered as a natural check, in that to a certain extent it prevents excessive abundance by reducing the number of offspring. This would also account for the rather surprising immunity that has heretofore been enjoyed by the northeastern portion of the country from the ravages of this destructive species.

NATURAL ENEMIES.

It is possible that there are some reasons which might appear to justify the placing of fungous enemies of the chinch bug among the natural checks, as they no doubt do exert a more or less powerful influence in that direction, but it seems more convenient to include them among natural enemies, especially as one at least has come to be applied artificially to overcome the insect. The fact that the abundance and consequent influence of these fungous enemies is almost entirely dependent upon meteorological conditions is sufficient to place them in a secondary position, even though they may under favorable meteorological conditions act as natural checks. All, doubtless, have other host insects, and the two most important have been known to break out again and again spontaneously and destroy myriads of chinch bugs when the latter were present in excessive numbers. But this has taken place only in connection with the necessary precipitation; hence these fungi become natural enemies only under certain favorable weather conditions; and though their season of most potent effect is during the time when the chinch bug is developing from the egg to the adult, yet as shown by observation they may exert powerful and fatal effects among the adults, where these last have congregated together in masses.

PARASITIC FUNGI.

The two species of entomogenous fungi to which reference has just been made are *Entomophthora aphidis* Hoffman [a] and *Sporotrichum globuliferum* Speg,[b] both having probably been associated in destroying the chinch bug spontaneously in the fields, and doubtless were distributed to correspondents by Professor Snow and others to be artificially established in fields where there was an overabundance of chinch bugs. For this reason it is impossible to separate the effects of the two in the earlier literature, even the first observations of Dr. Henry Shimer [c] probably applying to their joint effect.

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[a] Hoffman, in Fresenius's "Entomophthoreæ," p. 208, figs. 59–67.

[b] Spegazzini, "Fungi Argentini," II, p. 42.

[c] Proc. Acad. Nat. Sci. Phila., May, 1867.

Doctor Shimer, however, was the first to call attention to the widespread and fatal effects of fungous diseases among chinch bugs, and while his explanations therefor seem now crude and illogical, his observations were made with such care and accuracy that we have not yet had occasion to materially revise them. Under date of July 16, 1865, he makes this observation: "* * * I found many dying on the low creek bottom land from the effects of some disease, while they are yet in the larval state—a remarkable and rare phenomenon for insects thus in such a wholesale manner to be dying without attaining their maturity, and no insect enemy or other efficient cause to be observed capable of producing this important result." Again, under date of July 22: "On low grounds the chinch bugs are dead from the disease above alluded to, and the same disease is spreading to the hills and high prairies."

Under this date also he speaks of the very wet weather, and states that in a barley field the chinch bugs began to die at about the same time that they did on the low creek bottom, and that they rapidly met the same fate, so that few of them lived to find their way to a neighboring cornfield, while under date of August 8 he states that of those that migrated to the cornfields "very few are to be found remaining alive; but the ground around the base of the cornhills is almost literally covered with their mouldering, decomposing dead bodies. They are dead everywhere, not lying on the ground alone, but sticking to the blades and stalks of corn in great numbers, in all stages of development, larva, pupa, and imago."

"This disease among the chinch bugs was associated with the long-continued wet, cloudy, cool weather that prevailed during a greater portion of the period of their development. * * *"

These are precisely the conditions under which these fungi have been observed to prove the most fatal to the chinch bug during recent years, where their introduction among the host insects was accomplished by artificial means. Although Doctor Shimer probably never anticipated the artificial cultivation of his "disease," and the results which have since been obtained from its artificial dissemination in the fields, yet his careful and painstaking studies must ever be associated with the application of fungous diseases in the destruction of insects in America. It is certainly to be regretted that such practical entomologists as Mr. B. D. Walsh and Dr. C. V. Riley should have expressed themselves so discouragingly regarding Doctor Shimer's observations and conclusions, Doctor Riley, as late as 1870, even going so far as to ridicule the theory of disease being in any way responsible for the death of the chinch bugs observed by Doctor Shimer.[a]

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[a] Second Report State Entomologist of Missouri, pp. 24–25, 1870.

It was not until 1879 that an entomologist came to the rescue of Doctor Shimer's theory of disease among chinch bugs. Dr. Cyrus Thomas, in Bulletin No. 5 of the United States Entomological Commission, 1879, page 24, stated that while Doctor Shimer's plague among chinch bugs was somewhat extraordinary, yet it was in accordance with facts that he had himself ascertained in reference to other insects, and in proof he cited a similar wholesale destruction of flies in southwestern Virginia and eastern Tennessee in the year 1849, and also a similar epidemic among grasshoppers in western Minnesota, Dakota, and northern Iowa in 1872. This position of Doctor Thomas in support of Doctor Shimer may be regarded as a second step in our advance in a knowledge of the influence of meteorological conditions on the chinch bug. It paved the way for further research in this direction.

FUNGOUS ENEMIES OF THE CHINCH BUG DETERMINED.

While the subject of epidemic and contagious diseases of insects was discussed to a greater or less extent among scientific men, there was a decided lack of actual experimentation, and none at all with the fungous parasites of the chinch bug until 1882 and 1883, when Prof. S. A. Forbes began what ultimately proved to be a long series of studies of the chinch bug and its natural enemies. At this time, 1882, Professor Forbes was more especially interested in the bacterial diseases of the chinch bug, and though he found, at Jacksonville, Ill., many specimens of dead chinch bugs embedded in a dense mat of white fungous threads, which sometimes almost hid the body and reminded him of the fatal disease previously reported by Doctor Shimer, yet except to secure from Prof. T. J. Burrill a determination of this fungus as belonging to the Entomophthora no progress was made in the study of this particular phase of the chinch-bug problem.[a]

In July, 1887, Professor Forbes found attacking the chinch bug in Clinton County, Ill., a second fungus, which he determined as belonging to the genus Botrytis, but this conclusion has since been revised and the species is now known as *Sporotrichum globuliferum* Speg. This discovery of a second species of entomogenous fungi and its separation from the Entomophthora comprises what may be justly termed a third step in the advancement of our knowledge of this problem. Professor Forbes, however, seems to have still been too deeply interested in his bacterial studies to pay any special attention to the other phases of his problem, further than to record the occurrence of his new Botrytis in various localities in Illinois, and in one instance on a beetle, *Parandra brunnea* (observed by Mr. John Marten, at Champaign), and, similarly, to note the occurrence of the still specifically undetermined Entomophthora.[b]

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[a] Twelfth Report of the State Entomologist of Illinois, pp. 47–51, 1882.

[b] Sixteenth Report of the State Entomologist of Illinois, pp. 46–49, 1888.

The scene of action now changes from Illinois to Kansas, and to Prof. F. H. Snow belongs the credit of first applying the knowledge that had been gained up to that time (1889) by confining supposed healthy chinch bugs with others affected by either one or the other of the fungi, or possibly both Entomophthora and Sporotrichum, and using the bugs thus infected for the propagation, in the field, of the disease from which they had died.

As early as 1887–88 Professor Snow expressed, in the Sixth Biennial Report of the Kansas State Board of Agriculture, the opinion that "in the warfare of man against his insect foes a most valuable ally will be found in the bacterial and fungoid diseases which may be artificially introduced when nature fails to come to our aid," an opinion at that time largely based upon the investigations of Professor Forbes and his own observations of the chinch bug in Kansas, thus paving the way for the experiments of 1889. Professor Snow had now obtained a specific determination of the fungous disease as (*Empusa*) *Entomophthora aphidis* Hoffman, although there is some ground for the suspicion that *Sporotrichum globuliferum* was also present.

Entomophthora aphidis was already known to affect Hemiptera in Germany and the United States. Dr. Roland Thaxter [a] states that, as early as 1886, his attention had been called to the attacks of this fungus on aphides in the greenhouses at Cambridge, Mass., where it acted as a decided check, and later, in 1887, Dr. L. O. Howard had called his attention to great quantities of aphides dying with the same disease on clover near the Agricultural Department buildings in Washington, D. C.

FIELD AND LABORATORY EXPERIMENTS IN INDIANA.

On July 20, 1889, the writer, at that time a special agent of the Division of Entomology of the United States Department of Agriculture, stationed at Lafayette, Ind., received, through the kindness of Professor Snow, enough material with which to make some experiments, the chinch bug being at that time very abundant at Lafayette, and an exceptionally good opportunity thus being offered for experimentation. The results of these experiments were published in detail in Bulletin 22 (old series), United States Department of Agriculture, Division of Entomology (pp. 55–63), but as this was the first series of experiments carried out with a view of testing with exactness the precise effects of varying degrees of temperature and atmospheric moisture on the growth of the Entomophthora, and carefully following out the progress of the disease under varying meteor-

[a] Memoirs Boston Society of Natural History, Vol. IV, p. 176.

ological conditions, the matter is here republished in full, the bulletin in which it was originally included being now out of print.

These diseased bugs were placed under glass with living ones from the fields, the latter being provided with food and kept thus confined for fifty-three hours, when the major portion of them were placed on several hills of corn seriously infested by bugs, the remainder with the dried remains received from Professor Snow being scattered about over a small area of young wheat sown for experiment and also swarming with young chinch bugs. The hills of corn on which the bugs had been placed were isolated from others, equally badly infested, by narrow frames of boards placed on the ground and the upper edges covered with tar. This last precaution was taken in order to prevent communication with other hills, intended as checks on those used directly in the experiment. The area of young wheat over which infested bugs had been placed was not inclosed, but its limits carefully marked. Five days after, July 27, a single bug was found on one of the isolated hills of corn which had very evidently died from the effects of Entomophthora, and by the 30th enough others were found to show that the fungus had fully established itself and the barriers about the isolated hills were removed. On August 2 dead bugs covered with Entomophthora were found in considerable numbers about hills of corn 25 feet from where the original colonies had been placed and also throughout and even 55 feet beyond the area of young wheat over which dead and affected bugs had been distributed. Daily observations were now made, but the progress of the disease seemed to come to a standstill. From the 5th of August up to the 9th it was almost impossible to get sufficient material outside to enable me to carry on laboratory experiments. August 13 the spread of Entomophthora appeared to have taken on new life, and diseased bugs were becoming much more numerous. August 15 found diseased bugs 172 feet from any place where they had been previously observed. August 20 diseased bugs were very abundant over all of the area where disease had been distributed, and two days later examples were found a quarter of a mile from the starting point of the disease. Immediately after this, however, another halt was observed, both in the intensity of attack and rapidity with which it spread, due either to the dry weather or to the fact that the bugs had now all reached the adult stage and had become diffused over the country, no longer congregating together. From either one or the other, or both of these causes, I lost track of the Entomophthora and was not able to again find it in the fields. It seems proper to state here that chinch bugs were not at any time excessively abundant. The greatest numbers were in the exact localities where the disease was first distributed, the congregating at these places being brought about by the close proximity to a large number of small experimental plats of wheat, and when this was harvested the bugs collected *en masse* on the corn and young wheat. In connection with these facts, it is also interesting to note that from July 15 to August 31 there were ten days on which rain fell. The dates of these rains and the amount of precipitation is given below:

Date.	Precipitation.	Date.	Precipitation.
	Inches.		*Inches.*
July 17	0.02	July 29	0.78
19	1.25	30	.50
22	.20	Aug. 9	3.36
23	.04	13	.15
26	.13	14	.02

With a view of learning whether or not there was any difference as regards susceptibility to the attack of Entomophthora between bugs in different stages of development, a series of experiments was begun, as follows:

Young plants of *Setaria glauca* were transplanted to a box, and upon each plant was placed a dead bug covered with the fungus, and also healthy larvæ; larvæ just on the point of pupation; pupæ just prior to reaching the adult stage, and fully developed adults, each stage being placed on separate plants, and each covered with a small inverted glass vial designated by lettering. As checks, another series was prepared, like the first in every particular. The soil in the box was kept well moistened, and the plants remained fresh. This experiment was made on August 2, about the time when the attack outside began to diminish in intensity. The following are the results of examinations on the dates indicated, the original experiments being indicated by capitals and the checks by small letters, thus—A–a, adult; B–b, young larvæ; C–c, older larvæ; D–d, pupæ.

Date.	A.	a.	B.	b.	C.	c.	D.	d.
Aug. 5	Healthy..	Healthy..	Healthy..	Healthy..	1 dead....	Healthy.	1 dead...	1 dead.
Aug. 6	1 dead....	1 dead....	Healthy..	Healthy..	1 dead....	Healthy.	3 dead...	1 dead.
Aug. 7	All dead..	3 dead....	3 dead....	1 dead....	3 dead....	1 dead...	....	5 dead.
Aug. 16	All dead..	All dead..	All dead..	All dead..	All dead..	All dead.	All dead.	All dead.

On the same day this experiment was begun a second was also commenced, like the first in every particular, except that the healthy bugs used in experimentation were exposed to fungus-infected individuals for only five hours and then placed under their respective glasses. As a result, on August 15, thirteen days after, none had died, thus strongly indicating that the Entomophthora did not exist generally in the fields, and that it could not be communicated during a period of five hours' exposure.

On August 7 a large number of healthy bugs were placed under glass, with a number which had recently died from Entomophthora, the moisture in the vessel being absorbed by calcium chloride. A check experiment was also commenced, where the material and the conditions were the same, except the humidity of the atmosphere, care being taken to have the latter as nearly saturated with moisture as possible. August 10 the original experiment was divided and a portion of the healthy bugs removed and placed in a damp environment, the remainder being kept under the original dry conditions. The results on August 22 were as follows: In the original experiment, where the healthy bugs had been continually in dry quarters, not a single bug had died from Entomophthora. Not only this, but none of those which had been removed after three days and placed in dry quarters had died, showing that the disease was not contracted and did not develop in healthy bugs, though kept exposed in a dry atmosphere for fifteen days, nor could it be originated by placing in a damp atmosphere for twelve days bugs which had been exposed to contagion for three days in dry quarters. The results with the check experiment were quite different. Within five days after being confined with the Entomophthora the healthy bugs began to die from effects of the disease, and in three days more every one had died from the same cause, their bodies being covered with spores.

Still another experiment was tried, which consisted in confining a large number of healthy bugs with others diseased in a damp environment, and when the fungus had destroyed a portion the remainder were divided and a part removed to dry quarters. The result was that while those left in damp confinement continued to die, none of those inclosed in dry environment were destroyed. As the fungus had by this time become distributed over the experiment farm so that I could not tell with certainty whether material from the fields was in a perfectly healthy condition or not, no further experiments were made in this direction.

From the foregoing it will be observed that the essential element in all of these experiments was an abundance of moisture, without which the Entomophthora could neither become established nor flourish after it had gained a footing. Again, the extent to which the disease will prove contagious will depend upon the number of bugs. Without great numbers massed together comparatively few would contract the disease. To sum up the matter, there is little hope for relief to the farmer from the influence of Entomophthora, except when chinch bugs are abundant and massed together in great numbers, and during a period of wet weather. I have succeeded in getting the fungus established at two widely located points in Indiana, and do not consider it at all difficult to introduce in localities where chinch bugs are abundant, provided the weather is favorable. But if it is ever utilized by the farmer, which seems to me to be at present a matter of considerable doubt, it will only be after the pest has become very abundant, during the time between the first larval and adult stages and in a wet time. After the Entomophthora has been introduced into a certain field it will become diffused only in proportion as the bugs travel about and healthy bugs come in contact with spores from those which have died from the disease. This will not be very great until the pupal stage is reached.

The larvæ of chinch bugs seem to in some way understand that while molting they will be well-nigh helpless, and hence hide themselves away in vast numbers in secluded places. Under such conditions the spores thrown from diseased bugs would reach a larger number of their fellows. I have found adults but recently molted affected by the Entomophthora. After the bugs acquire wings and scatter themselves over the country, the liability to contagion will be again reduced, unless in case of very severe invasions, where, from force of numbers, congregating on or about food plants becomes a necessity. Hence the introduction of the fungus among larvæ will at first proceed but slowly, and only in extreme cases and under favorable conditions can it be expected to proceed much more rapidly among adult bugs. In short, the only way that this fungoid disease seems capable of being employed in agriculture is by the establishment of some central propagating station to which farmers can apply and receive an abundant supply of infected bugs on short notice. By this means they could take advantage of a rainy period of a week or ten days, and, if they can contrive by sowing plats of millet and Hungarian to mass the bugs in certain localities about their fields, they might accomplish something toward warding off an invasion. But the possibility of overcoming an invasion after it is fully under way, as is almost sure to be the case during a dry season, it must be confessed is not very encouraging. My failure after repeated experiments to produce this Entomophthora in the vicinity of Lafayette without the importation of germs is decidedly against the theory that might be advanced that the northeastern portion of the State was kept free of destructive invasions by reason of this disease brought about by wet weather. There is as yet no reason to believe that the disease has ever existed in that section of the State.

The fungus entering into these experiments was determined as an Entomophthora by Dr. J. C. Arthur, and the probability is that it was *E. aphidis*, though it is possible that Sporotrichum was also present and remained unobserved.

FIRST FIELD APPLICATIONS OF FUNGOUS ENEMIES OF THE CHINCH BUG.

As has been stated, the credit for first confining healthy chinch bugs with those diseased and utilizing the individuals thus infected by transporting them to sections of the country supposedly free from the disease in order to create new areas of infection, belongs to Prof. F. H. Snow. During October, 1888, the year prior to that during which Professor Snow began his experiments, Prof. Otto Lugger, of Minnesota, collected a quantity of diseased chinch bugs at the experiment station at St. Anthony Park and distributed them to eighteen different localities in the southern part of the State where the pest was known to occur in destructive abundance. The diseased material was sent out in tin boxes by mail, and the contents of the boxes, on arrival at their destination, were simply thrown in any field where there was an abundance of chinch bugs. Later in the season the condition of affairs where these distributions had been made was such that "careful search in the majority of places failed to produce a single living specimen, while the traces of the disease were found everywhere." With a spirit of caution and exactness in every way most commendable on the part of Professor Lugger, he says: "The disease spread so rapidly that even corn growing near wheat fields crowded with chinch bugs was entirely protected, and no bugs had entered it in all the places visited by myself. But the writer is by no means satisfied that the disease was really introduced in this manner. Is it not possible that the disease was already there, unknown to anyone, and that the writer had simply reintroduced its germs? The reason for this belief is based upon the fact that too large an area was infested by the disease—too large to be readily accounted for by the short time in which the atmospheric conditions were apparently in its favor."[a]

In this case Professor Lugger states that both Entomophthora and Sporotrichum were present and the latter was sent by him to Professor Forbes, so there is the same confusion of the two fungi in this case that existed in the writer's experiments in Indiana, except that in the one case it was certain that Entomophthora was present, while in the other it was the Sporotrichum.

THE WORK OF PROFESSOR SNOW IN KANSAS.

Although Professor Snow had the experience and observations of Shimer, Forbes, and Lugger to aid him in his first efforts to apply the knowledge gained by these gentlemen, yet it must be said that it has been largely due to his untiring energy and perseverance that the use of these fungi has reached the present state of importance. It will hardly be saying too much if we state that his persistent un-

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[a] University of Minnesota Experiment Sta., Bul. 4, Oct., 1888, pp. 40–41.

daunted labors, in the face of much skepticism and opposition, has won for him the admiration of his fellow-workers, even among those who were long in extreme doubt as to the success of his labor. He has done more than any other one person to call attention to the possibilities of practical benefits to be derived by farmers themselves; has done more to advertise the merits of these fungous diseases among the masses than anyone else, and, in fact, has made the "chinch-bug fungus" almost a household word over the entire United States.

It is therefore all the more to be lamented that he should have accepted and published in his several reports the unsubstantiated statements of farmers whose testimony on a matter of this nature is, as every entomologist knows, absolutely worthless unless accompanied by specimens. His own personal experience in this direction and in several States had long ago led the writer to disregard all reports relating to the efficiency or inefficiency of these fungous diseases among chinch bugs, when such came from the ordinary farmer without being accompanied by specimens for examination. The cast pupal skins of the chinch bug pass with nonentomologists very well for dead bugs, and if the former have been attacked by the ordinary white molds the deception, except to the eye of an expert, is complete.

There is probably not an entomologist who has distributed these fungous diseases among farmers who has not found just such conditions as did Professor Lugger in Minnesota, where it was impossible to determine whether these diseases had been introduced artificially or whether they were already present and had been overlooked. In the writer's experience, while receiving chinch bugs from different parts of Ohio to be infected with the disease, consignments have come to him with the insects dying and others dead and covered with Sporotrichum, showing that this was already present and that the very utmost that we could expect to accomplish would be to aid in locally spreading the contagion. Besides this, the writer has sent material to farmers sufficient to start the fungus in their fields, knowing perfectly well that it would be a considerable time before actual benefits could by any possibility be expected to materialize, and within a week received the astonishing information that the fungus was so perfectly successful that the bugs all disappeared within a few days after the application of the disease. There is little doubt that the distribution of upward of 7,000 boxes of these fungi to the farmers of Kansas has accomplished a vast amount of good, but beyond this it is impossible to go. Of Professor Snow's laboratory work or the labors of himself and assistants in the fields no criticisms can be made, and there will be occasion to quote from these in future pages of this bulletin.

Sporotrichum globuliferum, or at any rate the fungus which is now passing under that name, was first found by Professor Forbes to infest the chinch bug in Illinois in 1887, and its destructive effects observed in the fields in the autumn of 1888.

Since the last-mentioned date the writer distributed upward of 3,000 packages of this fungus to the farmers of Ohio during the outbreak of the chinch bug in the State in 1895, 1896, and 1897, and knows from personal observation and study that it is under certain favorable conditions a deadly foe of this species, that its use under these conditions is practicable, and that if its application can be made simultaneously with the commencement of the breeding season it will prove effectual. This statement is made for the reason that as late as 1895 Dr. M. C. Cook, in his popular work on entomogenous fungi, "Vegetable Wasps and Plant Worms" (p. 120), states that "no species of this genus is known to have occurred on living matter, as they are saprophytes pure and simple, and then, probably, only as the stroma or conidia of some fungus of higher organization, possibly the Sphæriacei." This statement was made in discussing *S. densum*, but on the following page (121), after dealing with *S. globuliferum*, he appends the following: "The remarks made under the previous species are applicable to this, which is not entitled to rank as a parasite, but rather as an accidental development upon one out of many forms of decaying animal matter."

OTHER INSECTS ATTACKED BY SPOROTRICHUM GLOBULIFERUM.

Spegazzini [a] described the species from Argentina as occurring on the dead bodies of beetles, notably Monocrepidius and *Naupactus xanthographus* Germ. Besides *Parandra brunnea* Fab., Professor Forbes has recorded this fungus on Lachnosterna and a number of other Coleoptera, and also on lepidopterous larvæ, as well as on the young of other insects, while the writer has infected, artificially, *Epicauta pennsylvanica* De G. and witnessed an instance of accidental infection of *Megilla maculata* De G., but failed to infect the harlequin cabbage bug (*Murgantia histrionica* Hahn) even when these were placed among dead and dying chinch bugs in the breeding cages. In both cases these beetles were almost entirely covered by the fungus after having to all appearances died from its effects. With respect to this matter one point is clear, either the determination of this fungus is incorrect or else Doctor Cook has made a very serious misstatement, which ought to be corrected. It is but just to state, however, that Professor Forbes, in his eighth report (p. 23), calls attention to the fact that it is closely allied to Botrytis, and would be placed by some botanists under that genus now.

[a] Spegazzini, Fungi Argentini, ii, p. 42.

FIRST ARTIFICIAL CULTIVATIONS OF SPOROTRICHUM GLOBULIFERUM.

In April, 1891, Dr. Roland Thaxter succeeded in cultivating *S. globuliferum* artificially on agar-agar, and a month later Professor Forbes made similar cultures on the mixture of corn meal and beef broth, this last being an exceedingly valuable discovery, as it revolutionized our method of distributing the fungus by securing chinch bugs to be kept for a time with those diseased and then sent out to be scattered over the fields—a cumbersome method which was never satisfactory. The writer's own work in Ohio was based on material obtained from Professor Forbes, and the first year he distributed infected chinch bugs, but after that he used the artificial base of beef broth and corn meal, finding the latter far more satisfactory to handle, and, so far as could be determined, equally effective.

RESULTS OF FIELD APPLICATIONS IN OHIO.

In regard to the writer's own experience, it is unnecessary to go into details, except to state that, under the most favorable laboratory conditions, he was able to kill apparently perfectly healthy chinch bugs within three days after bringing them in contact with the Sporotrichum. In the fields, during the season of 1895, though upward of 750 packages of diseased bugs were sent out to farmers, and some astonishing reports of results received therefrom, yet his own observations led him to believe that in many cases these were rather more imaginary than real. Over the areas where local showers occurred during the season of development of the first brood of young the effect was much more satisfactory. But in many cases the request for help came late, and soon after the fungus was applied the bugs scattered out over the fields, disappearing to the eyes of the ordinary farmer, who, of course, attributed all to the effect of the Sporotrichum. In 1896, however, meteorological conditions changed, and at last the writer had the good fortune to secure the very opportunity for which he had been waiting for years. All through April and up to the 10th of May in southern Ohio there was little rain, and even during the remainder of the latter month the light rains hardly sufficed to break the drought, so that there was a perfect breeding season for the chinch bug during the forepart of the breeding period. The result was that over some sections (see fig. 7) there were myriads of young bugs. Then the rains came on, and there were presented the two essential requisites for success with the fungus, viz, chinch bugs and wet weather.

Soon the demands for supplies of Sporotrichum began to pour in, and 1,200 packages were distributed within a few weeks, instructions being given to place the contents of the boxes where the chinch bugs were massed in greatest abundance, giving preference to the lower and damper localities in the fields.

After the distribution had been finished, the sections where the outbreak of chinch bugs had been the most severe and where the larger portion of the Sporotrichum had been distributed were visited. There was certainly no mistaking the effect of the fungus. Going to the place in a field (generally a wheat field) where the fungus had been introduced, the track of the chinch bugs as they moved in any direction was in many cases almost literally paved with the dead bugs more or less enveloped in their winding sheets of white. Along ravines, dead furrows, or other depressions, the ground would be nearly white, the dead diminishing in numbers as the higher grounds were reached, though these were by no means free from corpses. In one instance the bugs had left a field of wheat at harvest, the Sporotrichum having been applied there before the movement began, and entered an adjoining cornfield. The way was marked with white, not only the surface of the ground, but on stirring up the mellow soil of the edge of the cornfield it was found to be literally full of dead chinch bugs to the depth of 2 or 3 inches, the white fungus-covered bodies strongly contrasting with the black color of the rich loam. Not only this, but under the sheaths of the leaves and on the leaves themselves hundreds of dead were to be found on the outer rows of corn, on the grass and weeds, and, indeed, almost everywhere. Millions of chinch bugs were certainly destroyed in this one field.

In other fields, where the number of bugs had been less, the dead were less numerous, and then they were more apt to be scattered over the leaves of the corn, as in such cases a diseased bug seems to be animated with a desire to crawl upward on any object which presents itself, just as a larva of the clover-leaf weevil, *Phytonomus punctatus* Fab., when attacked by *Entomophthora sphærosperma* (Fres.) will climb to the tip of a vertical blade of grass and coil itself around it, and, holding it in the grasp of death, remain in that position so strongly attached that the winds and rains fail to dislodge it until it has become disintegrated. In other localities, where no Sporotrichum had been distributed, the ravages had certainly been greater and the writer failed to find any indication of the presence of the fungus. So far as his observation extended, unless there were a sufficient number of chinch bugs massed to become injurious, the fungus had but little effect upon them. In other words, the massing appeared to be an essential requisite. Whether this was sufficient of itself, or whether the effect of massing was to reduce the vitality of the individual bug, and thus render it more susceptible to the spores of the fungus, it is impossible for the writer to decide; but he has long suspected that the latter was the true solution of the problem. We know that most domestic animals or fowls thrive best and are the most vigorous when kept in small flocks, while among humans the maximum of health and minimum of disease is obtained where the individuals are scattered over a moderate area per capita and the atmosphere is dry and pure; low, damp, and ill-ventilated quarters, when overcrowded, being especially fatal, particularly to the young. The individual in perfect health and vigor may in one sense be said to be above and out of reach of disease, and before the two can be brought together there must be some interacting element that will bring the individual down to a point where he can be reached by the disease; that is, the disease can rise only to a certain plane and the victim needs to be first attacked by some element not necessarily fatal in itself, but sufficiently depressing to bring the individual down to where he can be grasped by the disease.

METEOROLOGICAL INFLUENCES FAVORING DEVELOPMENT OF FUNGOUS ENEMIES OF THE CHINCH BUG.

When human beings are overcrowded and some disease is introduced among them, everyone knows the effect of a low, damp locality under a high temperature and with both air and water more or less stagnant. Even the once healthy and vigorous are more or less reduced and enervated by their environment, and thus brought within the influence of the deadly disease. Again, if an individual is stricken and forsakes his miasmatic surroundings for those more salubrious, the disease may still overcome him, but seldom spreads to others, except such as come in actual contact with either himself or his belongings, while if not too much reduced before changing his habitation the chances are much more favorable for his recovery.

It seems to the writer that in this matter of metorological conditions and their relation to the effect of entomogenous fungi on the chinch bug we are really dealing with the same problem in a different field. The young chinch bug which has not yet come into possession of its full measure of strength, and the spent females, which have lost theirs, fall easiest as the prey to these fungi, while the fully developed bugs, endowed with health and vigor, appear to be to some extent immune to the attacks of these enemies, and if not massed in large bodies they seem still more likely to escape destruction. In the timothy meadows of northeastern Ohio an occasional dead adult has been found in late autumn, but the fungus had certainly not claimed many victims, though both the long and the short winged forms were present in considerable abundance, clustered about the roots of grass. With Forbes the writer believes that after becoming fully matured the chinch bug is, largely at least, beyond the reach of Sporotrichum. What is the element that serves to enervate and reduce the older larvæ and pupæ, as well as many recently developed adults among them? Is there nothing that, not of itself fatal, so acts upon the system of the bugs that they are brought into a condition of susceptibility—a sort of "go-between," so to speak, but which demands atmospheric moisture before it will rise to an aggressive state?

A BACTERIAL ENEMY OF THE CHINCH BUG.

Forbes finds that the bacterium *Bacillus insectorum* Burrill is normal to the chinch bug and occurs always in the intestinal cœca, and the writer has often wondered if this were not the very reducing element. In a paper contributed to the "American Practitioner," September, 1891, he describes the effect of this bacteria on the cœca as completely destroying the secreting epithelium, the cells of which break down and disappear, leaving the delicate tubes filled with a vast mass of microbes with some small intermixture of droplets of fat and a little nondescript *débris*, the result of cellular decomposition. Now, it certainly seems to the writer that we may here have the very enervating element necessary and which, in order to become sufficiently aggressive to perform its functions perfectly, requires the very conditions afforded by frequent showers, without which it is comparatively helpless. We know very well that human beings are far more susceptible to disease when weakened by fatigue, dissipation, or other forms of exhaustion, and under such conditions succumb to disease when they would otherwise enjoy immunity therefrom. We will not, however, follow this further, but submit it as a problem well worthy of careful consideration and study. In his own experiments with *Sporotrichum globuliferum* the writer has found that under the most favorable conditions the fungus will attack even the youngest larvæ, while Forbes states that it will also attack the eggs, but in the fields it seemed generally most prevalent among the more advanced larvæ, pupæ, and newly developed adults, though much depends upon meteorological conditions and the abundance of chinch bugs, as well as the time during the breeding season when the fungus is doing its work. That is to say, there is a time at the beginning of the breeding season when there are only adults and young larvæ; later there will be larvæ of various ages, and, toward the last, few if any of these, but all will be either pupæ or adults. For some reason it seemed more difficult to get the Sporotrichum to work satisfactorily when the chinch bugs were beginning to breed than later on, the last of June and the early part of July. These facts are mentioned here to show that, judging by their effects, these fungi hold a secondary place.

THE PRACTICAL UTILITY OF FUNGOUS AND BACTERIAL ENEMIES IN FIGHTING THE CHINCH BUG.

Regarding the practicability of utilizing these entomogenous fungi in agriculture, there seems no reason to revise a statement made ten years ago, viz, that this can be done only in cases of excessive abundance and during wet weather, the basis for infection being provided by some central propagating station from which farmers can receive promptly an abundant supply. The writer believes that for himself he could manage to get considerable benefit from their use in destroying chinch bugs, provided he were located within the area of the frequent occurrence. This could be done only by watching the seasons carefully, and in case there should occur two years in succession wherein the breeding periods were covered by drought, then every preventive measure known should be adopted, notably the burning of leaves, dead grass, and other rubbish during winter or early spring, followed up by sowing small plats of early millet, Hungarian grass, or, better yet perhaps, spring wheat, in low damp places in the fields, with a view of attracting the females or in fact massing the bugs, and then freely applying the fungi in their midst. Whether the average farmer, with his somewhat crude ideas of entomology, can do this successfully or not is very uncertain. It is almost impossible to determine even a few weeks in advance whether a season is to be favorable or unfavorable to the development of the chinch bug, which would of itself cause occasional false alarm, and the precautionary measures rendered entirely unnecessary by a few timely and drenching rains just at the critical time. Before we can expect to be eminently successful in this matter, not only the farmer but also the entomologist and meteorologist have much to learn.

THE BOBWHITE OR QUAIL.

Chinch bugs have few important enemies among the birds of the northern United States. To what extent the coast birds feed upon them it is impossible to say, but inland the common quail or bobwhite (*Colinus virginianus*) is the only species that can be said to devour any considerable number. As this is one of our most highly prized game birds, it is slaughtered annually in tremendous numbers.

The following list will show the degree of protection offered the quail by legislative enactment in the States where the chinch bug is the most destructive. The close season for quail in the several States, during which killing is prohibited by law, is as follows:[a]

Maine, all the year.

New York, December 1 to November 1, except in some counties where it is from December 1 to October 16. In Rensselaer County it is from December 1 to October 1 and in Richmond County all the year until 1908.

[a] Farmers' Bulletin No. 265, pp. 13–25, 1906.

Pennsylvania, December 1 to November 1.
Ohio, December 5 to November 15.
Indiana, January 1 to November 10.
Illinois, December 20 to November 10.
Minnesota, December 1 to October 1.
Iowa, December 15 to November 1.
Missouri, January 1 to November 1.
Nebraska, December 1 to November 15.
Kansas, December 15 to November 15, with some exceptions where the close season extends to March 11, 1908.[a]
Oklahoma, February 1 to October 15.
Texas, February 1 to November 1.

The breeding season from latitude 38° northward to Canada begins in May, and continues through July and occasionally into September or even October. A young bird just from the nest was taken in Wayne County, Ohio, September 5, 1887.[b] There are probably two, and southward three, broods each season, and, while rather prolific, the quails are kept well reduced in numbers, at times to the verge of extermination over considerable sections of country. They are hunted incessantly and slaughtered without consideration, except for gain. Some also are killed by flying against electric wires, while entire coveys are sometimes smothered or frozen under the snow. As a result, the helpfulness of the quail against chinch bugs is greatly diminished.

OTHER BIRD ENEMIES OF THE CHINCH BUG.

Among the other bird enemies of the chinch bug are the prairie chicken, redwing blackbird, catbird, brown thrush, meadowlark, house wren, tree swallow, and horned lark, but there is little doubt that in seasons when the chinch bug is excessively abundant the comparatively few eaten by all of these birds is insufficient to reduce the numbers of the pest to any extent.

THE FROG.

Dr. Cyrus Thomas quotes Professor Ross and others as stating that the common frog is an enemy of the chinch bug. While this is probably true, it is nevertheless well known that comparatively few frogs frequent grain fields as a rule, and thus the benefit derived from their attacks is of too little importance to merit further notice.

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[a] In Rawlins County, under restrictions, November 1 to January 1.

[b] A preliminary List of the Birds of Wayne County, Ohio, by Harry C. Oberholser. Bul. Ohio Agric. Exp. Sta., Tech. Ser., Vol. I, No. 4, p. 270.

INVERTEBRATE ENEMIES OF THE CHINCH BUG.

Of the invertebrate enemies the same may be said as of the frog. The writer has occasionally found a chinch bug containing a species of Mermis, "hair snake." Also occasionally ants may be seen dragging these bugs away, while lady-beetles have sometimes been found to devour them, as recorded by Walsh and Forbes. Perhaps the worst insect enemies of the chinch bug are to be found among its comparatively near relatives, the insidious flower bug, *Triphleps insidiosus* Say (*Anthocoris pseudo-chinche* of Fitch's Second Report) (fig. 15), and *Milyas cinctus* Fab. (fig. 16), the latter being reported by Doctor Thomas as the most efficient of the insect enemies of this pest, while Doctor Riley found that the former also attacked it. Professor Forbes ascertained by examinations of the contents of the stomach of a ground beetle, *Agonoderus pallipes* Fab., that one-fifth of the total food of this species was composed of chinch bugs. Doctors Shimer and Walsh both claim that lace-wing flies (*Chrysopa*) destroy chinch bugs, and they are doubtless correct. The writer has also very often found dead chinch bugs entangled in spider webs, though whether killed for food or by accident it has been impossible to determine. It will be seen, however, that the combined influence of all of the natural enemies of the chinch bug, parasitic fungi excepted, is far too weak to offer any material protection to the agriculturist against this pernicious enemy of his crops, with nothing to promise an improved condition of affairs in this direction in the future. There may sometimes appear hymenopterous parasites of the eggs, but we have as yet no proof of the existence of such in this country, and only suspect the possibility of such a phenomenon because other allied species have similar enemies, which destroy their eggs. In short, the immunity of the chinch bug from attacks of other organisms is so striking that it has attracted the attention of all entomologists who have made a study of the species, and all accept this as indicating that it is an exotic, not originally belonging to our insect fauna.

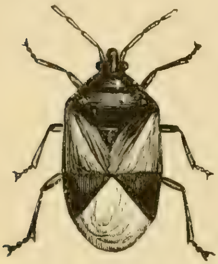

FIG. 15.—*Triphleps insidiosus* Fab. (From Riley.)

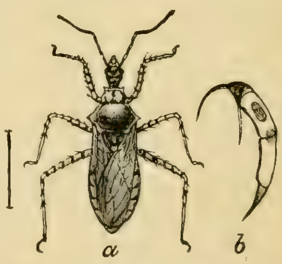

FIG. 16.—*Milyas cinctus* Fab. (From Riley.)

REMEDIAL AND PREVENTIVE MEASURES.

The list will include all remedial and preventive measures that have been found to possess the merit of reasonable efficiency and practicability. These may not all prove applicable in all localities or under every variety of circumstance, and the farmer will often have to fit his protective measure to meet weather conditions, location of field and its surroundings, as well as the thousand and one other variations of a similar nature.

DESTRUCTION OF CHINCH BUGS WHILE IN HIBERNATION.

The first effort that may be made with a view to warding off an attack of chinch bugs is to destroy them in their winter quarters. This can be accomplished by burning all dried grass, leaves, or other rubbish during winter or early spring. Forbes (First Report, p. 37) and Marlatt (Insect Life, VII, p. 232) have cast some doubt upon the statements to the effect that the chinch bug hibernates to any great extent among dried grass, leaves, and rubbish, but the evidence is so overwhelmingly in favor of the assertions of nearly every entomologist who has studied the insect in its hibernation to the effect that it does select such places in which to pass the winter that there is hardly any use of raising the question at all. A good illustration of the fact that large numbers of chinch bugs may be in hiding in such places and escape detection is shown by the fact that a quantity of dried leaves from about a vineyard located on a narrow neck of land about a quarter of a mile from the Bay of Sandusky on the one side and about 1½ miles from the shore of Lake Erie on the opposite side were collected late in April and brought to our insectary and placed in a breeding cage. At the time of collecting the leaves only an occasional chinch bug was to be observed, but under the warm atmosphere of the insectary they began to stir themselves, and soon demonstrated that there had been a large number ensconced unseen among the dried and curled dead grape leaves. So it is with the matted grass along roadsides and fences, especially the Virginia worm rail-fence.

While it is not possible to find the hibernated chinch bugs by searching, yet if pieces of boards are laid down on the grass in early spring the bugs will collect on the under side and may be found there, or they may be discovered by the method of collecting known to entomologists as sifting. The burning of all such grass will destroy thousands of bugs in their winter quarters; but sometimes the matted bluegrass remains green in winter, or the weather is not sufficiently dry to enable the farmer to burn over such places. In such cases a flock of sheep, if given the freedom of the fields during winter and spring, will eat off all living vegetation and trample the ground with their small feet, so that not only is all covering for the bugs removed, but also the bugs are trampled to death. The ease with which the narrow strip of grass land along a post and wire fence can be kept free of matted grass and leaves, as compared with that along a hedge or rail fence, indicates that there may be an entomological factor connected with the modern fence that has been overlooked, giving it, in this respect, an advantage over the more ancient form. Shocks of fodder corn left in the fields over winter certainly afford protection for many chinch bugs, as also will coarse stable manure spread on the fields before the chinch bugs have selected their place of hibernation in the fall. In short, the first protective measure to be carried out is a general cleaning up in winter or early spring either by burning or pasturing or both.

SOWING DECOY PLATS OF ATTRACTIVE GRAINS OR GRASSES IN EARLY SPRING.

Judging from the manner in which the wintered-over adults are attracted to hills of young corn, wheat fields, or plats of panic grass and foxtail, it has always seemed to the writer practicable to take advantage of this habit and sow small patches of millet, Hungarian grass, spring wheat, or even corn, early in the spring and thus bait the adults as they come forth from their places of hibernation. Their instincts will prompt them to seek out the places likely to afford the most desirable food supply for their progeny, and if an artificial supply can be offered them that will be more attractive than that furnished by nature, the bugs will certainly not overlook the fact, but will take advantage of it to congregate and deposit their eggs there, whereupon eggs, young, and adults can, a little later, be summarily dealt with by plowing both bugs and their food under and harrowing and rolling the ground to keep the former from crawling to the surface and escaping. The writer has thoroughly tested this method in a case where the bugs, young and old, had taken possession of a plat of neglected ground overrun with panic grass (*Panicum crus-galli*), which was mown and promptly removed and the ground plowed, harrowed, and rolled before the bugs could escape, thus burying them beneath several inches of soil out of which they were unable to make their way, and as a consequence they were almost totally annihilated, hardly 1 per cent making their escape to an adjoining cornfield.

DIFFICULTY OF REACHING CHINCH BUGS IN MEADOWS.

There is, however, some doubt in regard to the practicability of applying these measures in meadows. Meadow lands can be burned over with perfect safety to either the grass or clover, if done while the ground is frozen, but there is danger of injury if burned over in spring, and it is somewhat doubtful if the hibernating chinch bugs would be killed unless the surface of the ground was heated to a degree that the grass and clover plants would hardly be able to withstand.

Infested areas of meadow land could be plowed, it is true; but the work would have to be done very carefully, else the grass and stubble would be left to protrude above ground along each furrow and constitute so many ladders by which the chinch bugs could easily crawl out and make their escape. Where the ground will admit of subsoiling, or where a "jointer" plow can be used, this latter difficulty can be easily overcome. Usually, however, the chinch bug works too irregularly in a field to permit of plowing under infested areas without disfiguring it too much for practical purposes, especially in the case of meadows, unless it be where the bugs have migrated *en masse* from an adjoining field, when a narrow strip along the border can often be sacrificed to good advantage. In many instances the heroic use of the plow in turning under a few outer rows of corn would have saved as many acres from destruction. In the majority of cases it is the fault of the farmer himself that these measures are not effective, as he will seldom take the trouble to burn the dead leaves, grass, and trash about his premises at the proper time, and when there occurs an invasion of chinch bugs, instead of resorting to heroic and energetic measures to conquer them on a small area he usually hesitates and delays in order to determine whether or not the attack is to be a serious one, and by the time he has decided which it is to be, the matter has gone too far, and the chinch bugs have taken possession of his field. This is especially true in the West, where the bugs breed exclusively in the fields of wheat and remain unobserved until harvest, when they suddenly and without warning precipitate themselves upon the growing corn in adjacent fields. In fighting the chinch bug promptness of action is about as necessary as it is in fighting fire.

WATCHFULNESS NECESSARY DURING PROTRACTED PERIODS OF DROUGHT.

It has always appeared to the writer as though a little watchfulness on the part of farmers during periods of drought might enable them to determine whether or not chinch bugs were present in any considerable numbers in their fields, in time to interpose a strip of millet between the wheat and corn, to be utilized later as previously indicated. Instances have come under observation where, the wheat fields being overgrown with panic grass and meadow foxtail, the bugs transferred their attention to these as soon as the wheat was harvested, and a prompt plowing of the ground would have placed the depredators beyond the possibility of doing any serious injury. If the weather at the time is hot and dry, a mower may be run over the stubble fields or along the borders of them, cutting off grass, weeds, and stubble, as the case may be, leaving them to dry in the hot sun, when, in a few hours, they will burn sufficiently to roast all bugs among them, and, while not destroying every individual, this will reduce their numbers to such an extent that they will be unable to work any serious injury.

In case the weather at the time should, on the contrary, be wet and rainy, so that it is impossible to mow and burn, the prompt distribution of the fungus Sporotrichum will prove of immense value; for in this case the more the bugs are massed over a limited area, the more fatal will be the effects of the fungus, and especially will this prove true if the land is low and inclined to be damp. This statement will also hold good with reference to meadow lands during the breeding season, though later the adults do not appear to succumb to the effects of the fungus nearly as readily, and the writer has found the fungus present in spring among masses of hibernating individuals, with little indication of its contagious nature, only an occasional individual being attacked.

UTILITY OF KEROSENE IN FIGHTING CHINCH BUGS.

In fighting the chinch bug there is at present no more useful substance than kerosene, either in the form of an emulsion or undiluted. From its penetrating nature, prompt action, and fatal effects on the chinch bug, even when applied as an emulsion, it becomes an inexpensive insecticide, while it has the further advantage of being an article of universal use in every farmhouse, and is therefore always at hand for immediate use. The emulsion has the further advantage of being capable of sufficient reduction in strength to prove fatal to insect life and yet not injure the vegetation upon which such may be depredating. Diluted and ready for use, the emulsion is prepared as follows: Dissolve one-half pound of hard soap in 1 gallon of water, preferably rain water, heated to the boiling point over a brisk fire, and pour this suds while still hot into 2 gallons of kerosene. Churn or otherwise agitate this mixture for a few minutes until it becomes of a cream-like consistency and, on cooling, will form a jelly-like mass which adheres to the surface of glass without oiliness. For each gallon of this emulsion use 15 gallons of water, mixing thoroughly. If applied to growing corn it will be best to use the emulsion either during the morning or evening, say before 8 a. m. or after 5 p. m., as at those times it will be less likely to affect the plants than if applied in the heat of the day.

Where an invasion of the chinch bug is in progress from a field of wheat to an adjoining field of corn, as an illustration, the marginal rows of corn can frequently be saved, even after the bugs have massed upon the plants, by spraying or sprinkling them freely with kerosene emulsion, being careful not to get much of it directly into the crown of the plants and using a sufficient quantity so that the emulsion will run down the outside and reach such bugs as are about the base of the plants. This treatment will kill the bugs clustered upon the corn, and in case of those on the way to the field, while it will not keep them out, it will cause a halt in the invasion, and thus give the farmer an opportunity to put other measures in operation, one of which will include the use of kerosene in another manner. If a deep furrow is plowed along the edge of the field, running the land-side of the plow toward the field to be protected, the furrow will form a temporary barrier to the incoming hordes.

UTILITY OF DEEPLY PLOWED FURROWS SUPPLEMENTED BY THE USE OF KEROSENE EMULSION.

In dry weather the sides of this furrow can be made so steep and the soil so finely pulverized that when the chinch bugs attempt to crawl up out of the furrow they will continually roll back to the bottom, where they can be sprinkled with either kerosene alone or with the much less expensive emulsion, and killed. In case of showery weather, which prevents the sides of the furrow from remaining loose and dry, the bottom can be cleared out with a shovel, making it more smooth and the sides more perpendicular, thus rendering it so much easier to follow along the bottom than to attempt to climb the sides. If holes are dug across the bottom at distances of, say, 30 or 40 feet, the bugs will fall into them and can be still more easily disposed of by the use of kerosene. That both of these measures are thoroughly practicable the writer has ample personal experience in evidence, and knows that under most conditions that are likely to obtain, prompt and efficient application is all that is necessary. During a few days this work will demand the closest watching and application, but fields of grain can be protected thoroughly and effectually if these measures are faithfully carried out, and the expense of time and money will be found to be less than in almost any other plan that has been up to this time discovered. In his own experience, in no case has a field attacked by a migrating army of chinch bugs come under the writer's observation, but that might have been saved from very serious injury by the prompt use of either of these measures, though under some conditions the farmer might find it advantageous to apply some of the other methods of protection here given.

THE SURFACE AND COAL-TAR METHOD.

The objections made by farmers to the use of most forms of these barriers is that the finest pulverized soil soon becomes incrusted by even the slightest rainfall and the bugs then pass over it without difficulty, while barriers of boards are expensive.

It is feasible to eliminate both by simply smoothing off a path along the margin of an infested field where such a one adjoins the one to be protected. This can be done with a sharp hoe, and as the margins of wheat fields usually become compacted it is but little trouble to thus clear off a path a foot or more in width, smooth as a floor, with the surface almost as hard. In the midst of this path post holes are sunk as in the bottoms of furrows, and a train of coal tar is run between them, being so arranged that it will reach the post hole near the inner side opposite the field from which the bugs are migrating. In this way as the bugs reach the train of coal tar they will follow along until they reach the post hole, while those meeting with the post holes will usually divide and, following around it, join with the flow of bugs moving along the train of coal tar. The result is that they become congested in the acute angle where the coal-tar train is intercepted by the post holes. Those in the apex of this angle can not turn back, and thus are continually pushed into the post holes by those behind. As the bugs, varying from the red larvæ to the almost black pupæ, mass along the line of coal tar they have much the appearance of a reddish-brown stream running into the holes. From these holes there is no escape and here the bugs can be readily killed by sprinkling with kerosene. The slightest train of coal tar is sufficient to obstruct the passage of the bugs, and light rains will not affect its efficiency. In dry weather these trains of coal tar soon become covered over with dust and must be renewed; but in showery weather there is no dust, and if the coal tar is renewed daily or, at most, twice each day it will accomplish its work and nothing further will be needed than to kill the bugs that have collected in the post holes. This measure is inexpensive and can be promptly put into operation if the coal tar is at hand. The writer has been able in this way to effectively protect a field of corn surrounded on two sides by a wheat field literally overrun with chinch bugs at harvest and during a time when light showers were occurring, frequently several times each day.

THE RIDGE AND COAL-TAR METHOD.

Differing quite materially from the preceding are the various combinations of coal tar and ridges of earth, smoothed and packed along the apex, or, instead of the ridge of earth, 6-inch boards, such as are ordinarily used for fencing, placed on edge and the upper edge coated with tar. Forbes has reported excellent results from the application of a line of coal tar put directly upon the bare ground where the surface has been rendered compact by a recent fall of rain. Even in this series of protective measures kerosene can be used to great advantage. In the experiment recorded by Professor Forbes the coal tar was put upon the ground between a wheat field and a cornfield from an ordinary garden sprinkling pot from which the sprinkler had been removed and the orifice of the spout reduced in size with a plug of wood until the tar came out in a stream about the size of the little finger and made a line on the surface of the ground about three-fourths of an inch in width. Post holes were sunk along the line from 10 to 20 feet apart on the side next to the wheat field, thus practically completing the barrier, and the chinch bugs being unable to cross the line of tar accumulated in the post holes in vast numbers, where they were killed; and those bugs that had already entered the cornfield before the barrier was constructed were prevented from spreading farther by tar lines between the rows of corn, the infested corn itself being cleared of bugs by the application of kerosene emulsion. The same writer states[a] that several farmers in Vermilion County, Ill., prepared for the coal-tar line by hitching a team to a heavy plank and running this, weighted down with three or four men, over the ground once or twice until a smooth, hard surface had thus been made to receive the tar. If the barrier was to be made in sod, a furrow was plowed and the bottom of this made smooth by dragging the plank along the bottom. In both cases post holes were sunk along the tar lines, and in these were placed cans or jars into which the bugs fell in myriads and were destroyed.

On one farm of 250 acres a coal-tar line 90 rods in length was renewed once each day and killed about 8 gallons of chinch bugs. In the case of another farmer there were 300 rods of tar lines with post holes, cans, etc., which resulted in destroying about 10 bushels of chinch bugs. A 6-gallon jarful was destroyed in less than half a day at one point on the line. In this last instance the lines of tar were renewed three times a day, but even then less than a barrel of tar was used. Still another farmer, with 120 rods of tar line, used about a third of a barrel of tar and did not lose a hill of corn; he caught chinch bugs by the bushel. In some of the cases cited the tar line was run in a zigzag course, the post holes being situated at the angles, and in others leader tar lines were run obliquely to the main tar line, one end terminating at the traphole, but both of these plans were afterwards regarded as unnecessary, a single straight line being entirely sufficient and less expensive. The numerous cases where these methods were put into execution with entire success and at small expense is the best possible proof of their practical utility. If a farmer is situated near town, where refuse tin cans are dumped in any locality where they can be got out of the way, he can select the larger of these, set them in the post holes and partly fill them with kerosene and water. The water being heavier than the kerosene will sink to the bottom, leaving a stratum of kerosene on the surface.

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[a] Twentieth Report of State Entomologist of Illinois, p. 39, 1898.

The chinch bugs falling into this will be forced down by the weight of those coming after, and thus all will be passed through the kerosene into the water below. This will obviate the necessity of frequently emptying the cans or treating their contents. It may also be stated that where the post holes are quite deep and enlarged at the bottom the bugs falling into them will perish without further attention.

OTHER BARRIER METHODS.

Professor Snow, working in Kansas, followed a somewhat different method and one that, under certain conditions, might be found superior to that used by Professor Forbes, or the furrow and kerosene method applied by the writer in Ohio. This modification consists in throwing up a double furrow, known among farmers as "back furrowing," and thus forming a ridge, the top of which is smoothed and packed with a drag having a concave bottom of the form of the ridge to be made. If the bottom of this drag is covered with zinc, it will be found to keep bright and polished and by this means make a smoother ridge. The substances used were coal tar as it came from the gas works and crude petroleum as taken from the oil wells. The former is the more easily obtained, except in certain localities, and will probably be found the more practical, as it stands on the surface better and is not so readily washed away by rains. Both of these substances are, however, offensive to the bugs, and they will seldom attempt to cross them or even come close enough to touch them, but on approaching will turn and run along the ridge in the evident hope of finding a gap through which they can pass. Post holes were dug on the outside of the line, but close up to it, so that the bugs in passing along beside the tar line would crowd each other into them. Professor Snow suggests that it will be better to construct this barrier several weeks prior to its being needed, as then the tar line has but to be run along the ridge and the post holes dug, when the whole system is complete and the chinch bugs can be thus shut out from the first.[a]

With these barriers of either ridge or furrow and the use of coal tar or crude petroleum, supplemented by kerosene emulsion, a very large percentage of the injury from chinch bugs may be prevented, and, in fact, with a reasonable degree of watchfulness and prompt action, all injury from migrating hordes may be prevented. The use of tarred boards set on edge or slightly reclining might, under some circumstances, take the place of the ridge or furrow, but these cases will be exceptional, and the use of kerosene emulsion will probably

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[a] Fifth annual Report of the Director of the Experimental Station of the University of Kansas, for the year 1895 (1896), pp. 45–47.

be found equally practicable here, as also will the post holes for collecting the chinch bugs. This method is merely cited in order to call attention to its possible use where the others are found impracticable. The plowing of furrows has been in vogue since the first writings of Le Baron and the second report of Doctor Fitch, and may be utilized in other ways than those previously mentioned. A heavy log dragged back and forth in this furrow will pulverize the soil in dry weather, and Forbes has recorded the fact that where this has a temperature of 110° to 116° F. it is fatal to the young bugs that fall into the furrow, even if they are not killed by the log. As 120° is not uncommon in an exposed furrow on a hot summer day, it will be observed that there may be cases where this method will be found very serviceable, and especially is this likely to prove true in a sandy soil with a southern exposure. In sections of the country where irrigation is practiced these furrows may be flooded and in this way rendered still more effective without the expenditure of either time or money to keep them in constant repair. Doctor Riley long ago laid considerable stress on this measure, believing it of much value, especially in the arid regions of the far West. The same writer advised the flooding of infested fields, wherever it could be done, for a day or so occasionally during the month of May. It is hardly probable, however, that this will often be found feasible except in rice fields, where it is sometimes practiced.

NECESSITY FOR PREVENTING CHINCH BUGS FROM BECOMING ESTABLISHED IN FIELDS OF WHEAT AND GRASS.

In the foregoing it will be observed that prevention of migration has been the chief end in view either by destroying the chinch bugs in their hibernating quarters, and thus preventing the spring migration to the breeding places, or by various traps and obstructions to prevent them from migrating from such places to others not already infested. The great problem remaining to be solved is to prevent their breeding in wheat fields at all. As has been shown, it is absolutely impossible, with our present inability to forecast the weather months in advance, to be able to foretell whether or not an outbreak of chinch bugs is likely to take place. There may be an abundance of bugs in the fall—enough to cause an outbreak over a wide section of country—and these may winter over in sufficient numbers to cause some injury in spring, yet a few timely, drenching rains will outbalance all of these factors, and our wisest prognostications fail of proving true. It is this very factor of uncertainty that renders unlikely the successful carrying out, over any large area of country, of any protective measures where, as in this case, the benefit to be derived will only be realized nearly a year afterwards, if at all. The average farmer, when smarting under a heavy loss, will often take such long-range precautions as to sow belts of flax, hemp, clover, or buckwheat around his wheat field once; but if the chinch bugs do not appear, and he sees the useless investment of time, labor, and seed, he will be likely to conclude next year to take the risk and do nothing. For the present, then, we have no method whereby we can prevent the chinch bugs from taking up their abode in wheat fields or timothy meadows and raising their enormous families there, except to destroy the adults in their winter quarters.

The writer once tried to destroy the young in a wheat field by spraying with kerosene emulsion the small areas of whitening grain that indicated where the pests were massed in greatest abundance. The result was unsatisfactory, and it is very doubtful if it is possible to apply this measure with any degree of success, and we are forced to the conclusion that, for the present at least, we shall be obliged to rely upon the measures previously given. It therefore becomes of the utmost importance to clean up the roadsides, and along fences and patches of woodland, as well as any other places likely to afford protection for the hibernating chinch bugs. There are of course obstacles in the way of carrying out this plan generally over any large area of country, and especially in sections where the rail fence predominates. But as the country gets older it will be found that it is not chinch bugs alone that seek these places in which to pass the winter, but myriads of the other insect foes of the farmer as well, and that careful attention to the condition of roadsides, lanes, hedgerows, and waste places about the farms, during the season when insects seek out these places wherein to pass the winter, will pay well for the time expended in that direction. It may come about that some phase of the street-cleaning reform may invade the country, and it is certain that if such were to occur it would, in time, save the country enough to go far toward reducing the expense of securing good roads. In fact, the term "good roads" ought to include the proper care of the roadsides, as well as the grading and macadamizing of the roadbed itself.

There are at present so-called weed laws in many States, and, though more or less of a dead letter in most cases, these laws are steps in the proper direction. The time when insect pests will be looked upon in the eye of the law as so many public nuisances, and the harboring of them a corresponding crime, may be a long way off, but as it gradually draws nearer to us we shall come to learn that, after all, it is the rational view to take and will go far toward solving not only the chinch bug problem, but many others of a similar nature. So far as the chinch bug is concerned, when we burn over the waste lands and accumulated rubbish about our farms in autumn or winter, we are simply applying the same check that the dusky savage did when he lighted the prairie fires, though unwittingly and for an entirely different purpose. In the timothy meadows of the northeastern portion of the country, where, for lack of wings fitted for locomotion, the chinch bug does not so largely migrate to the waste lands in autumn, the problem is somewhat different, and it will require some careful experiments to determine the exact effects of burning over the meadow lands in winter, both on the hibernating chinch bugs and on the grass roots. There can be little doubt, however, that a rapid rotation of crops, so as not to allow the short-winged form to become thoroughly established in a meadow, and the burning over of waste places, thus destroying such rubbish and débris as will serve to offer hibernating places for the long-winged form, will go far toward settling the chinch bug problem in grass lands.

As previously stated, the chief drawback in putting preventive measures in force is in the difficulty of foretelling an invasion. In northeastern Ohio in 1897 hundreds of acres of timothy meadow were destroyed after the hay crop had been removed, but so late that the farmers did not suspect the true condition of their meadows until the spring of 1898, when the young grass failed to put forth and an examination revealed the fact that the roots had been killed, the abundance of chinch bugs pointing unerringly to the cause of the trouble, though in many cases a heavy crop of hay had been removed the previous year where now the ground was entirely bare. While in the case just cited a previous knowledge of the presence of chinch bugs in these meadows might not have enabled the owners to have saved them in the fall of 1897, yet the fall plowing of the land, possibly early enough to have sown the ground to fall wheat, would have buried the majority of the bugs so deeply in the soil as to have killed vast numbers of them and thus prevented their migrating to other lands in the spring of 1898. A rotation of crops that would have included grass for not to exceed two successive years, followed by wheat, would have amounted to precisely the same remedial measure as the one suggested.

A case in northeastern Ohio has come to the writer's notice where an infested timothy meadow was plowed late in the fall of 1897. Late in April of 1898 this ground was cultivated, rolled, and harrowed several times and most carefully and completely prepared for corn, which was planted, but with the result that a portion of the field was attacked and destroyed by chinch bugs, largely of the brachypterous or short-winged form. An examination about June 10 revealed the bugs in considerable numbers about the still remaining plants, but scattered over the field were more or less numerous clumps of timothy, in some cases apparently having been killed by the chinch bugs, while in others these were literally swarming about the dying but still green clumps of grass, thus showing that the former had either not been buried by the plowing and cultivation of the ground, or else the grass had not been thoroughly covered, and thus ladders had been left whereby they were enabled to climb to the surface.

SUMMARY OF REMEDIAL AND PREVENTIVE MEASURES.

In summing up the matter of remedial and preventive measures for the control of the chinch bug, it may be stated that the insects can be destroyed in their places of hibernation by the use of fire. They can, under favorable meteorological conditions, be destroyed in the fields, if present in sufficient abundance during the breeding season, by the use of the fungus *Sporotrichum globuliferum*, if promptly and carefully applied. They can be destroyed while in the act of migrating from one field to another by tarred barriers or deep furrows supplemented by post holes, and by being buried under the surface of the ground with the plow and harrow; or the latter method can be applied after the bugs have been massed upon plats of some kind of vegetation for which the bugs are known to have a special fondness, which decoys should be so arranged as to either attract the females and induce them to oviposit therein, or they should be arranged with the idea of intercepting an invasion from wheat fields into cornfields. When these decoys have been turned under with a plow and the surface immediately smoothed and packed by harrow and roller, the bugs will be destroyed. While in the cornfields they can be destroyed on the plants by the application of kerosene emulsion. Without vigilance and prompt action, however, only indifferent results are to be expected from any of these measures.

PROBABLE ORIGIN AND DIFFUSION OF THE CHINCH BUG.

For the farmer engaged in attempts to check the ravages of the insect in his fields the question of origin, or how it came to reach him, will at the time have little interest for him. It will suffice that it is present in overwhelming numbers, and what he will most desire will be to learn how to rid his premises of its most unwelcome presence in the most summary manner possible.

If, however, the farmer happens to be a thoughtful and observing man he will sometimes wonder how it is that, except in Virginia and the Carolinas, a person need not be very aged in order to remember a time when the chinch bug was an unknown factor in his profession, with a possible value far too small to merit consideration. If he happens to reside in northeastern Ohio or in some portions of New York, and has spent some time in Illinois, Iowa, Kansas, or Minnesota, he will probably marvel at the striking difference in appearance between many of the chinch bugs of his own locality and those found in any of the last-mentioned States, and will probably be able to satisfy himself of their identity only by the similarity of their vile odor. Again, he will probably be equally at a loss to understand why it is that his own timothy meadows are overrun by these pestiferous insects and destroyed, while in other localities, perhaps less than 100 miles away, similar meadows are left untouched, the injury there being confined to the wheat and corn fields.

If wondering leads to questioning, as it often does among the constantly increasing number of educated and up-to-date farmers, it will not satisfy him to receive an evasive or obscure reply to his query as to why such differences exist, for if he can not get a clear explanation he will want ideas, theories, or possibilities. He wants the best explanation possible to give until some one finds out a better one, realizing that had mankind been perfectly satisfied with the knowledge that a stroke of lightning would split a tree or destroy human life, and had stubbornly refused to listen to possibilities or to anything but facts, we would not now be able to understand and utilize electricity in the many ways that we do at the present time. Such men understand perfectly that the solution of most problems in natural science must of necessity commence with theories which must be patiently tested and adopted or rejected as the results demand, while the scientific man knows that the solution of one problem often opens up the way for the solution of another, the last not infrequently having an entirely different application from the first.

The science of applied entomology is growing rapidly and becoming both broader and deeper, and it is not enough simply to tell the husbandman what an insect is and how to kill it. He must have something along with that information to set his own mind to thinking, to work out problems or improve upon the solutions already given him, otherwise it is much like giving money to a professional beggar. If we can not give facts based upon demonstrations, then give the best explanation possible, even though it be a theory which is only expected to stand until some one does better. It is for the thoughtful, progressive farmer, as well as the student of geographical distribution, that this possible solution of the problem of the chinch bug has been prepared, and while the full practical value of the ideas advanced has yet to be demonstrated, this of itself can not be urged as sufficient grounds for not sending it forth for study and consideration.

Thanks to the careful observations of Professor Sajö, on the European species of chinch bug, *Blissus doriæ*, it is now for the first time possible to compare the habits of this species with our own.

INDICATIONS OF A PROBABLE DISTANT ORIGIN AND LATER DIFFUSION.

In the United States our chinch bug, *Blissus leucopterus*, has a number of peculiar characteristics, which, while having an economic interest, also point to a probable previous condition differing somewhat from the present, and not in all cases tending toward its present numerical strength. On the other hand, we find that it is now following some probably ancient habits which do not appear to be of any special benefit, but rather the reverse.

In the first place, over its area of greatest destruction, it appears to prefer level tracts of country where the damp conditions consequent upon frequent rainfalls remain the longest, and in the second place, the period of spring oviposition is for the most part included within that during which the spring rains of the United States usually occur—that is to say, throughout the great grain belt, east of the Rocky Mountains, April and May are not normally months of severe drought, and it is during these two months that the larger portion of the eggs are deposited. As in the reverse of this, however, the period of fall oviposition, August and September, is far more likely to be favored by a lack of precipitation. These conditions do not always obtain, and it is because of the fluctuations that the insect is able to reach its maximum in point of numbers.

Another factor which plays quite an important part in reducing the number of adults maturing during unfavorable seasons may be found in the almost universally gregarious habits of the young, thereby rendering the ravages of fungous diseases the more universal and fatal. In all of these peculiar characteristics as well as in some anatomical features, it would seem as if we had a series of guide posts, so to speak, which indicate more or less clearly the ancient home of the species, and at least throw some light on its origin and diffusion.

UNIQUE APPEARANCE AND GREGARIOUS HABIT.

Mr. E. A. Schwarz [a] some time ago called attention to "the unique appearance of the full-grown chinch bug, with its white wings and chalky-white pubescence," which, he declared, "forcibly indicates that the insect is either a psammophilous or a maritime species," and expressed the opinion that its geographical distribution fully bears out the theory that it belongs to the latter class. The same author states that the species has the habit of clustering about the roots of tufts of grass along the Atlantic coast, from Florida to Atlantic City, N. J., and Mr. W. H. Harrington [b] observed it to have the same habit along the seashore at Sydney, Cape Breton, in 1884. The late Dr.

[a] Insect Life, Vol. VII, p. 420.
[b] Can. Ent., Vol. XXVI, p. 218.

J. C. Neal, while at Stillwater, Okla., wrote me that he had observed the species to have the same habit in that Territory, miles from any human habitation. Dr. Asa Fitch[a] found them swarming amidst extensive prairies in Illinois, in 1854, while more recently Mr. C. L. Marlatt has witnessed the same phenomenon in Kansas.[b] In short, this gregarious habit seems to be most tenaciously adhered to wherever these insects are found in any numbers. When migrating from one field to another, after crossing a roadway or plowed field they will at once flock together on a few plants along the margin of the, to them, new field instead of scattering about, two or three to a plant. It may also be added that Mr. Koebele found the species in large numbers along the seashore not far from San Francisco, Cal., in the first, second, and third stages of development, on a species of grass growing along the coast.

It has not, so far as is known to the writer, been observed in similar places along the shores of the Great Lakes, though search has been made for it there, but it occurs in destructive abundance in timothy meadows inland in northern and northeastern Ohio 25 to 75 miles distant, most generally clustering about the roots of grass—which, by the way, is about the only vegetation attacked—as the species is described as doing along the seacoasts. It may also be stated that it seems to hibernate there precisely as observed by Mr. Marlatt in Kansas; Doctor Neal in Oklahoma; Mr. Schwarz in Virgina in the vicinity of Fortress Monroe, and as the earlier observations of Doctor Fitch in Illinois would imply. Thus we find this habit of clustering upon the plants attacked to be a constant one, and where the natural grass vegetation has not been displaced by farm crops, thus leaving the ground more or less bare during winter, the chinch bugs continue to hibernate there. With these two characteristic habits generally followed over the great area inhabited by the species in North America, we may add a third possible factor in the problem of origin and diffusion of the species which, though an anatomical dimorphism, may be discussed as likely to throw considerable light upon the probable ancient habitat of the insect.

OCCURRENCE OF THE LONG AND SHORT WINGED FORMS AND THEIR DISTRIBUTION.

The occurrence of both the long and short winged forms, intermixed along our seacoasts and in the northeastern section of the country, but not elsewhere, shows very plainly that this dimorphism is not due to the temperature of any particular locality, but must be regarded as having been brought about by disuse of the wings

[a] Second Report, Insects of New York, p. 283.

[b] Insect Life, Vol. VII, pp. 232–234.

for a considerable period of time, thus indicating a seashore habit on the one side, while the total lack of the short-winged form elsewhere indicated otherwise.

In a paper presented before the Entomological Society of Washington,[a] "On the insects found on *Uniola paniculata* in southeastern Florida," by Mr. E. A. Schwarz, the author stated that *Blissus leucopterus* occurred in large numbers on the upper part of the plant, the imagos and larger young among the ears and the smaller individuals between the upper blades. Mr. Schwarz attributes this habit to the tough woody nature of the storm-beaten plant nearer the ground, thereby driving the insects to the more tender though more exposed portion of the plant. In connection with this statement the writer tells us that the insect occurs in that southern latitude only in the short-winged form, and that in the examination of thousands of specimens from that region he had never found a single long-winged specimen. Under date of May 4, 1896, Mr. W. H. Harrington wrote of this species as follows: "In September, 1890, I found it at Aulac, almost on the border between New Brunswick and Nova Scotia. It seemed not uncommon and occurred under stones, about the roots of grass, in a pasture adjoining the marsh where I found *Diabrotica longicornis*, the pasture being on the upland skirting the marsh. Both the long and short winged condition occurred, as in Cape Breton."[b] Dr. A. S. Packard communicated to Dr. J. A. Lintner the following extract from his diary: "June 17, 1871, at Salem, Mass., chinch bugs with wing covers extending over the basal third of the abdomen, seen in copula, end to end.[c] In the serious outbreak of this insect in the timothy meadows of northern New York, in 1882 and 1883, about 20 per cent of the bugs were of this short-winged form."[d]

Although Dr. Asa Fitch, as early as 1855, refers to this form along with nine others, he does not give the source from which he obtained specimens, but just previous to this he says (p. 287) that he had met with but three specimens from his own State, and these were found on willow in the spring of 1847.[e] Had any of these been of the short-winged form he would have been very likely to have mentioned the fact. Mr. E. P. Van Duzee[f] states that he had known of the occurrence of the species in western New York as early as 1874, and had also found it at Ridgeway and Muskoka, Ontario. Ordinarily the short-winged form predominates, but in hot, dry summers the chinch

[a] Proc. Ent. Soc. Washington, Vol. I, p. 104. Read Nov. 3, 1887.

[b] Canadian Entomologist, Vol. XIV, p. 218.

[c] Lintner's Second Report, State Entomologist of New York, p. 164.

[d] Second Report, State Entomologist of New York, p. 156.

[e] Second Report on Noxious Insects of New York, p. 291.

[f] Canadian Entomologist, Vol. XVII, pp. 209–210, 1886.

bugs mostly acquire fully developed wings. He had never found the species in grain fields of any sort, but always in grass lands, generally in timothy or clover, but sometimes in wild grasses. Of eleven specimens collected from under the bark of an old log by Mr. J. Pettit, of Grimsby, Ontario, in 1866, and sent to Mr. B. D. Walsh for determination, all were of the short-winged form.[a] It was these specimens that doubtless led Doctor Riley[b] to call attention to the fact that in Europe there are many genera of half-winged bugs which occur in two distinct or "dimorphous" forms with no intermediate grades between the two, viz, a short-winged or sometimes a completely wingless type and a long-winged type. Frequently the two occur together and copulate promiscuously, while sometimes the long-winged type occurs in particular seasons, especially in very hot seasons, while more rarely the short-winged type occurs in a different locality from the long-winged type, and usually in that case in a more northern locality. In northeastern Ohio the species occurs during some years in great abundance and very largely at least on timothy. Here the short-winged form is very largely in the majority, and in the spring of 1897, of 1,900 specimens collected indiscriminately, only about 400 were of the long-winged type.

In northern Indiana, where the insect occurs but rarely, this short-winged type does not predominate; but aside from these two localities, with an acquaintance with this species running over forty years, chiefly in Indiana and Illinois, the writer has never met with the short-winged type among millions of adults. If this short-winged type occurs elsewhere to the westward, except along the Pacific coast, where both forms have been collected by Koebele and others, it has not been found by entomologists, even to the northward as far as Minnesota, Winnipeg, and Manitoba, while to the eastward of this Mr. Van Duzee collected the brachypterous form on Muskoka River, Ontario, near the lake of that name.[c] On comparing specimens from New York with a large series from Kansas, the former were found to be quite uniformly more robust, with longer hairs on the pronotum.[d]

It would seem that here we have evidence of two distinct tides of migration, the one sweeping north and eastward, while the other has mainly been to the north and westward, meeting the former in northeastern Ohio and northern Indiana, and possibly somewhere farther to the north in British America. The two, besides differing in the length of the wings, are sufficiently unlike in appearance to attract the attention of students of Hemiptera.

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[a] Practical Entomologist, Vol. II, p. 23.

[b] Second Report on the Insects of Missouri, p. 22, 1870.

[c] Can. Ent., Vol. XXI, p. 3, 1889.

[d] Loc. cit., Vol. XVIII, p. 209.

RELATION OF THE INLAND AND SEACOAST SHORT-WINGED FORMS.

It is possible that the short-winged form of chinch bug found in Ohio is precisely the same form as that found along the seacoasts, but it seems to the writer that the inland form originating from this maritime short-winged element, instead of acquiring wings of normal length as it drifted away from the coast, has really moved in the other direction, and the wings have become still further aborted.

It will be observed by the illustrations given of both the inland and maritime short-winged forms (see figs. 3 and 4) that in some of the former the wings have become so aborted as to become almost invisible, while in the latter, though the wings are very much shortened, they are nevertheless very clearly to be observed. It would seem, then, that we might reasonably presume that the species was originally long-winged, but, living along the seashore, the winged individuals have either flown each year inland or else been blown into the sea to such an extent that a short-winged form has thus been evolved which was unable to migrate and not easily blown into the sea. In pushing inland while the country was still inhabited by the aborigines another source of destruction would confront these insects in the annual recurrence of fires whereby vast areas of country were burned over in autumn, winter, or early spring, and these must have destroyed very many of the hibernating insects, while such individuals as migrated to sections not so burned over would escape destruction.

PROBABLE COURSE OF DIFFUSION.

Let us suppose that the species originally worked its way northward from South America, or even Panama, along the lowlands between the more mountainous interior and the Gulf of Mexico until it reached Texas with its vast areas of level country extending not only across the State itself, but northward into British America, and, generally speaking, with the exception of the Ozark Mountains in Missouri and Arkansas, eastward to the Appalachian system extending from Cape Gaspé, Quebec, Canada, to northern Alabama. This area is more or less covered with a grass flora that affords ample food for these insects, and it would seem that there was here offered every incentive to migration broadly to the northward and eastward, and at the same time there would be the Gulf coast along which those individuals which either could not or did not migrate inland could make their way as had their progenitors along the coast in Mexico. (See fig. 17.)

Now, it would appear as though the short-winged individuals, if there were any such, would remain along the coast, while the long-winged individuals would, at least more or less of them, migrate inland, and at least some of these, but far more of those unable to fly,

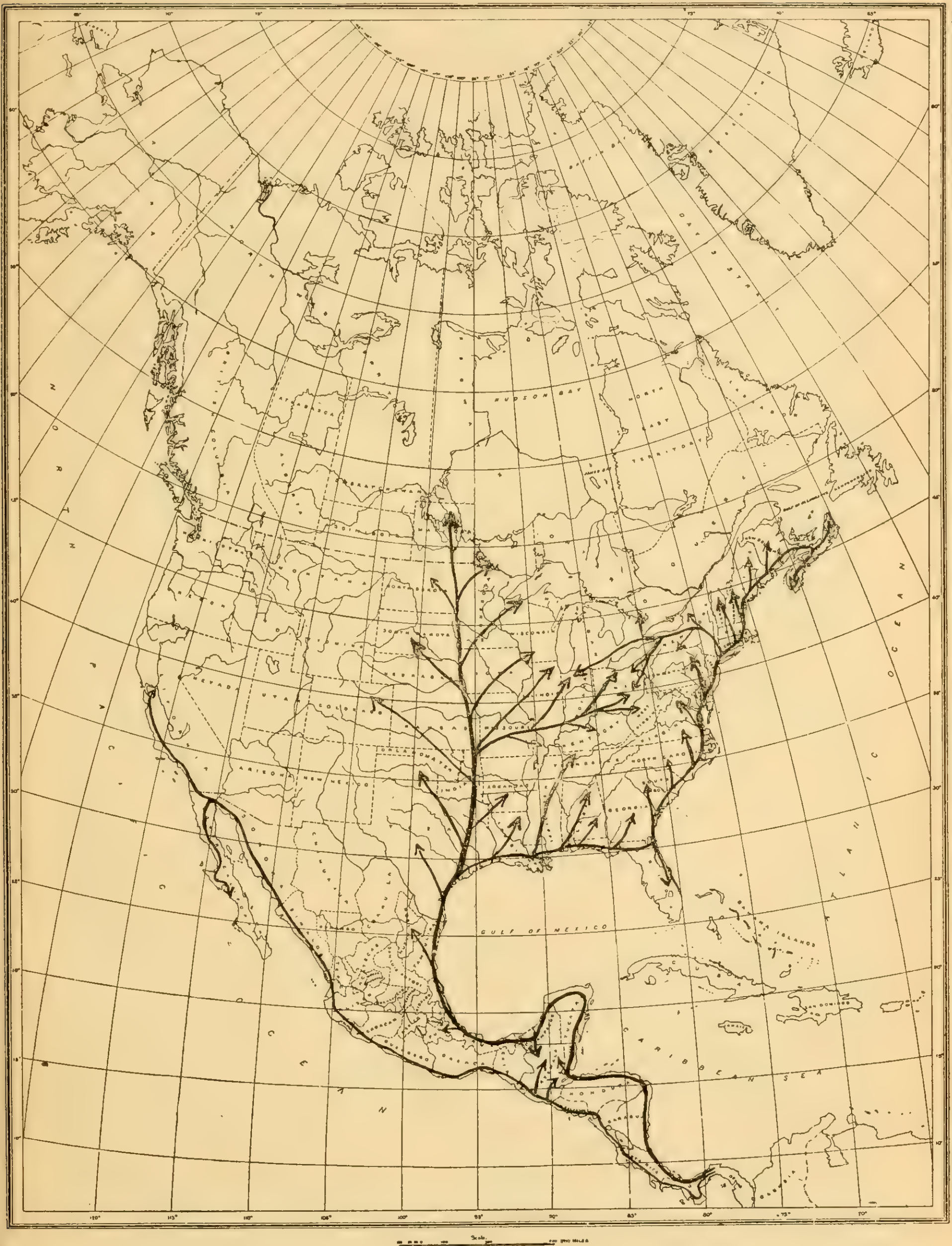

FIG. 17.—Map showing probable course of diffusion of chinch bug over North America. (Author's illustration.)

would be annually destroyed by the prairie fires, thus eliminating whatever tendency there might be to perpetuate the brachypterous forms, and develop a fully winged more or less nomadic race which, as it slowly advanced inland, lost all vestige of its brachypterous ancestry, if such had existed.[a]

On the other hand, we might expect the shore-inhabiting individuals to continue in their progress along the coast, the winged individuals continually migrating inland, leaving a mixture of the two forms to push forward to the east coast of Florida—where as late as 1906 it attacked grass on lawns about Palm Beach—and northward along the Atlantic to Cape Breton. As soon as this migration had passed the southern terminus of the Allegheny Mountains the inland spread would, very largely at least, be restricted to the area lying between the eastern slope of these mountains and the coast, thus leaving the whole area to the west to be occupied by the northward tide of migration instead of that from the east. East of the Mississippi River and south of the Ohio River the country is more heavily timbered and the prairies are lacking, so that forest fires would here take the place of prairie fires; but in the Southern States the woods are composed more largely of pine, and Doctor Lugger, in Minnesota, found that the chinch bug did not invade the region on which only pine and other Coniferæ grew, but that the more southern counties of his State, which are more or less wooded with deciduous trees, were invaded. He also called attention to the fact that before the country was settled by the whites these timbered lands were burned over frequently, probably annually, but now the wooded areas are confined to small tracts interspersed among the farms, and as these are not annually burned over they afford suitable shelters for the chinch bug during winter, and the grain fields of the farmer afford ample food during the summer, while on the prairies which are burned over such is not the case.[b]

Along the eastern coast the chinch bug has never been especially destructive to the wheat crop north of North Carolina, where, according to Doctor Fitch,[c] the earliest depredations occurred in 1783, while Webster[d] states that it threatened total destruction to the grain in 1785; but since that time the ravages have not been nearly as severe as farther west in the Mississippi River Valley. In 1899, 1900, 1901,

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[a] Prof. H. A. Morgan, then entomologist of the State Experiment Station of Louisiana, writing under date of May 30, 1898, states that he has never found the brachypterous form of chinch bug in that State, and the writer did not observe a single individual of these among the many macropterous specimens taken by himself in that State.

[b] First Annual Report of the Entomologist of the State Experiment Station of the University of Minnesota, 1895, p. 26.

[c] Second Report on Noxious, Beneficial, and other Insects of New York, p. 278.

[d] Webster on Pestilence, Vol. I, p. 279.

and 1902 this maritime form destroyed the timothy in the vicinity of Reidsville, N. C. This is on the southern border of timothy culture along the Atlantic coast, and some years ago an attempt was made to grow timothy in that section. The grass did very well until the above-mentioned attack occurred, and by 1905 there was but little remaining.[a] Strangely, too, nowhere along the Atlantic coast do we find the short-winged individuals far inland until we reach New York and the New England States, and what is equally perplexing they do not there attack grain, but grass, whereas to the southward, except near the sea-coast, it is the grain fields that are devastated by the long-winged form. In other words, throughout New England, New York, north-eastern Ohio, northern Indiana, and the Dominion of Canada we have both the long and short winged individuals occurring together, but depredating almost or quite exclusively upon timothy (*Phleum pratense*).

In Bulletin 17, old series, Division of Entomology, U. S. Department of Agriculture, Dr. L. O. Howard, the author, stated that in 1886 a timothy meadow located near Wakeman, Huron County, Ohio, was considerably injured by chinch bugs. Since that time the species has never been reported from that section of the State, and the writer has found that depredations of that particular character are only committed by the more or less brachypterous race. This has been supposed to be largely confined to the northeastern portion of the State, though there seems to be no good reason why it should not appear in northwestern Ohio also. Owing to these facts this single occurrence in meadows, recorded by Doctor Howard, formerly puzzled the writer greatly.

During the fall of 1898 there came reports of very serious destruction of meadows in Huron and Lorain counties, which lie contiguous to each other, the cause being attributed to the dry, hot weather. But an examination of the meteorological records for that section revealed the fact that there had been no weather condition sufficiently severe to affect timothy meadows in that way. A survey of the affected meadows during early spring of 1899 revealed the presence of great numbers of brachypterous chinch bugs hibernating in these meadows, and the problem was solved. The species had doubtless been doing more or less injury since 1886, entirely unknown to the farmer or any-one else, thus showing the extent to which its secluded life in meadows protects it from observation. This section of the State since 1886 has been more largely devoted to dairying, and the meadows are not as rapidly rotated with other crops as when the cereals were grown more extensively.

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[a] Extract from correspondence of Prof. Franklin Sherman, jr., State entomologist.

In Ohio, which appears to be the frontier of destructive abundance, the line separating the habitat of the combined forms and that of the macropterous form, exclusively, indistinctly marks the line of separation between the most serious depredations and almost total immunity of attack on timothy meadows by chinch bugs. To the west and south of this a short-winged adult chinch bug is rarely seen, timothy meadows are seldom attacked, and then only where fields of small grain or corn are not in easy reach; as, for illustration, where the insect happens to breed in a wheat field surrounded by timothy, and, when the grain is harvested, there is no other recourse left it but to attack the grass. In the opposite direction from our line, however, the conditions are quite the reverse. Here, while fields of wheat are occasionally badly injured, thousands of acres of timothy meadow have been entirely killed out from its attack.

The area of destructive infestation of timothy meadows seems to extend on the east in Ohio from Lake Erie to the Ohio River at the northernmost point of West Virginia, and on the west, in the vicinity of Sandusky, it extends only 25 or 30 miles from the lake shore. In limited numbers the area of distribution extends westward, probably narrowing gradually, around the lower end of Lake Michigan into northern Illinois, where it seems to be on the increase, though still far from common. As will be shown further on, this form is not likely to become destructive where timothy is grown in rotation with other farm crops.

So far as it is possible to determine, there are a considerable number of winged adults produced in this area every year—perhaps from 30 to 50 per cent some seasons—and these breed in the grain fields; but at wheat harvest, instead of migrating to the corn, as is done elsewhere, they go by preference to the timothy meadows. In western New York, where both the long and short winged forms occur, Mr. Van Duzee wrote that he had never found an individual of either form in grain fields, but that they both literally swarm in timothy during some years. Doctor Lintner told the writer that in the serious outbreak of this pest in the meadows of New York in 1882 and 1883 about 20 per cent were of the short-winged form. Doctor Perkins has recorded an attack of the chinch bug in a timothy meadow in northern Vermont. Whether or not the short-winged form was the depredator in this last-named locality the writer is unable to say, but, generally speaking, the short-winged form is unknown at any considerable distance from the coast, except in Maine, New York, Ohio, Ontario, and northern Indiana, and but rarely does it occur in either form in the two latter localities.

Just why this short-winged form should occur in such abundance in the three States named is a matter that the writer is at present unable fully to explain; but it does seem that this difference in food habits as between the two forms and the limited distribution of the short-winged form inland might open the way to a solution of the mystery. The writer believes that the insect is primarily a tropical macropterous species, and that it has followed the coast from South America along the Gulf and Atlantic northward to Cape Breton, and along the Pacific coast to San Francisco and possibly beyond; also that it spread from northern Mexico and Texas northward as far as Winnipeg, subsisting upon the native grasses, and in the meantime spreading also to the eastward to northern Indiana and Ohio.

On the other hand, from the Atlantic coast there has originated a tide of diffusion the trend of which has been westward, the bugs here partaking more of the nature of their seashore ancestors, more or less of them being of the short-winged form, which their less nomadic habit has served to further emphasize. This tide of diffusion has encountered what the western tide did not, at least until much later, namely, the timothy meadows of the Caucasian agriculturist, and, adapting itself to this food plant, has held closely to it, thus avoiding the necessity of seasonal migration. In northeastern Ohio and possibly in northern Indiana and northern Illinois the western tide of diffusion has met the eastbound tide and is perhaps amalgamating with it. (See map, fig. 17, illustrating supposed direction of diffusion of chinch bug.)

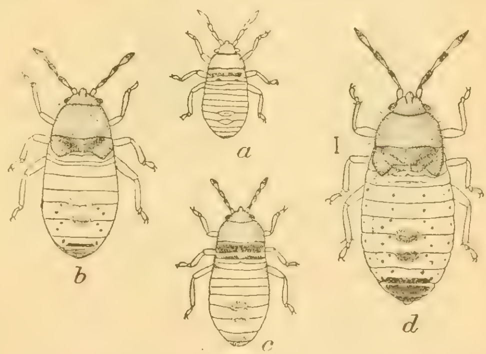

FIG. 18.—*Blissus doriæ*: *a*, first nymph; *c*, second; *b*, third; *d*, fourth. (From illustrations prepared in the Bureau of Entomology.)

Although not at all conclusive evidence, it might be added that the single specimen taken at Winnipeg by Doctor Fletcher was of the macropterous form, while the single example taken by Mr. Van Duzee at Muskoka, Canada, was of the brachypterous form; and this, with the fact that the specimens from the island of Grenada were of the former and the Florida coast specimens of the latter exclusively, shows that latitude and climate have no effect.

HABITS OF THE EUROPEAN SPECIES, BLISSUS DORÆ FERR.

Prompted apparently by a review of one of the writer's papers read before the eighth annual meeting of the Association of Economic Entomologists at Buffalo in 1896, Prof. Karl Sajö, formerly of the Kg. Ung. Staatliche Entomologische Versuchsstation, at Budapest, published a short paper on "*Unser Blissus doriæ*," [a] which is so full of

[a] Illustr. Wachenschrift für Entomologie, Vol. II, pp. 449–451, July 18, 1897.

interest that the writer has reproduced it here, together with figures of the larval, pupal, and adult stages of the insect (figs. 18 and 19).

Professor Sajö writes as follows:

In the article on the eighth annual meeting of the Association of Economic Entomologists (No. 26, pp. 401–403, Illustr. Wochenschrift für Entomologie) the very instructive observations of Mr. Webster on the "chinch bug" (*Blissus leucopterus*) in the State of Ohio were discussed.

In view of this communication I will give more in detail that which I have observed concerning our European species of this genus, namely *Blissus doriæ* Ferr.

Like the North American larger species, the smaller European one appears in two forms, namely, the wingless and the winged. The first describer of this species, Ferrari, in Genoa, recognized only the wingless form, which with its aborted wings looks very much like Hemipteron-nymphs, and probably by all entomologists who previously saw it was not considered as a sexually developed adult, but only the immature form of some already known species. I discovered the winged form seventeen years ago (1880) in the steppes sand desert, called "Nyires" of the Kis-Szent-Miklos, and described the same.[a]

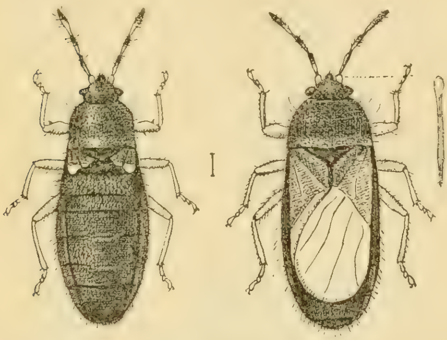

FIG. 19.—*Blissus doriæ:* Wingless form at left; winged form at right. (From illustration prepared in the Bureau of Entomology.)

I at that time made known the characters of the immature forms, which can not be confused with the individuals which have reached complete sexual development, in that the immature individuals are vermilion red while adult individuals are dark brown. It is interesting that the relationship between the winged (macropterous) and the wingless (brachypterous) individuals of the American and European species is very different. For while in America those individuals which reach maturity are almost always winged, with us in Europe they are in general only short-winged, and individuals capable of flight are not observed; and the fully developed macropterous individuals were not thus far, according to my knowledge, found in any other place than in the central Hungarian sand dunes already named, and here they occurred only on a single little portion which only measured a few paces in diameter. It was a "Dunenhugel" (sandy hill) covered with high, scattered poplars, whose fallen, dried foliage sparsely covered the ground.

Here lived the colonies of *Blissus doriæ* on the bases of the bushy, growing grass, almost under the surface of the ground, and well concealed. The habits of the European species are also in the main similar to those of its American relative, since the latter also lives only on grasses, and during its development also lives very close to the surface of the ground.

It is extremely remarkable that, even though *B. doriæ* is very widely distrib-

[a] K. Sajö: "Die bisher unbekannte makroptere Form von *Blissus doriæ* Ferr." Entomolog. Nachrichten, 1880, p. 235.

uted here, and is met with not only on the "Flugsande" (sand drifts), but also in the hilly regions (e. g., on the southern exposure of the hill which stands between Duka and Szod, in the midst of bluffs or rolling hills), the winged specimens were to be found only on the very small "Blissus Island" under the poplars. But here also they were found but rarely, and only then when the transformation from the pupa to adult stage was in full force. When there were no more pupæ to be found, then also the search for long-winged individuals was in vain.

This appearance I explain in this way: That the winged examples, as soon as they were able to fly, quickly flew away and disappeared in order that they might serve as progenitors for new colonies.

But the place of discovery has since been transformed into an immense vineyard by the Government, whereby grass, poplars, and also *B. doriæ* had to disappear from thence. For four years I have, though seeking with the greatest diligence, been unable to get track of the winged specimens anywhere in this region, even though I know of a number of colonies of this species upon my own premises. While formerly I captured a few specimens each year and gave them partly to museums and partly to entomologists, I scarcely hope to attain such interesting finds in the future.

The difference just mentioned between those individuals capable of flight and those not capable of flight in our species and also in the transatlantic species can hardly be accidental, but may be sought for in the influences of environment.

Next there crowds to the front the fact that in North America *B. leucopterus* is continually subjected to the attack of its deadly fungus parasite to a high degree, and its colonies die out as soon as rainy, moist atmosphere prevails. Consequently, the Blissus species living there must always hunt new habitats and be wandering continually to far distant localities. For this wings are of course necessary, and only by means of these is the species enabled to sustain itself at such a high grade of importance that it can, now here, now there, become a veritable plague to agriculture.

With our European species it seems, on the contrary, in regard to many points to be otherwise; for, while her habits in the main are similar to those of her sister across the sea, yet there are found many important differences in their environment.

Blissus doriæ never congregates in such close masses as we read of in the American reports. It forms only insect islands, and even individual families seem to scatter out to some distance. In the steppes, moreover, the growth of grass is not matted, but stands in isolated bunches on the partially bare ground, the bunches being not infrequently separated by several paces.

Our species will not go into cultivated fields. I have never found even a single specimen among forage plants that have been sown, and already this condition is one of the reasons why the European species does not cluster together in such uninterrupted masses.

If, then, this is true the attacks of entomogenous fungi will hardly be able to create such havoc in *B. doriæ* as it does among *B. leucopterus* in America.

I have also during eighteen years never observed a wholesale dying off in the localities of occurrence known to me. The fungus *S. globuliferum* has perhaps never attacked it, and even though the European form were susceptible to similar pestilences, yet it is always hardly to be doubted that the fungus in the European homes of *B. doriæ* would not find favorable circumstances in that here during the period of development of this species in normal years great drought prevails. Rains lasting for a number of days, with continued moist and warm atmosphere, belong, with us, among the rarities, especially during the summer, and it is the young stages that are especially sensitive to the fungus attack, as has proven to be the case in America.

Among insects there may possibly be found Blissus enemies, even though the extremely penetrating odor of this bug, which is identical with that of the one living in beds in houses, may serve as a protection.

Taking all of this together, we observe that our European species is in less danger than the American, and that it is not subjected to catastrophes of total destruction, so far as has yet been observable in the stationary localities of occurrence in the open field, for I have never yet observed a sudden disappearance from the localities known to me. It is not necessary, therefore, for it to be continually hunting up new fields in which to thrive, and there was no apparent reason which in the struggle for existence would have given preponderance to the long-winged form; and so in time, in the generation of our species, which originally, perhaps, was full winged, the winged form became less and less numerous, until to-day we see almost entirely brachypterous individuals in the adult stage, exactly the same as in the bedbug, *Acanthia lectularia*, with this difference, that among the swarming masses of the latter nowadays not a single example with fully developed wings can be found, fortunately for us.

It is evident that the long-winged tendency in *B. doriæ* is disappearing, and the time may come when one will be unable to find any long-winged specimens. The designated dangers, on the contrary, against which the chinch bug must fight in North America require very strong migratory powers, and, consequently, well-developed wings, through which this especially significant difference between *B. doriæ* and *B. leucopterus* has been brought about.

As to the question whether or not our species shall be considered injurious, I can answer that it in no wise belongs to the entirely indifferent insects, but, on the contrary, contributes to the complete drying up of the rather sparse grasses of our steppe meadows during the summer. But since it has not thus far housed in the cultivated fields, it can not be placed upon the black list of serious depredators. Whether, moreover, in the future, when in consequence of the continued destruction of its herding meadows, its original food plants disappear more and more, *B. doriæ* may become, like so many other insect species, a depredator through necessity can only be conjectured. We have in this regard already recorded entirely too many remarkable transformations in the menu of other species to disregard entirely the possibility of a similar transformation in the life habits of our *B. doriæ*.

I wish also at this time to state, for the benefit of our many readers who may not be familiar with it, that in the dimorphic bugs, especially those in which the macropterous and brachypterous forms are found simultaneously, the former possess a much stronger and broader thorax than the latter. As a result of this difference in their physical structure, one is, when comparing them for the first time, easily inclined to designate them as two distinct species.

In addition to this, there is in Blissus the strikingly beautiful coloration of the long-winged specimens, whose clavus and corium are light ocher-yellow, and the unusually large membrane, which is about twice as large as corium and clavus together and of an entirely milk-white color, making the long-winged individuals very prepossessing. The individuals with rudimentary wings, on the contrary, are of an obscure chocolate-brown. The larvæ are, as has already been stated, of a bright vermilion-red color, marked with black.[a]

With the foregoing, relative to the habits of an allied species of Blissus, it seems to the writer that we can the better understand how,

[a] Translated from the German by Mr. C. W. Mally.

under one set of conditions, all traces of a short-winged form might entirely disappear, while with another set of conditions this tendency might not only be perpetuated, but greatly emphasized. The two species, *B. leucopterus* and *B. doriæ*, are fully illustrated in all stages of development, as well as both macropterous and brachypterous forms. (See figs. on pp. 21, 22, 23, 83, 84.) For specimens of the latter species, *B. doriæ*, we are indebted to Professor Sajö.

PREVIOUS IDEAS ON THE DIFFUSION OF THE CHINCH BUG.

Formerly it was supposed that the chinch bug was a native of the Atlantic coast States, and that it made its way westward with the advance of civilization and the consequent progress of wheat growing. This theory was based upon the fact that the original description was drawn up from a specimen from the eastern shore of Virginia, collected by Mr. Say himself,[a] and, as before stated, the earliest destruction on record caused by this insect occurred in North Carolina, and it also committed great depredations in Virginia in 1839. Up to this time it had been supposed that it was a southern species, confined to the country south of latitude 40° north. But about this time chinch bugs appeared in Illinois, at Nauvoo, simultaneously with the settlement of the Mormons at that place, and as many supposed that this sect brought the bugs to the country with them, they were locally termed "Mormon lice."

In his second report, page 284, Doctor Fitch states that Mr. William Patten, of Sandwich, Dekalb County, Ill., informed him that the chinch bug first appeared in that locality in 1850. Mr. Patten, the father of Prof. Simon Patten, of the University of Pennsylvania, and the writer's father, settled in the immediate vicinity of Sandwich, Ill., in 1852. This was ten years after the Pottawattamie chief, Shabbona, and his tribe had migrated to Kansas or Nebraska, the writer does not remember which, but he does recall that it was about this time that the prairie fires ceased to occur over any wide areas, as the prairies were no longer fired annually by the Indians. The whole country was fast being occupied, and he well remembers that the settlers would decide upon a certain date on which they would set fire to the wild grass—in late autumn—so that all could be prepared. It may also be stated that there were very few timothy meadows at that time, as the wild grass afforded an abundance of hay, and not until years after did cultivated grasses come into general use. The writer also knows from personal experience and observation that with the decrease in prairie fires there came an increasing abundance of chinch bugs, which attacked the wheat fields of the farmer. Up to about 1862 these fields were largely of spring wheat, but about that time there

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[a] The complete writings of Thomas Say, edited by Le Conte, Vol. I, p.

was a rapid decline in the growing of this grain in northern Illinois. It seems possible that spring wheat might be more liable to attack from chinch bugs than fall wheat, as the former is, at the time when chinch bugs seek out their breeding grounds, more tender and inviting than the latter. Mr. Walter Young, writing from Galesville, Wis., states that his spring wheat was totally destroyed in 1897, though there had been none sown for ten years previous on the premises, and while the chinch bugs did not ordinarily do much injury, just as soon as spring wheat was sown they returned, as it were, and destroyed it.

If spring wheat is so attractive to chinch bugs in spring as this would indicate, might it not be used for baits instead of millet, as is advised further on, in order to draw off the females in spring when seeking localities for oviposition?

This was in a country where there was comparatively little timber, the only forests, if such they could be called, being along the streams of water. The writer is confident that the chinch bug did not suddenly make its appearance in that section, but that with the increase of grain growing and the decrease of prairie fires its effects began to be more and more marked. Since then Prof. S. A. Forbes has secured information of the occurrence of these insects in sufficient numbers to attract attention as early as 1823 in southern Illinois, and within 25 miles of New Harmony, Ind., where Thomas Say resided and did the most of his entomological work.

REASONS FOR THE PRESENT THEORY OF DIFFUSION.

It seems to the writer that in all of this we have good grounds for supposing that the chinch bug occupied the most of the country prior to its occupancy by the white man, and that its first depredations were caused by its own advance coming in contact with the advance of civilization; and the simultaneous cessation of forest and prairie fires, with the displacement of the native grasses by large areas of wheat, so combined that the points of contact were in Illinois in the West and Virginia and North Carolina in the East. Not until within the last twenty-four years has the chinch bug been known to work serious and widespread injury east of the Allegheny Mountains, north of Virginia; and west of these mountains they have done scarcely any damage north and east of a line drawn from Chicago southeast to Cincinnati. Thousands of farmers in Ohio never saw a chinch bug until within the last thirteen years, and there are thousands more in northwestern Ohio, southern Michigan, and northern Indiana that, even yet, would not be able to recognize one were they to see it among their growing grain, or even if in abundance. But in considering this matter the fact must be borne in mind that timothy meadows are not burned over annually as were the forests and prairies, and the stubble does not die with the harvesting of the crop as in wheat, and therefore annual migrations are not necessary for the bugs in order to preserve life. In a timothy meadow the species may live on and reproduce year after year without ever being obliged to abandon the field. It was the wheat fields of the West that the eastbound macropterous tide of migration found confronting it in Illinois, and the smaller fields of grain and timothy meadows that the combined macropterous and brachypterous forms, more or less maritime and northbound, came in contact with along the Atlantic coast, while at the present time the two tides of migration have met in northeastern Ohio and northern Indiana.

In figure 17 is illustrated the theoretical directions and courses taken by each of these tides of migrations from the tropical regions, and in figure 1 the areas over which the species is now known to occur in Central and North America are indicated.

The writer believes that this same course of migration has been pursued, at least in the West, by the several species of Diabrotica, and especially *D. longicornis* Say, and to a less extent by another species of Hemiptera, *Murgantia histrionica* Hahn and possibly also by *Dynastes tityus* L., while the two latter with others are now working northward along the Atlantic coast. Besides, the westward tide of migration has been followed in all probability by *Pontia rapæ* L., *Phytonomus punctatus* Fab., *Hylastinus obscurus* Marshm., and *Crioceris asparagi* L., all of which have first become destructively abundant west of the Allegheny Mountains in extreme northeastern Ohio. The last four species, having been introduced from Europe, have undoubtedly migrated westward.

With an almost total lack of natural enemies in the United States, and with nearly all of its closest allies belonging in Mexico and the West Indies, it would seem as though we were in possession of additional evidence of the chinch bug's tropical origin. Besides this the name "chinch bug" is of Spanish origin, and this language has never been in common use in North America except in Florida and the country along the Mexican border.

The species certainly prefers the low country to the higher, and is seldom found in any numbers at an altitude of over 2,000 feet. Generally its habitat is 1,000 or lower. The altitude where it was found breeding on Volcan de Chiriqui, in Panama, is 6,000 feet; and of its habitations in Guatemala, San Geronimo, is 3,000 feet; Panzos, 2,000 feet; Champerico, sea level, and Rio Naranjo, about 2,000 feet, while in Colorado it occurs sparingly near Fort Collins at an elevation of 5,500 to 6,000 feet, while Professor Cockerell did not find it at all in the same State at elevations of 7,000 to 8,000 feet. On Mount Washington, in New Hampshire, it has been found only once, and this time by Doctor Packard, on the summit, which has an elevation of 6,500 feet.[a]

In his own experience, running over something like forty-five years, the writer has never witnessed serious injury by chinch bugs to crops on hilly land. It may be stated, however, that all of his studies of the insect have been carried on in a level country, Ohio being the most uneven and hilly, but even here all of the outbreaks observed were on level areas. In Minnesota, however, Doctor Lugger found that those grain fields which were most seriously injured were located near the edges of woods or on slopes. In some published observations of Professor Osborn, in Iowa, kindly placed at the writer's disposal by Doctor Howard, we find that in 1894 about 90 per cent of the infested fields examined by Professor Osborn were on high ground and about 80 per cent of the fields were hilly and ridges, in most cases the damage being first apparent upon the higher portions of the fields. The exceptions were where the chinch bug had evidently hibernated in wild grass and weeds occurring in the lower places, and these had been very dry for the twelve months preceding the damage of that year. Besides, both the Iowa and Minnesota areas are below 1,000 feet elevation.

The area over which the chinch bug is more especially abundant and destructive comprises such a variety of soils and geological formations that a study of these factors at once shows that neither has any material influence in the distribution of the species, at least in the United States. In its northernmost habitat it would not be at all surprising that it should prefer a sandy, rather than a clay, soil, the former being looser and warmer on or near the surface. (See fig. 10.)

In conclusion, then, on this point it may be stated that if *Blissus leucopterus* originated in the Western Hemisphere it was probably near the Tropics, and it is not impossible that its generic ancestors may have been carried from Europe or Africa by either the north equatorial or the main equatorial Atlantic currents, landing them on the northern shores of South America or on some closely located islands, from which the species has spread coastwise around the Caribbean Sea and the Gulf of Mexico, as previously indicated. In this connection it is interesting to note that specimens from Grenada, collected on the Mount Joy and Caliveny estates by Mr. H. H. Smith in June and September, show that the species here attains a large size and is more variable, both in size and markings, than is commonly found to be the case in the eastern United States.[b]

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[a] See paper by the writer on Origin and Diffusion of *Blissus leucopterus* and *Murgantia histrionica*, in Journal of Cincinnati Society of Natural History, Vol. XVIII, February, 1896.

[b] Uhler on Hemiptera-Heteroptera from St. Vincent and Grenada. Proc. Zool. Soc., London, 1894.

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 70.

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

REPORT OF THE MEETING

OF

INSPECTORS OF APIARIES,

SAN ANTONIO, TEX., NOVEMBER 12, 1906.

Issued June 17, 1907.

WASHINGTON:
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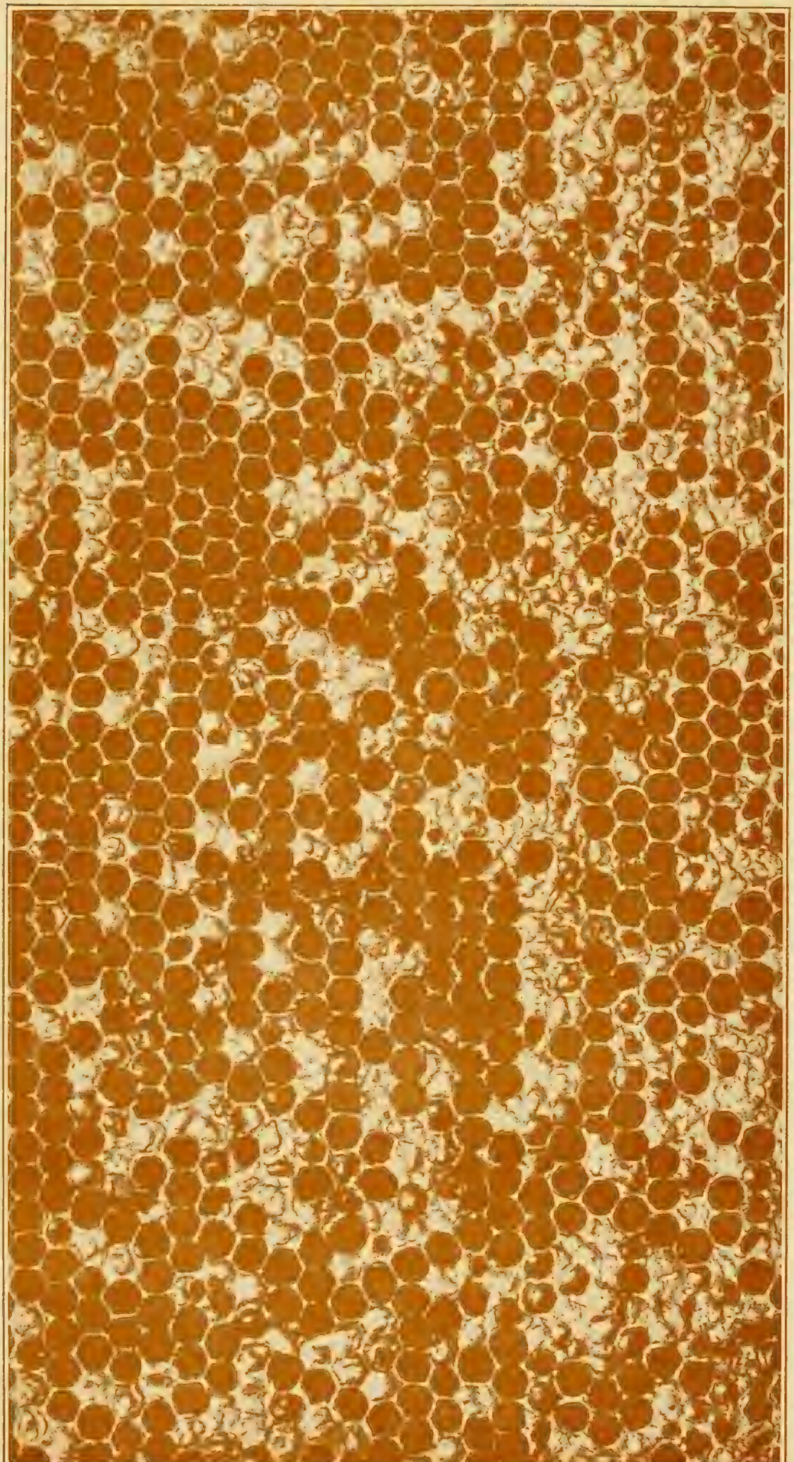

PORTION OF COMB FROM COLONY INFECTED WITH AMERICAN FOUL BROOD.

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JESSIE E. MARKS, *apicultural clerk.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., March 18, 1907.

Sir: I have the honor to transmit the manuscript of the proceedings of a meeting of inspectors of apiaries held in San Antonio, Tex., November 12, 1906. The meeting together and conference of the persons interested in the eradication of the diseases which are such a drawback to apiculture can not fail to bring out many points of importance. In such a meeting the subject is presented in a way which is not possible in articles written for journals devoted to bee keeping or for publication in other forms. There is no organization of inspectors and no funds are available by which these proceedings may be published, and since this meeting was to a large extent the result of the efforts of members of the Bureau of Entomology, and since these men took such an active part in the meeting, it would seem fitting that the proceedings be issued as a publication of the Department of Agriculture. I therefore recommend that this manuscript be published as Bulletin No. 70 of this Bureau.

Respectfully,

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

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The meeting of inspectors of apiaries was held on the Monday following the close of the National Bee Keepers' Association convention, November 12, 1906, at San Antonio, Tex., as a result of a call issued by Mr. N. E. France, inspector of apiaries for Wisconsin, Mr. W. Z. Hutchinson, inspector of apiaries for Michigan, and the writer.

The object of this meeting was to get together for consultation the men interested in the eradication and control of bee diseases. The closer cooperation of these men in their work can result only in good to apiculture and is greatly to be desired. Inspectors are chosen from among the practical bee men of the county or State, and the majority of them are familiar with their work on entering the service. They also accumulate a vast amount of information concerning diseases, most of which never reaches the bee journals or gains publicity in any way. A meeting of these men brings out many points which would otherwise remain unknown.

The meeting at San Antonio was most interesting and valuable, and since much that was said there has never been published it seems desirable to issue the proceedings of the meeting in the form of a bulletin to add to the knowledge of the bee-keeping public on bee diseases.

At the close of the meeting the writer was asked by the inspectors present to prepare a list of questions based on the laws now in force for the control of bee diseases. This list was prepared at once and a copy sent to each of the inspectors whose name and address could be obtained. At the same time the questions were taken up for detailed examination, and various persons were consulted on points of importance which arise. This work is not yet complete, for it has assumed proportions which were entirely unexpected at the beginning. It was originally intended that this discussion of the laws should be inserted as an appendix to the present report, but this would only delay the present publication. This aspect of the subject may therefore be submitted for future publication as soon as it can be prepared. It is very important that the best possible wording be used in a law to control bee diseases. The bee keepers of several States which do not have such laws are at present interested in this subject.

In the preparation of the manuscript for publication it was necessary to rewrite the articles by Doctor White and the present writer because the manner of presentation of these subjects in a meeting is not suited for publication. It was also necessary to edit the discussions, for the stenographic report was inaccurate in numerous places. It is believed, however, that even if the exact words of each person are not recorded, the meaning is the same as was intended to be conveyed. In certain places it has seemed desirable to enlarge somewhat on certain things which were said by the writer. This bulletin therefore can not be called a verbatim report, but it represents nevertheless the proceedings of the meeting.

It is hoped that similar meetings may be held in the future.

E. F. Phillips,
In charge of Apiculture.

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REPORT OF THE MEETING OF INSPECTORS OF APIARIES, SAN ANTONIO, TEX., NOVEMBER 12, 1906.

The meeting was called to order in Market Hall at 9.30 a. m. by Dr. E. F. Phillips, of the Bureau of Entomology, Department of Agriculture, Washington, D. C., who addressed the members as follows:

LADIES AND GENTLEMEN: Last summer it was my pleasure and privilege to visit a considerable number of the men at work on bee-disease inspection throughout the United States. After talking with them and going with them on inspection trips, it became evident that there is a great deal yet to be done in regard to the making of better methods of inspection in work against bee diseases, entirely apart from the scientific aspect of the subject.

On the 3d of last August Mr. N. E. France, inspector of apiaries for Wisconsin, who is attending this meeting, and Mr. W. Z. Hutchinson, the inspector of apiaries for Michigan, and myself met in Milwaukee, Wis., to talk over certain plans for making bee-disease inspection more effective. A circular letter, addressed to the persons now acting as inspectors in the various counties and States of the United States, was drawn up, suggesting that they meet in some place this fall to take up the work of bringing about more uniformity in the methods employed. The meeting of to-day is the result of that circular letter.

There are several things in work against bee diseases that are not at all clear to the bee-disease inspectors and others interested in the subject, and we wish to take some of them up for discussion to-day. We have with us Dr. G. F. White, of the Bureau of Animal Industry, U. S. Department of Agriculture, Washington, D. C., who has made a most thorough scientific study of the cause of bee diseases, and we shall first ask him to give his demonstrations and the result of his work. After he finishes I shall myself attempt to summarize the investigations of bee diseases which have previously been made by different men. It is perhaps well to take up the scientific aspect of this work first in order to make this clear, and later we shall take up the methods of inspection and treatment and the form of desirable laws controlling bee diseases.

It would perhaps be well for the inspectors of apiaries in the United States to be organized in some way so that there might be greater uniformity in the work and more harmonious cooperation. In Buffalo several years ago such an association was organized. At that time Mr. France, Mr. Hutchinson, and several others met together and organized an association of bee inspectors of the United States and Canada, but they had only an organization meeting and have never met since. Such an organization is desirable, but perhaps not all of those that would care to take part in the association are present.

Doctor White will now give us a demonstration on the brood diseases of bees, a subject on which he has made exhaustive studies.

THE BACTERIOLOGY OF BEE DISEASES.[a]

By G. F. White, Ph. D.,
Of the U. S. Department of Agriculture.

The object of this paper is to discuss briefly the science of bacteriology as it is used in the study of bee diseases and to give a summary of the results of my work on these diseased conditions.

In our discussion of bacteriology, or the science which deals with bacteria, it may be well to consider the subject under the following headings: (1) The nature of bacteria; (2) their distribution; (3) the methods for studying them, and (4) the results of their activity.

THE NATURE OF BACTERIA.

Bacteria are considered by some scientists to be a form of life lower than either animals or plants, but by the majority of authors they are looked upon as plants, and we shall so consider them at this time without going into a detailed discussion of the arguments in favor of such a view. Bacteria, often referred to as germs, microbes, or parasites, are, then, very small plants, so small indeed that they must be magnified 600 diameters or more before they can be seen.

[a] At the meeting of the inspectors of apiaries Doctor White gave a demonstration of the work which he has done on the brood diseases of bees, showing, in illustration of his address, slides and cultures of the various bacteria under consideration. In view of this fact the stenographic report of his address is not clear on all points, since the demonstrations are lacking. It has, therefore, seemed best for Doctor White to write the article here published, giving a popular discussion of this phase of the work which would be intelligible without the demonstration. The substance of his remarks is all included in this paper except the part pertaining to the work of other bacteriologists, which is dwelt on at some length in the article herein published on "The Present Status of Bee Disease Investigation." This method of handling the subject in a published report will make the subject much clearer to those who did not attend the meeting at San Antonio.—E. F. P.

These plants, then, constitute an invisible flora, which we can see only by the use of a microscope of very high magnifying power. The morphology, or the structure, including form and size, is principally of two types, rod-shaped or cylindrical and round or spherical. The size of bacteria varies. Those which are rod-shaped usually measure from 1 to 3–6 microns in length and from one-half to 1 micron in diameter. A micron is the unit of measure for very small objects and is equivalent to $\frac{1}{25000}$ of an inch. For example, if a single bacterium of the rod form measures 2 microns, it would take 12,500 placed end to end to measure 1 inch in length. The spherical bacteria or cocci have about the same diameter as the rod-shaped ones.

Bacteria grow or multiply after a manner called fission; that is, after increasing in size they become constricted in the middle, which constriction finally severs the rod completely, and we then have two bacteria where there was but one before. Under favorable conditions for growth, each bacterium divides by fission every twenty minutes, or, in other words, gives rise to three generations in one hour. Such being their marvelous rate of increase, a little calculation will demonstrate that countless millions may be formed in a short time under favorable conditions, which are proper temperature, moisture, food in correct proportions, and the absence of much light. The temperature most favorable for the growth of a species of bacteria which is able to produce a diseased condition in animals is approximately the temperature of the animal which is affected by such species. Moisture is universally necessary. The food must not be too concentrated. Light inhibits the growth of bacteria. Direct sunlight is bactericidal; that is, it kills bacteria.

Many species produce spores when the conditions are not favorable for the multiplication of bacteria. These are small bodies formed in the bacteria (probably never more than one in a single bacterium) which are somewhat comparable to the grain in wheat and corn. These spores constitute a resting stage and usually also a very resistant stage, for high temperature and strong disinfectant solutions are necessary to kill them. It is these spores which probably make the control of the bee diseases more difficult. When the spores again gain access to a suitable "soil," for example, the body of an animal, they germinate and a new growth takes place as before.

Many species of bacteria have the power to move when they are in a liquid medium, while others do not. This ability to move is due to long, slender processes, which we call flagella, extending from the body of the bacterium.

THE DISTRIBUTION OF BACTERIA.

Bacteria are very widely distributed. Everyone is familiar with the very wide distribution of the higher members of the plant kingdom, as the trees, shrubs, flowers, and grasses, and we may for convenience refer to these plants as the visible flora. There is also an invisible flora, made up of the plants we can not see except with the aid of the miscrope. This flora includes the very minute plants referred to as bacteria, and also the yeasts and some fungi. The distinct species of plants which belong to the invisible flora outnumber by far those which are visible to the naked eye. These microscopic plants are found upon the surface of the animal body and along the digestive tract; they are found in the soil, in the food we eat, and in the water and milk we drink, but are not found within the normal tissues of animals and higher plants.

HOW BACTERIA ARE STUDIED.

The morphology or structure of bacteria is studied with the aid of a microscope of high magnification. Since the number of distinct species of bacteria is so extremely large, and since the shapes assumed by them are so few, it is obvious that many different kinds must look alike under the microscope. This is a point of considerable value in connection with bee-disease work, since in some cases attempts have been made by the use of the microscope alone to determine what species of bacteria was causing certain diseased conditions. With our present knowledge it is not possible to make a positive diagnosis of these diseases with the microscope alone. With the microscope we are able to determine usually only the genus to which any bacterium belongs. If we are trying to identify *Bacillus alvei*, for example, we are able with the microscope alone to say only that it is a Bacillus, since it is seen to be a straight rod. Some other means is necessary to determine the species (*alvei*) to which it belongs. For this purpose we use artificial media or "soils" in which pure cultures of the bacteria are inoculated or planted.

The media in common use are bouillon and sugar-free bouillon. gelatin, agar, and sugar-free bouillon to which has been added small amounts of various sugars known in chemistry as glucose, lactose, saccharose, maltose, and levulose. In addition to these media, use is made of potato, milk, and milk to which litmus has been added, so that the reaction—whether acid, alkaline, or neutral—may be noted. The bouillon is prepared from beef juice to which some peptone and salt are added. Sugar-free bouillon is similar, except that the muscle sugar has been removed. Gelatin is made from pure sheets of gelatin somewhat similar to that used in cooking, to which bouillon is added. The bouillon affords the food for the bacteria or other small plants, while the gelatin keeps the medium solid at ordinary temperatures. Agar-agar (or simply agar) is the dried stem of a certain seaweed which liquefies on heating; to this is added bouillon, as in the case of gelatin, which solution congeals, as does gelatin, on cooling. The milk used is cow's milk with the butter-fat removed. Before using, all these media are sterilized by heat to kill all bacteria or fungi which might be present.

Having prepared these soils in this way, before the inoculation of them the bacteria must be obtained in pure culture. By pure culture is meant the growth of one species only in a medium. Such a culture is obtained by diluting a small quantity of the material, e. g., decayed larvæ, containing the bacteria with a relatively large amount of liquefied agar, and then pouring it into a shallow sterile glass box (Petri dish). In this way we get only a few bacteria scattered throughout a thin layer of the medium. Each bacterium then begins to grow, and after a few hours it has produced a large number, which, being massed together, we are able to see with the naked eye. This mass of bacteria, having been produced from one individual, constitutes a colony, and such a colony can contain but one species, therefore we speak of it as pure. Pure cultures are then made by inoculations from such a colony. The next step is to identfy this species which we now have isolated from all other species. To do this we inoculate a few or all of the differential media mentioned above. After inoculating and growing the bacteria in these different media or soils at about the body temperature for a day or longer we observe the effect upon the various media produced by the growth of the bacteria and the appearance of the growth in or upon these media. All these phenomena and appearances we speak of as cultural characters. Having obtained in this way the cultural characters of a species of bacteria, we are able to classify it by comparing these cultural characters with the cultural characters of known species.

To illustrate this, let us take for example *Bacillus coli communis*, found normally in the intestine of man and many animals, including the intestine of the adult bee, *Bacillus alvei*, found in European foul brood, and *Bacillus larvæ*, found in American foul brood. *Bacillus coli communis* by its growth in bouillon causes the latter to become heavily clouded; *Bacillus alvei* makes it feebly clouded; while *Bacillus larvæ* does not grow at all in this soil and the bouillon remains clear. In gelatin *Bacillus coli communis* grows very well and does not liquefy the medium by its growth; *Bacillus alvei* grows very slowly and only feebly and liquefies the gelatin; while *Bacillus larvæ* does not grow at all in this medium. When *Bacillus coli communis* is planted on potato it produces a brownish growth; *Bacillus alvei* on this medium produces a lemon-yellow growth, and *Bacillus larvæ* fails to show any growth. When *Bacillus coli communis* is planted in milk there follows a rapid souring of the milk and a firm coagulation of the casein; *Bacillus alvei* produces a soft coagulum which is followed by a slow digestion or liquefaction of the casein; *Bacillus larvæ* does not grow in milk. In litmus milk, *Bacillus coli communis* produces a large amount of acid, which is indicated by the change of the litmus to the red color; *Bacillus alvei* produces no marked change in reaction, and *Bacillus larvæ* does not grow in this medium. In the bouillons to which the sugars, glucose, lactose, saccharose, etc., have been added, there is produced by the growth of *Bacillus coli communis*, gas, and a large amount of acid; *Bacillus alvei* does not produce gas and only a small amount of acid by its growth in the media containing sugars, while *Bacillus larvæ* does not grow when planted in these "soils." (I shall speak later of a medium upon which *Bacillus larvæ* will grow.)

It is by these differences which we observe in the growth upon the various media and the effect produced upon the different media by the growth of the bacteria that we are able to determine one species of bacteria from another.

THE RESULTS OF THE ACTIVITY OF BACTERIA.

In the consideration of this question it is convenient to divide the bacterial flora into two groups—nonpathogenic, or those which do not produce disease, and pathogenic, or those which do produce disease. Some of the nonpathogenic bacteria are economically very important as scavengers. The bodies of dead animals and plants are largely brought to decay by them. The flavors of butter, cheese, and wines are thought to be improved by the growth of bacteria or other micro-organisms—the fungi and the yeasts. Others of these micro-organisms ruin the food, causing the souring of milk, the spoiling of fruit, etc. Many diseases in man and animals are known to be caused by bacteria, as tuberculosis, diphtheria, glanders, and anthrax.

I wish now to speak briefly of how bacteriology has been used in the study of bee diseases, and to summarize the results which have been obtained. For a more detailed account you are referred to a bulletin issued by the Bureau of Entomology of the United States Department of Agriculture—Technical Series, No. 14, "The Bacteria of the Apiary, with Special Reference to Bee Diseases," issued November 6, 1906.

From what has been said one would naturally infer that in every apiary, whether diseased or not, there are on the hives, combs, and bees a large number of bacteria that are perfectly harmless. If one is trying to find in a diseased apiary the species of bacteria which is the probable cause of the trouble, what is the method of procedure? Suppose there were two herds of cattle on adjoining farms and the cattle on one farm were dying while those on the other remained well. If it were suspected that some plant which the cattle were eating was the cause of death, naturally the plant would be selected which was found on the farm where the animals were sick and which was not found on the farm where the animals remained well. This is exactly the kind of reasoning used when we are looking for the bacteria which are causing the diseases among bees. This necessitates, as you see, the study of all the bacteria which are present in any apiary, whether diseased or not, as well as those in diseased apiaries.

At the time we began the work on bee diseases, in June, 1902, the disorders which were causing the greatest trouble were known to bee keepers as black brood, foul brood, pickle brood, and paralysis. After the study of a large number of samples of brood affected by disease which was being called black brood and the finding of *Bacillus alvei* in all of them, it is very clear that this disease is the same as that investigated by Cheyne in 1885 and called by him "foul brood;" he first described *Bacillus alvei*. "Black brood" was a name given by Dr. William R. Howard, of Fort Worth, Tex., to a disease which he thought existed in New York State, and he described as its cause *Bacillus milii*. After a careful search in New York State for a disease containing *Bacillus milii* we were unable to find it, and there seems to be no ground for the description of a new disease. What has been called black brood by Doctor Howard is obviously the type of foul brood which we now distinguish as European foul brood.

In the decaying larvæ and dried scales found in the cells in the disease which was receiving the name of foul brood there were seen by the use of the microscope a very large number of the spores of bacteria, and in the larvæ in the early stage of the disease there were observed bacteria in the rod form. When these spores were planted upon the media or soils which have been explained earlier in this paper, they would not grow. It became necessary, then, to devise a soil in which the growth could be obtained. After a number of unsuccessful attempts, a medium or soil was made from healthy bee larvæ in which the spores would germinate and the bacteria would grow. By a study of this species, which was found in the dead larvæ of this disease and which was not found in the healthy apiary, it was evident that it was not *Bacillus alvei*, and, since *Bacillus alvei* is not present at all, we know that this disease is not the foul brood which Cheyne had reported in his work in 1885. Since it is not this type of foul brood, what could it be? By carefully reviewing all the work which had been done by others, the conclusion was inevitable that this diseased condition had not been described properly from a bacterial standpoint as a disease separate and distinct from the foul brood of Cheyne, but that the mistake had been made for a long time of calling two different and distinct diseases which affected the brood of bees by one name. This condition was reported to the New York State department of agriculture in a report to that department made in January, 1903, and another in January, 1904. In the latter report this condition, for want of definite information, was referred to as "X brood" and the bacillus as *Bacillus X*. At the suggestion of Dr. E. F. Phillips, of the Bureau of Entomology, United States Department of Agriculture, it was thought best for very good reasons to retain the name foul brood in the name of each disease and add a qualifying word to designate the difference between the two diseases. "European" is added to foul brood to designate the disease which Cheyne studied in England (Europe) in 1885, and "American" is added to the foul brood which was first studied in the United States (America). We distinguish, then, European foul brood and American foul brood. Both of these diseases of the brood of bees seem to be found in Europe as well as America. It must therefore be remembered that these names do not put any stigma on either country, Europe or America, but, on the contrary, Europe is thereby given the credit of having first studied the European foul brood and America for having first studied American foul brood.

In a study of the so-called "pickle brood" we are unable to suggest from a bacteriological standpoint any cause for the disease. A study has been made of the bacteria found upon the healthy adult bee and those found in the intestine and also the bacteria found upon and within the adult bees suffering with palsy or paralysis, but so far no suggestion can be made from a bacteriological standpoint as to the cause of this disorder of the adult bee.

To conclude, I shall read, with your permission, the summary of the work reported in the bulletin referred to above.[a]

SUMMARY TO PART I.

The results of the study of the bacteria found normally in the apiary may be briefly summarized as follows:

(1) The temperature of the hive approximates that of warm-blooded animals.

(2) Upon adult bees and upon the comb there occurs quite constantly a species of bacteria which we refer to in this paper as *Bacillus A*, and which, it is believed, is the organism that some workers have confused with *Bacillus alvei* which is universally present in European foul brood.

(3) There occurs very constantly in the pollen and intestine of adult bees a species here referred to as *Bacillus B*.

(4) From the combs *Bacterium cyaneus*, *Saccharomyces roseus*, and a Micrococcus referred to here as *Micrococcus C*, have been isolated and studied.

(5) Honey from a healthy hive is, as a rule, sterile.

(6) The normal larvæ are, as a rule, sterile.

(7) There is an anaërobe found quite constantly in the intestine of the healthy honey bee. It is referred to in this paper as *Bacterium D*.

(8) From the intestine there have been isolated and studied the following micro-organisms: *Bacillus cloacæ*, *Bacillus coli communis*, *Bacillus choleræ suis*,

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[a] Technical Series, No. 14, Bur. Ent., U. S. Dept. Agric.

Bacillus subgastricus, Bacterium mycoides, Pseudomonas fluorescens liquefaciens, and two referred to as *Bacillus E*, and *Saccharomyces F*. Others less frequently present have been isolated, but not studied.

(9) In two samples of brood with unknown disease there was found a species of yeast plant here referred to as *Saccharomyces G*.

SUMMARY TO PART II.

Following is a brief summary of the results of the present investigation of bee diseases:

(1) There are a number of diseased conditions which affect the apiary.

(2) The disease which seems to cause the most rapid loss to the apiarist is European foul brood, in which is found *Bacillus alvei*—first isolated, studied, and named by Cheshire and Cheyne in 1885.

(3) The distribution of *Bacillus alvei* in the infected hive is as follows:

(*a*) The greatest number of infecting germs are found in the bodies of dead larvæ.

(*b*) The pollen stored in the cells of the foul-brood combs contains many of these infecting organisms.

(*c*) The honey stored in brood combs infected with this disease has been found to contain a few bacilli of this species.

(*d*) The surface of combs, frames, and hives may be contaminated.

(*e*) The wings, head, legs, thorax, abdomen, and intestinal contents of adult bees were found to be contaminated with *Bacillus alvei*.

(*f*) *Bacillus alvei* may appear in cultures made from the ovary of queens from European foul-brood colonies, but the presence of this species suggests contamination from the body of the queen while the cultures are being made and has no special significance.

(4) The disease which seems to be most widespread in the United States we have called American foul brood, and the organism which has been found constantly present in the disease we have called *Bacillus larvæ*. This disorder was thought by many in this country and other countries as well to be the foul brood described by Cheshire and Cheyne, but such is not the case.

(5) From the nature of American foul brood it is thought that the organism has a similar distribution to that of *Bacillus alvei*.

(6) It appears that European foul brood was erroneously called "New York bee disease" or "black brood" by Dr. William R. Howard in 1900.

(7) There is a diseased condition affecting the brood of bees which is being called by the bee keepers "pickle brood." No conclusion can be drawn from the investigation so far as to the cause of the disease.

(8) *Aspergillus pollinis*, ascribed by Dr. William R. Howard as the cause of pickle brood, has not been found in this investigation and is not believed by the author to have any etiological relation to the so-called "pickle brood."

(9) Palsy or paralysis is a diseased condition of the adult bees. No conclusion can yet be drawn as to its cause.

(10) Formaldehyde gas as ordinarily used in the apiaries is insufficient to insure complete disinfection.

CONCLUSIONS.

In a paragraph the author wishes, if possible, to present the status of the bee diseases in this country. It should be remembered, firstly, that "black brood" can now be dropped from our vocabulary, and probably does not exist; secondly, that the term "foul brood" was being applied to two distinct diseases. One of these diseases we now refer to as European foul brood, because it first received a scientific study from a European investigator. We refer to the other disease as American foul brood, because it was first studied scientifically in America. There is one more disorder in the brood of bees which has attracted considerable attention—the so-called "pickle brood." There are, then, these three principal diseases: European foul brood, American foul brood, and the so-called "pickle brood."

Doctor PHILLIPS. We surely have all been glad to listen to Doctor White in his most interesting account of his work. It will be well at this time to ask him any questions concerning this work which may have come to mind. Before opening this subject for discussion I wish to say that after this discussion I shall take up in detail the works which Doctor White has criticized. Consequently, if you have no objection, we will hold over until later any discussion of these papers.

Mr. C. P. DADANT. As I understand it, there exist these two bacilli (*Bacillus alvei* and *Bacillus larvæ*) and also *Bacillus mesentericus vulgatus*. Have you samples of all three of the bacilli?

Doctor WHITE. Yes, sir; that (pointing to slides) is *Bacillus larvæ;* that (showing cultures) is the *Bacillus alvei*, and the next, *Bacillus mesentericus*. There are a number of varieties of *Bacillus mesentericus*, and *vulgatus* is one of them.

SYMPTOMS OF BEE DISEASES.

Mr. DADANT. Will you please give us a description of the two diseases—that is, of the conditions arising when *Bacillus larvæ* and *Bacillus alvei* are present in the combs?

Doctor WHITE. I should like to ask Doctor Phillips to answer that question.

Doctor PHILLIPS. I shall simply quote from Doctor White's bulletin. There was issued from the Bureau of Entomology some time ago a small circular, Circular No. 79, entitled "The Brood Diseases of Bees," and in this circular was included a description of the two diseases which Doctor White has been studying. Doctor White was kind enough to quote in his bulletin from Circular No. 79, and I shall read the descriptions.

AMERICAN FOUL BROOD.

American foul brood (often called simply "foul brood") is distributed through all parts of the United States, and from the symptoms published in European journals and texts one is led to believe that it is also the prevalent brood disease in Europe. Although it is found in almost all sections of the United States, there are many localities entirely free from disease of any kind.

The adult bees of an infected colony are usually rather inactive and do little toward cleaning out infected material. When the larvæ are first affected, they turn to a light chocolate color, and in the advanced stages of decay they become darker, resembling roasted coffee in color. Usually the larvæ are attacked at about the time of capping, and most of the cells containing infected larvæ are capped. As decay proceeds, these cappings become sunken and perforated, and, as the healthy brood emerges, the comb shows the scattered cells containing larvæ which have died of disease, still capped. The most noticeable characteristic of this infection is the fact that when a small stick is inserted in a larva which has died of the disease, and slowly removed, the broken-down tissues adhere to it and will often stretch out for several inches before breaking. When the larva dries, it forms a tightly adhering scale of very dark-brown color, which can best be observed when the comb is held so that a bright light strikes the lower side wall. Decaying larvæ which have died of this disease have a very characteristic odor, which resembles a poor quality of glue. This disease seldom attacks drone or queen larvæ. It appears to be much more virulent in the western part of the United States than in the East.

EUROPEAN FOUL BROOD.

European foul brood (often called "black brood") is not nearly as widespread in the United States as is American foul brood, but in certain parts of the country it has caused enormous losses. It is steadily on the increase and is constantly being reported from new localities. It is therefore desirable that bee keepers be on the watch for it.

Adult bees in infected colonies are not very active, but do succeed in cleaning out some of the dried scales. This disease attacks larvæ earlier than does American foul brood, and a comparatively small percentage of the diseased brood is ever capped. The diseased larvæ which are capped over have sunken and perforated cappings. The larvæ when first attacked show a small yellow spot on the body near the head and move uneasily in the cell. When death occurs, they turn yellow, then brown, and finally almost black. Decaying larvæ which have died of this disease do not usually stretch out in a long thread when a small stick is inserted and slowly removed. Occasionally there is a very slight "ropiness," but this is never very marked. The thoroughly dried larvæ form irregular scales which are not strongly adherent to the lower side wall of the cell. There is very little odor from decaying larvæ which have died from this disease, and when an odor is noticeable it is not the "glue-pot" odor of the American foul brood, but more nearly resembles that of soured dead brood. This disease attacks drone and queen larvæ very soon after the colony is infected. It is as a rule much more infectious than American foul brood and spreads more rapidly. On the other hand, it sometimes happens that the disease will disappear of its own accord, a thing which the author never knew to occur in a genuine case of American foul brood. European foul brood is most destructive during the spring and early summer, often almost disappearing in late summer and autumn.

GEOGRAPHICAL DISTRIBUTION.

Mr. France (Wisconsin). When I was with Doctor Phillips and Inspector Hutchinson in Michigan studying the difference between American and European foul brood, it occurred to me that it was possible to bring together at this time specimens of diseased brood from different localities. In my own city (Platteville, Wis.) I found samples of diseased comb and had reserved them for this meeting, but unfortunately three of the four samples in my possession contained moth larvæ, and it was impossible to tell anything about the disease. The only one that I still have is now in my grip.

Mr. Dadant. Where were those samples from?

Mr. France. From Michigan.

Doctor Phillips. Our first accurate knowledge of European foul brood in the United States was the epidemic in New York State, and most bee keepers still look on the disease as still being confined to that State. However, European foul brood is now found in New York, Vermont, Massachusetts, Connecticut, New Jersey, Pennsylvania, Ohio, West Virginia, Michigan, Indiana, and Illinois. Reports have been received at the Bureau of Entomology from all those States. The disease is rapidly going west.

COMPARISON OF DISEASES.

Mr. William Atchley (Texas). Which of the two diseases is considered worse, the American or the European foul brood?

Doctor Phillips. That is a point which was simply suggested in the descriptions just read. European foul brood spreads more rapidly than the other, but at the same time it will at times absolutely disappear of its own accord, which is something that the American foul brood seems not to do. We have these two factors over against each other, and I should as soon try to eradicate one disease as the other. As far as loss is concerned there seems to be very little difference.

Mr. J. Q. Smith. (Illinois). How many specimens have been sent to the Bureau of Entomology from Illinois?

Doctor Phillips. Two, I believe.

Mr. Smith. I was in correspondence with some of the persons having this disease among their bees, and I advised them to send samples to you.

INFECTION IN HONEY.

Mr. R. A. Holekamp (Missouri). Have the bacteria of both diseases been found in honey from infected hives?

Doctor White. We believe that the infecting agent may be present in honey in each case, since the experience of the bee keeper has been that the infection of a healthy colony has followed the feeding of honey from hives affected by either disease.

INFECTION OF LARVÆ.

Mr. A. H. Anderson (Utah). How does the larva become infected?

Doctor Phillips. The manner by which this is brought about is not all entirely certain, but the facts would tend to show that it is through feeding on infected material.

Doctor White. It would appear that internally the contamination is caused by being carried by worker bees. As they move over the combs and clean out the cells they come in contact with contaminated material. On any part of the body one can find *Bacillus alvei;* so I shall leave it to you, as you are more conversant with bees.

Doctor Phillips. The bacteria in a diseased colony are present everywhere. They are found all over the adult bees, on the queens, on the outside of the comb, and every place else. They do not, however, grow in honey; they quickly go from the rod condition to the spore condition and remain in the latter condition indefinitely when in honey. According to the statement just made, it would seem that a bee from an infected hive would always carry disease. The fact is, however, that if the bees have been away from this infection for some time they will not transmit the disease. Give them a new clean hive with no food, so that all the honey is used up from the inside of the body. The infection from the outside does not seem to spread the disease if no brood is reared for a few days.

Mr. Smith. I believe that the reason why the bee loses the infection is because a certain time elapses before the comb is drawn out and young larvæ are present which are large enough to become infected. But I know this fact: If you shake bees from a diseased colony onto combs that contain healthy larvæ, you might as well leave the larvæ, for disease at once appears. I have tried that.

BACTERIA IN QUEENS.

Mr. Dadant. In either case have the bodies of queens been inspected?

Doctor White. The bodies of queens have been inspected, and while the internal organs contained these organisms, the ovaries seldom do, and where *Bacillus alvei* is found in the ovary, or in our cultures made from the ovary, they occur very seldom, and the probability is that they get there through contamination in making the cultures rather than from being found in the ovary itself. The ovaries are very small and one must work with instruments that are sufficiently large to handle. It is almost impossible to take cultures from the ovary and not get contamination from the outside.

"BLACK BROOD."

Mr. H. H. Root (Ohio). I thought I understood Doctor White to say that the disease called black brood has not been found in New York.

Doctor Phillips. What Doctor White said was that there is no such thing as black brood. The name black brood was a blunder.

INFECTION CARRIED TO FLOWERS.

Mr. Smith. Then if, as you say, the contamination is always present on the adult bees from diseased colonies, why is it not possible to carry it to the blossoms and leave it on the pollen, so that the next bee visiting the same flower would carry germs to its hive?

Doctor Phillips. It is, of course, possible, but highly improbable.

VITALITY OF SPORES.

Mr. France. As to the duration of this bacillus in the spore form, how long can it remain in honey and still have vitality to grow under proper conditions?

Doctor Phillips. I have never determined any limit. It is known that very old honey from an infected hive will transmit disease to a colony.

Mr. France. In my State (Wisconsin) we had an experience bearing on this point where combs contained American foul brood. The bees had died, leaving the combs containing dead dried-up larvæ, and the owner, anxious to start in bees again, put the hives away in the granary, and four years afterwards hived bees on them and American foul brood started anew.

Mr. D. H. Coggshall (N. Y.). When honey was shipped from Cuba several years ago and scattered all over the United States, if it was left where bees from this country could get to it, the disease was certainly scattered broadcast.

PUBLICATIONS ON BEE DISEASES.

Doctor Phillips. I desire at this time to announce the publication of three pamphlets on bee diseases issued by the Bureau of Entomology. Circular No. 79, "The Brood Diseases of Bees," was issued three or four weeks ago. I have just this morning received copies of a paper by Doctor White, Technical Series, No. 14, entitled, "The Bacteria of the Apiary, with Special Reference to Bee Diseases." This was issued on November 6, and was received here this morning. I have also a pamphlet here from the Bureau of Entomology containing all the laws in force relative to bee-disease inspection. This is a reprint from Bulletin No. 61, "The Laws in Force Against Injurious Insects and Foul Brood in the United States." A recent order of the Secretary of Agriculture has put a stop to the free distribution of bulletins, but they can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The price of Technical Series, No. 14, is 10 cents.

The following paper was then read by Doctor Phillips:

THE PRESENT STATUS OF THE INVESTIGATION OF BEE DISEASES.

By E. F. Phillips, Ph D.,
Of the U. S. Department of Agriculture.

I wish to take up two or three phases of this work about which Doctor White has been speaking, and to add some additional points. In regard to the history of the investigation of bee diseases prior to 1885, I can do no better than to quote the historical résumé contained in a paper by Prof. F. C. Harrison, entitled "Foul Brood of Bees," published as Bulletin 112 of the Ontario Agricultural College:

In all probability the first definite reference to foul brood is by Aristotle (Historia Animalium, Book IX, ch. 27), who mentions an inertness which seizes the bees and causes a bad smell in the hive. He also suggests that bees are liable to become diseased when the flowers on which they work are attacked by blight. Bee dysentery as well as foul brood causes a bad odor; but in the former disease the spotting and consequent smell are usually outside the hive.

Columella (De Re Rustica, Book IX, ch. 13) mentions a bee pestilence and an annual distemper which seizes the bees in spring. Pliny (Natural History, Book XI, ch. 19, A. D. 79) writes of a disease of bees, but as he uses the same term as Aristotle he has probably copied it from the latter author.

Schirach (Histoire des Abeilles, ch. III, p. 56, La Haye, 1771), in 1769, was the first writer to name the disease "foul brood." He says:

It is dangerous and a most destructive disorder to the bees, a genuine plague when the complaint has reached a certain stage. The cause can be attributed to two sources: (1) The putrid (or tainted) food with which the bees feed the larvæ for lack of having better. (2) By the mistake of the queen bee in misplacing the larvæ in their cells, head upside down. In this position the young bee, unable to get out of its prison, dies and rots away.

Further, Schirach clearly distinguishes between foul brood and chilled brood, and mentions the fact that putrefaction follows the death of the brood from frost, but in this case "it is only an accident and not a disease."

The remedy Schirach recommended was to remove all diseased combs from the infected hives and to keep the bees fasting for two days, after which they are furnished with other cakes of wax and a suitable remedy given, "as a little hot water mixed with honey, nutmeg, and saffron, or a syrup composed of equal parts of sugar and wine seasoned with nutmeg." Thus, as Cowan (Journal of the Royal Agricultural Society, Vol. VI, Part IV, 1895) remarks: "We had given us nearly one hundred and thirty years ago a method of cure almost identical with what is by some claimed as new to-day."

Tessier (L'Encyclopedie Methodique, Abeille, p. 32, 1765) about the same time as Schirach says that when the larvæ die in their cells it causes an infection in the hive which makes the bees sick. It is then necessary to drive away or sometimes move the bees from the hive, and to take care to fumigate the infected hive if it is going to be used again. It is necessary, in order to avoid the same inconvenience, to take out the parts of the comb that may be moulded by reason of the dampness. Duchet (Culture des Abeilles, p. 315, Vevey, 1771), who wrote on bees in 1771, does not mention any disease that can be certified as foul brood, but he describes bee dysentery.

Della Rocca (Traite Complet sur les Abeilles, Vol. III, p. 261, Paris, 1790), vicaire-general of Syra, an island in the Levant, relates with much detail the history of an epidemic of foul brood, which caused great destruction in the island during the years 1777 to 1780. Della Rocca describes very minutely the symptoms, destruction, and mistakes that were made in attempting to combat the disease. He says:

The disease manifests its presence by defects in the combs filled with brood, and which only contain a putrid mass; instead of the bee pupæ there is only rottenness in the cells, which, however, being capped, always preserve a healthy appearance. If these cells are broken open, a blackish liquid flows out, which spreads the infection through the hive. This disease only manifests itself in cells which contain a nearly mature larva or a capped one. The bees themselves remain in good health, and work with the same activity, but their numbers decrease daily. This disease, however, was not so general in a hive but that a small portion escaped. Some new bees emerged, but in too small numbers to supply the daily losses. Thus a hive attacked by this scourge will perish from scarcity of population. At first it was not noticed that this disease was epidemic, and the hives emptied by death of the bees were filled with fresh swarms, and these contracted the same disease and perished. Yet another mistake was made. The remains of the hives that were lost were taken into the streets of the town to expose them to the sun in order to extract all the wax, and the bees from the neighborhood sucked up the honey, caught the disease, and communicated it to other hives, and all, without exception, perished in a short time. The epidemic having reached the island spread everywhere, and the mortality among the bees was general, either from eating infected honey, or from stopping up the infected combs, or from the bees nourishing their brood on infected honey.

Della Rocca criticises Schirach's statement regarding the misplacement of the larvæ by the queen as a cause of the disease, because "everybody knows that the queen has nothing else to do but deposit eggs. These are then cared for and nourished by the bees; and when the larva is nearly ready to change into the pupa, the bees close the cell, and every position which is given the larva depends on their good pleasure and not on the queen's." Della Rocca himself thinks that "some pestilential blight had without doubt corrupted the quality of the honey and the dust from the anthers," and recommends "burning everything without pity, as there is no other resource when the disease is well established, as the pest is without doubt the most terrible in the natural history of bees."

Neither Wildman (Treatise on the Management of Bees, London, 1796), Keys (Ancient Beemasters Farewell, London, 1796, Woolridge), Needham (Brussels Memoirs, Vol. II, 1780, Rhein), Reaumur (Memoirs pour Servir a l'Histoire Naturelle des Insectes, T. V., p. 1734), and other authors about the same time (latter end of the eighteenth century) mention this disease.

Bevan (The Honey Bee, London, 1827) names the disease "pestilence," and also quotes Schirach's name, "foul brood," and says regarding it that the "pestilence has been attributed to the residence of dead larvæ in the cells, from a careless deposition of ova by the queen. * * * It has also been attributed to cold and bad nursing; that is, feeding with unwholesome food."

Nothing further of note appears in bee literature till the year 1860, when Doctor Leuckhart (Bienen Zeitung, Eichstadt, 1860, p. 232) writes that he was formerly of the opinion that foul brood was caused by the same fungus (*Panhistophyton ovatum*) which is noticed in a disease of the silkworm, but now, after observation and experiment, is quite certain that the disease is caused by neither vegetable nor animal parasite. He also notes that the term "foul brood" is applied to a number of diseases affecting bees.

Molitor Muhlfeld (Bienen Zeitung, Eichstadt, 1868, p. 95) recognizes two forms, one contagious and the other not contagious, and thinks that the only cause of contagious foul brood is a fly (*Ichneumon apium mellificarium*) which lays its eggs on the young larvæ of the bee.

A discovery of note was Preuss's (Bienen Zeitung, 1868, p. 225), in 1868. He contradicts Muhlfeld's statement about the fly, and states that foul-brood cells can be detected by the sunken cap. With a microscope magnifying 600 diameters he found small, dust-like bodies, with a diameter of $\frac{1}{500}$ mm., belonging to the genus *Cryptococcus* (Kutzig), and called the specific form *alvearis*, likened it to the fermentation fungus (*Cryptococcus fermentum*), and thought that the last germ gained access to the young bee and changed to *Cryptococcus alvearis*. He notices that many experts lay the cause of the disease to fermenting food, but the larvæ are easily contaminated by the fermentation fungus, which is always present in the air. He also mentions the enormous rapidity with which the fungus multiplies, and gives an elaborate calculation of the number that might be found in a cell containing a deceased larva.

As might have been expected, Preuss's statement aroused considerable discussion at the meeting of German bee-keepers a short while after the publication of his paper.

Vogel (Bienen Zeitung, Nos. 21 and 22) expressed doubt as to whether *C. alvearis* was the real cause of foul brood or only a consequence of the disease, but on the whole agreed with Preuss.

Wiegand (Bienen Zeitung, Nos. 21 and 22) agreed with Preuss's theory, and in giving his experience said that the disease was introduced into his apiary through honey brought from a distance.

Pollman (Bienen Zeitung, Nos. 21 and 22) believed that the disease was introduced by feeding honey from Havannam, where, when extracting the honey, both brood and honeycomb were mashed up and the honey pressed out.

Doctor Leuckhart (Bienen Zeitung, Nos. 21 and 22) agreed with those who thought the disease due to a fungus, but discredited the supposition that it was the same as the fermentation fungus mentioned by Preuss, and rather thought it was related to the silkworm fungus and that most of the brood diseases ending in death were called "foul brood," while they were really something else. He believed that the fungus was present in the eggs of the queen when laid.

Geilen (Bienen Zeitung, Nos. 21 and 22) believed that the disease came from the putrefying remains of animal bodies upon which the bees alighted.

Muhlfeld (Bienen Zeitung, 1869, No. 3) again, in 1869, presented his former views and also those of Preuss and gave directions for maintaining the health of bees. He recommended the boiling of the honey and a use of carbolic acid in the strength of 1 : 100, or permanganate of potash 1 : 300, as disinfectants.

Lambrecht (Bienen Zeitung, 1870, No. 2) thought that foul brood was caused by fermentation of the bee bread.

Hallier (Bienen Zeitung, 1870, No. 2) considered it no specific disease, but thought it was probably produced by different fungi.

Cornallia (Bienen Zeitung, 1870, No. 5) proved contrary to the above and found a fungus which he thought developed foul brood. He called it *Cryptococcus alvearis* and used carbolic acid, potassium permag, and lime water as disinfectants.

Fisher (Bienen Zeitung, 1871, pp. 105–125) advanced a new foul-brood theory in 1871, which somewhat follows the view of Liebig regarding the silkworm disease and plant diseases. According to this theory, the predisposing cause was insufficient nourishment, especially short stores for winter and spring. Shortage of pollen supply was the next cause. Fisher tried to prove his views by the practical experience of bee keepers and explained that the first result of repeated and continued feeding was an increase in the production of bees; and a consequent disproportion between brood and brood feeders arose, which should be looked upon as another cause of foul brood. The disease, he said, might be lessened or exterminated by applying means to reduce the production of brood, as the removing of the queen and the area which the brood occupied. Foul brood is probably the cause of a quantitative dearth of nourishment and a consequent degeneration of the bees. The appearance of fungus growths was only a secondary matter.

Schonfeld (Bienen Zeitung, 1874, pp. 201 and 261) infected several hives with foul brood, and when it had fully developed he took a comb of the rotten brood to the Physiological Institute at Breslau and had it submitted to a microscopical examination by Doctors Cohn and Eidam (Bienen Zeitung, 1874, pp. 201

and 261). This examination showed that in every dead larva and in each foul brood cell, whether the contents were yet white and fluid or brown, tenacious, and ropy, there were to be found long oval bodies, which Preuss called "micrococci." Close to and among them, Cohn was the first to find, with the most powerful of the five microscopes that were used, a countless number of slender pale rods, joined together, and which he at once identified as bacteria of the genus *Bacillus*. The length of a single rod was about 6 micromillimeters, but many of them were two and three jointed, so that these foul brood bacteria microscopically resembled the anthrax bacteria, though of course they were different physiologically and in the manner in which they acted as ferments.

It is not surprising when we remember the state of bacteriological knowledge in 1870, that Preuss should have mistaken micrococci for the spores of a bacillus.

In 1885 the first investigation which merited close attention was published in the Journal of the Royal Microscopical Society, entitled "The Pathogenic History and History under Cultivation of a New Bacillus (*B. alvei*), the Cause of a Disease of the Hive Bee Hitherto Known as Foul Brood," by Frank R. Cheshire, F. R. M. S., F. L. S., and W. Watson Cheyne, M. B., F. R. C. S. One point is here to be especially noticed, there were two authors of this paper. The paper was divided into Part I, Pathogenic History, by Mr. Cheshire, and Part II, History Under Cultivation, by Mr. Cheyne, and with the latter part Mr. Cheshire had nothing whatever to do. Bee keepers are generally giving Mr. Cheshire the credit for this work, but it is clear that Mr. Cheyne, the man who did the bacteriological work, should be the one to get the credit. The description of the disease, contained in Part I, is as follows:

The nature of foul brood as a germ disease.—If a comb be removed from near the center of a healthy hive during the summer months its cells will normally be filled with eggs, larvæ, and pupæ in every stage of development. The eggs as left by the ovipositor of the queen or mother adhere commonly by the end to the base of the cells they occupy, and favored by the high temperature constantly maintained within the hive, the germinal vesicle at about three days matures into a larva ready for hatching. These eggs I have shown as liable to the disease even before they leave the body of the mother, but most careful microscopic examination is needful to make this apparent (and of which I shall speak presently more particularly). On the contrary, the larvæ, which are constantly fed by the workers, so change in appearance soon after infection that a practiced eye at once detects the presence of the disease. Whilst healthy their bodies are of a beautiful pearly whiteness, lying, at first floating, in the abundant pabulum the nurses are ever ready to supply. As they grow they curl themselves at the bottom of the cells until they become too strait for their occupants, which now advance to the head to be in readiness for the cocoon spinning, which follows upon the close of the eating stage. When the disease strikes the larvæ they move uneasily in their cells, and often then present the dorsal surface to its mouth, * * * so that mere posture is no insufficient evidence of an unhealthy condition. The color changes to yellow, passing on by degrees toward a pale brown, whilst the skin becomes flaccid and opaque; death soon occurs, when the body, now shrunken by evaporation, lies on the lower side of the cell, increasing in depth of tone, until in a few days nothing more than a nearly black scale remains. Should the larvæ, however, escape contamination until nearly the period of pupahood, they are sealed over in the normal way by a cover made of pollen-grains and wax, * * * and which is pervious to air. The cover furnishes a screen, on which part of the cocoon is soon after spread, but the inhabitant of the cell is marked out for death, and before very long the capping or sealing sinks and becomes concave, and in it punctures of an irregular character appear, * * * and this is a nearly conclusive sign of the diseased condition of the colony. The sense of smell is also appealed to, as a peculiar, very offensive, and extremely characteristic odor now escapes from the diseased combs. The bees, in addition, lose energy, but become unusually active in ventilating their hive by standing at the door, heads toward home, and flapping their wings persistently so that a strong outcurrent, and as a necessary consequence, a correspondingly indraught are set up. Should any attempt be made at removing a dead larva which has assumed a deep brown tint, its body tenaciously adhering to the cell wall will stretch out into long and thin strings like half-dried glue. The microscopist can easily explain this. The thin chitinous aerating sacs and tracheæ do not undergo decomposition at all easily, and these remaining, occasion the peculiarity referred to. * * * The disease is terribly infectious, and once started soon spreads from cell to cell and not unfrequently from stock to stock.

Mr. Cheshire was doubtless quite familiar with the disease of the brood and this description of the symptoms, we may assume, was not made from any one case, but from his entire experience. At that time two diseases of the brood were not recognized. We are justified in concluding that both diseases existed in England at that time, as they do now, and doubtless Mr. Cheshire had seen both without realizing that he was dealing with two distinct maladies. In this description he speaks of the disease as attacking brood at various times, for he says: "Should the larva, however, escape contamination until nearly the period of pupahood," etc. His description before that sentence applies as well to what we now call European foul brood as to American foul brood, while the latter description, especially where he speaks of the odor and ropiness, is undoubtedly drawn from experience with what we now call American foul brood. There is, at any rate, ground for the supposition that Mr. Cheshire was dealing with two diseases.

In the case of Mr. Cheyne, however, the case was entirely different. He was probably not familiar with the brood disease from practical experience. He also probably did all his work from one specimen, for he says: "On August 11, 1884, Mr. Cheshire brought to me a piece of comb containing larvæ affected with foul brood, with which I performed the following experiments." In describing this specimen he says: "These larvæ were dead, of a yellowish color, and almost liquid." This description certainly applies as well to European foul brood. Since the original description of *Bacillus alvei* is so important in this work, it may be well to quote entire Mr. Cheyne's part of this paper. This is practically unavailable to bee keepers, since it is contained in a journal to which few bee keepers can have access. It is as follows:

On August 11th, 1884, Mr. Cheshire brought to me a piece of comb containing larvæ affected with foul brood, with which I performed the following experiments: Selecting cells which were closed, but which Mr. Cheshire thought contained diseased larvæ, I brushed them over with a watery solution of bichloride of mercury (1 : 1000) to destroy the organisms on the outside. With several forceps, that had been heated and allowed to cool, the covering of the cell was picked off so as to display the diseased larvæ. These larvæ were dead, of a yellowish color, and almost liquid, and on examination afterwards their juices were found to contain numerous moving bacilli. By means of a heated platinum wire, tubes of meat infusion rendered solid by gelatin (10 per cent), or by Japanese isinglass, were inoculated from several of these larvæ and kept at a suitable temperature. Development of bacilli, microscopically similar to those seen in the juices of the larvæ, occurred. The characteristics of this development will be presently described. Further, in the tubes, kept at the body temperature, there was not only a development of bacilli but also of spores.

These bacilli, as seen in the larval juices, measure about $\frac{1}{7000}$ inch in length and $\frac{1}{20500}$ inch in breadth. They are rounded or slightly tapering at their ends and often have a clear space near one end. In the juices of the larvæ during life they apparently do not produce spores, although after death spores abound.

In the cultivation in the peptonized meat infusion, rendered solid by agar-agar, the bacilli vary considerably in size, their average length being $\frac{1}{7200}$ inch, some being as small as $\frac{1}{10000}$ inch and others as large as $\frac{1}{5000}$ inch. When they have attained the latter size, division of the rod seems to begin. They are always somewhat pointed at their ends. Their average breadth is $\frac{1}{30000}$ inch, varying from $\frac{1}{35000}$ to $\frac{1}{25000}$.

The spores are largish oval bodies, averaging in length $\frac{1}{12000}$ inch (varying from $\frac{1}{13100}$ to $\frac{1}{10200}$ inch), and in breadth $\frac{1}{23700}$ inch (varying from $\frac{1}{24000}$ to $\frac{1}{25000}$ inch). In the agar-agar material the spores are generally arranged side by side in long rows, and in old cultivations only a few bacilli can be seen, some forming spores, some without any indication of spores. That these small bacilli can produce such large spores seems at the first glance at a microscopical specimen almost inconceivable, but I have been able to trace on the one hand the development of the spores in the rods, and on the other the sprouting of the spores into adult bacilli. This can be done in the following very simple manner:

Take a number of glass slides, each having a moderate-sized cell hollowed out in its middle; clean it and pass through a Bunsen flame several times to destroy any bacteria on its surface. With a brush apply a little vaseline around the depression, and then place the slide under a glass shade to keep it from the dust. Clean a number of cover glasses, purify them in the flame, and place them on a pure glass plate beneath another shade. With a fine, pure pipette put a small drop of sterilized cultivating fluid (meat infusion with peptone) on the center of each of these cover glasses; then with a fine platinum wire inoculate each of the drops with the spores, or with nonspore-bearing bacilli; rapidly invert them over the cell, press down the cover glass so as to diffuse the vaseline around its edge, and place the slides in an incubator kept at the temperature of the body. These slides are removed at different intervals of time, and as soon as each is taken out the cover glass is turned over and the drop of fluid rapidly dried. The specimen can then be stained, mounted in Canada balsam, and studied at leisure. This method seems to me to be much more satisfactory than the observation of the organisms swimming about in the drop of fluid, while the specimens can be kept permanently and compared with one another.

In order to study the growth of the spores, I used a cultivation on the agar-agar cultivating material which had been kept at the temperature of the body for fourteen days, and which consisted almost entirely of spores, though a few bacilli were present. As the result of several experiments, I have got a series of preparations which have been taken at various times (15 minutes, 30 minutes, 40 minutes, 1 hour, 1½ hours, 1 hour 50 minutes, 2 hours, 2 hours 20 minutes, 2 hours 50 minutes, 2 hours 55 minutes, 3 hours 20 minutes, 4 hours 20 minutes, 5 hours, 5 hours 35 minutes, 5 hours 40 minutes, and 7 hours 50 minutes), and the course of events is shown in Plate X.[a] The bacilli stain with various anilin dyes—best, I think, with methyl-violet; but the spores resemble the spores of other bacteria in not taking on the stain. The cover glasses on which the organisms are dried are passed three times through the gas flame and floated on the surface of a fairly strong watery solution of methyl-violet for one or two hours. They are then washed in water, and afterwards laid in weak acetic acid (1 per cent) till no more stain comes out. They are again washed in water, allowed to dry at the ordinary temperature, and mounted in Canada balsam. A spore-bearing cultivation shows the bacilli stained violet and the spores unstained, with the exception of their outline, which is of a faint violet color. In most cases no trace of the rod in which the spore was formed can be seen. The first change which is observed on cultivation is that in many cases the outline of the rod in which the spore was formed becomes faintly visible. This can be seen in 15 minutes, and is, I think, simply due to swelling by the fluid, as it is also evident to some extent in the case of spores soaked in water for the same length of time. In from half an hour to an hour it is evident that the bacilli which were present in the original material are beginning to multiply, and a considerable number of rods are now seen containing spores. It is evident that these spores are newly formed, as extremely few bacilli containing spores were seen in the original material, whereas in the preparations taken from a half hour to an hour a considerable number are present. That some of the rods, instead of growing by fission, at once proceed to form spores is probably to be explained in this way. When the cultivation was removed from the incubator, some bacilli were growing by fission, some were forming spores, and some had passed into a state ready to form spores. The first go on growing by fission, the last complete their spore-formation, which was arrested by removal from the warm temperature. That actively growing rods would not have formed spores so early is evidenced by the facts observed in the second series of observations on the formation of spores. The next thing that is observed is that several of the spores take on the stain, and are as intensely violet as the adult bacilli. The number of the spores which take on the stain in this way goes on increasing as time passes, till in about four hours almost all the spores stain violet. In three hours the first indication of sprouting of these spores becomes evident. The stained part of the spore loses its oval shape, becomes elongated, and is soon seen to burst through the spore-capsule at one part. It then presents the appearance of a short rod, with a pale envelope embracing one end. This rod gradually leaves the spore-capsule and then goes on multiplying as a full-grown bacillus. In specimens taken from four to five hours all stages of growth can be seen, and the remains of the ruptured spore-capsules are evident.

The bacilli appear to grow mainly by fission, but I have seen appearances

[a] Not reproduced here.

which seem to me only explicable on the supposition that they also grow by sending out buds from one end. A bacillus may be seen with a small, somewhat conical stained point attached to one end, though separated by a marked division. This is certainly not the common mode of growth by fission, for there the rod seems to divide into two pretty equal halves, while here we have but a minute piece attached to one end.

The mode of formation of spores may be traced in a similar manner to that described above in the case of the sprouting of the spores. It is, however, as a rule, necessary to leave the organisms to grow for a much longer time than in the former instance. I have not found development of spores as a rule before twenty-three hours, but this depends very much, apparently, on the amount of fluid that was present and the number of bacilli introduced at the time of inoculation. The first thing noticeable is that the rod begins to swell and becomes spindle shaped. The swelling, which generally affects the middle of the rod, may in some cases be most marked toward one end, increases in size, and the center of the swelling gradually ceases to take on the stain. The capsule of the spore is apparently also formed within the rod, and is not merely the outer part of the rod. In three or four hours the rod is seen to have almost or completely disappeared, leaving the spore lying free or within the faint outline of the original bacillus. It seems to me that the view that spore formation occurs when the food is getting exhausted is correct, for the time at which this appearance is found depends greatly on the drop placed on the cover glasses, and I have found in one experiment that in one specimen, after twenty-three hours, most of the rods were forming spores, while in another specimen where the drop was much larger there was no trace of spore formation after twenty-eight hours. I have here described the results of my earlier and rougher attempts to study the formation of spores. I have, however, now improved the method in the following way. As I have just now shown, the period at which spores are first seen seems to depend mainly on the amount of fluid used and the number of bacilli introduced, and as in the above method, both these factors vary in each case, one can not get a regular series of preparations showing the different stages at different times. In studying the sprouting of spores the amount of fluid and the number of spores does not matter, for if sufficient nutriment is present and a proper temperature is maintained the spores must sprout, and probably they always take about the same length of time. The difficulty of obtaining a series of specimens illustrating spore formation is easily obviated in the following manner. Take a pure flask containing a small quantity of sterilized infusion and inoculate it from a cultivation containing only bacilli. Place it in the incubator for two or three hours so that the bacilli may increase somewhat in number and diffuse themselves through the liquid. Thus the cultivating material contains bacilli pretty equally diffused through it, and if after shaking the flask drops of equal size are taken, each will probably contain about the same number of bacilli. The minutest quantity of fluid can easily be obtained by means of a syringe having a fine screw on its piston and a large nut revolving on this screw. The circumference of the nut being equally divided into a number of small segments, the same quantity of fluid can always be expelled from the syringe. By proceeding in this way equal-sized drops containing an equal number of bacilli can be used and a regular series of specimens obtained. I have found that using two-fifths of a minim containing one bacillus and keeping the specimen at 36° C., the earliest appearance of spore formation was evident in forty-one hours.

Leaving these matters, which are of great interest not only in regard to the *Bacillus alvei*, but to all spore-bearing bacteria, and which I have therefore dwelt on at length, we must pass on to the further consideration of this particular organism. The first point to be determined in investigating its relation to foul brood was whether this was a new bacillus, unknown except in connection with this disease of bees, or whether it was a more or less well-known form. To ascertain this point with regard to micro-organisms the microscope is of little use; recourse must be had to the study of their life history, more especially to their peculiarities of growth on different soils. Of all the materials employed as cultivating media, Koch's gelatinized meat infusion is the most useful for purposes of diagnosis. This is composed of an infusion of meat containing 1 to 3 per cent of pepton, 10 per cent gelatin, made neutral by carbonate of soda, and thoroughly sterilized. This material was first introduced with the view of having a highly nutritive solid and at the same time transparent medium on which to carry on pure cultivations, but it was soon found that owing to the remarkably diverse ways in which different micro-organisms grew in it, it could be used as a means of diagnosis of the kind of organism, a means more certain than any other which we at present possess. For purposes of diagnosis, as well as with the view of carrying on pure cultivations, this material is used in three ways. While the material is still fluid a small portion is poured into a number of pure tubes plugged with cotton wool, sterilized, and allowed to solidify. A fine platinum wire, heated in a flame and allowed to cool, is dipped into the material containing the bacterium in question, and then, after the removal of the cotton-wool plug, is rapidly plunged down through the gelatin to the bottom of the tube and then withdrawn. The plug is reinserted and the tube kept at a temperature suitable for the development of most forms of bacteria, but not high enough to melt the gelatin. If growth takes place at this temperature it occurs either on the surface around the point of entrance of the needle, or along the needle track, or in both places, and the appearance of the growth varies remarkably, according to the different species of micro-organisms studied. The second way is to liquefy and pour out a little of the gelatinized material on microscopic slides or on larger plates of glass which have been sterilized by heat. These plates are placed in glass vessels containing moist blotting paper to prevent drying of the gelatin and to protect them from the dust. After the gelatin has solidified the purified platinum needle charged with the bacteria is drawn rapidly over the surface of the gelatin. Bacteria are sown along the track, grow there, and the whole can be placed under a microscope and the characteristics of the growth studied with a low power. In the third mode a tube of the gelatin mixture is inoculated with a very minute quantity of the bacteria. The tube is then placed in water at the body temperature to melt the gelatin. When the material is melted, it is thoroughly shaken up to diffuse the bacteria through it and, while still liquid, is poured out on sterilized glass plates kept in a moist chamber, as in the former case. Solidification very soon occurs, and the bacteria being caught at various parts of the gelatin grow there in the form of groups or colonies, which can be observed under the low power of the microscope. I shall now describe the characteristics of the *Bacillus alvei* when cultivated in these three modes.

(*a*) *Test-tube cultivations.*—If an infected needle be plunged into a tube of gelatinized meat infusion in the manner described above, growth occurs both on the surface and along the needle track. On the surface the bacilli shoot out in all directions from the point of entrance of the needle, forming a delicate ramifying growth on the top of the gelatin; the characteristics of this growth will be presently described under *b*. Along the track whitish irregular shaped masses appear, which slowly increase in size and run together. In a few days processes are seen to shoot out from these masses, which may extend through the gelatin for long distances from the track, being thickened at various parts and clubbed at the ends. These processes do not appear to join one another at their ends. A very beautiful and characteristic appearance is got where very few bacilli are introduced with the needle and where, therefore, at various parts of the track, more especially at the lower part, individual bacilli or groups of bacilli are planted at a considerable distance from each other. In a few days minute round whitish specks become visible to the naked eye. These increase in size till in about ten days shoots begin to appear. These radiate from the central mass in all directions and become nodular at various parts, as described above. When such a cultivation is old, the white branches disappear, and only little whitish collections of bacilli are seen at various parts. On examining such a tube with the pocket lens, however, numerous watery-looking tracts are seen running through the gelatin from the central mass to the whitish collections. The gelatin at the upper part of the track generally evaporates, to some extent giving rise to the air-bubble appearance so characteristic of the cholear bacillus. These are the appearances seen where the material contains gelatin in the proportion of 10 per cent. Where less gelatin is present, the naked eye appearances, while possessing the same characteristics, are somewhat different. The shoots are much more numerous and appear much more rapidly, giving rise to a haziness around the middle track, which with the pocket lens is seen to consist of numerous delicate branches clubbed at the ends, as in the former case. I think the amount of pepton present also makes a difference in the appearance, though of this point I am not yet absolutely certain. The most characteristic growth is, however, obtained when the material contains 3 per cent pepton as well as 10 per cent gelatin, the shoots being then less numerous and much coarser. And I can easily understand that this would be the case, for the bacilli would have a large supply of nutriment in their immediate vicinity without the necessity of having, so to speak, to spread out through the gelatin in search of food as may be the case where no pepton, or only a small amount, is present. This appearance is quite characteristic of this bacillus and is not seen in the cultivation of any other organism that I know of. The bacilli of anthrax and of mouse septicæmia also spread out from the needle track, but the appearance of their cultivation is quite different. In anthrax delicate threads, not clubbed, shoot out from the track, soon anastomosing with other threads and forming a delicate network throughout the gelatin. In mouse septicæmia the appearance is that of a delicate cloudiness spreading through the gelatin. These foul-brood bacilli, growing in this material, render it liquid after a time, the liquefaction beginning at the surface and only spreading slowly downwards, but ultimately the whole tube becomes liquid. After two or three weeks' growth the appearance presented by the tube is that of a layer of liquid at the upper part, and the growth along the needle track with the other appearances described at the lower part. The liquid portion is clear, except at the bottom of the liquid, where there is a loose white flocculent deposit of bacilli, and on the surface there may be a very thin scum. The liquid becomes yellowish in colour after a time and gives off an odor of stale but not ammoniacal urine, or what may be better described as a shrimpy smell. This yellowish colour and the peculiar odour have been found by Mr. Cheshire to be distinctive of the diseased larvæ.

(*b*) If gelatin be poured out on a plate, allowed to solidify, and then stroked with an infected needle, we learn the explanation of the appearances seen in the test-tube cultivations. The bacilli at first grow along the needle track, but very soon they are seen to be collecting at parts forming pointed processes. From the processes the bacilli grow out into the gelatin, often a single series of rods, in Indian file, or two or three rods side by side. These processes are not quite straight, but tend to curve, and at a little distance from the track they grow round so as to form a circle. From this circle, which may be formed of single bacilli, the process continues forming a fresh circle farther on. The bacilli in the circle increase in number till ultimately it becomes completely filled up, and we have a nodule consisting of bacilli in the course of the shoot. These shoots may also join one another, forming a curved anastomosis, and the gelatin in the immediate vicinity of the bacilli becoming liquid, a series of channels are formed in the gelatin containing fluid in which the bacilli swim backwards and forwards. Later on parts of these channels become apparently deserted by the bacilli, so that the circles look to the naked eye as if they were detached from the main track, but with a low power of the microscope the empty channels can be traced.

It is impossible to give a proper idea of the appearance of the growth. The forms assumed are the most beautiful shapes I have ever seen, but they are very numerous, always, however, retaining the tendency to form curves and circles; thus we have the explanation of the appearances previously described in the test-tube cultivations.

(*c*) The appearances of the colonies on plates on which the mixture of bacilli and gelatinized infusion has been poured out is also very characteristic. The earliest appearance of colonies is a small oval or round group of bacilli. This group is not homogeneous in appearance under a low power of the microscope, but lines indicating the bacilli are seen in it. It very soon becomes pear-shaped, and from the sharp end of the pear processes begin to pass out into the gelatin as before described.

These bacilli do not grow below 16° C. The best growth in gelatin is obtained at a temperature of about 20° C. They grow most rapidly in cultivating materials kept at the body temperature. Very few spores are formed at the lower temperatures, but they appear rapidly and in large numbers at the body temperature. I have several times observed bacilli containing spores swimming about freely. The reaction of the medium is not of any great importance, but a neutral medium is apparently the best. The bacilli swim freely in fluids with a slow oscillating movement.

They grow rapidly at the body temperature in meat infusion with pepton and rendered solid by agar-agar, but the appearance of their growth is not nearly so characteristic as in gelatin. This, indeed, is the case with most bacteria, so that agar-agar preparations, though very useful for carrying on pure cultivations at the temperature of the body, are of little value for diagnostic purposes. They grow most rapidly on the surface of the agar-agar, forming a whitish layer, but the shoots described above in the case of gelatin do not occur, or only very imperfectly, in agar-agar. Here the bacilli arrange themselves apparently side by side, and, producing spores in this position, we have as a result, after a few days' cultivation, long rows of spores lying side by side with here and there an adult bacillus.

On potatoes they grow slowly, forming a dryish yellow layer on the surface. They grow very slowly indeed at the lower temperature. In order to get good growth it is necessary to keep the potato at the body temperature.

In milk they grow well at the body temperature, and in a few days cease coagulation of the milk, which also assumes a yellowish colour and gives off the odour previously described. The coagulum is not firm, like that caused by the *Bacterium lactis*, but is like a tremulous jelly, and may remain for a considerable time without the separation of any fluid, but ultimately it becomes liquid, and after some months assumes the appearance of a dirty, brownish-yellow, glairy fluid. It is very slightly, if indeed at all, acid.

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They grow extremely slowly in coagulated blood serum, though kept at the body temperature, and there form very long filaments with comparatively few spores.

In meat infusion kept at the temperature of the body they grow readily, causing muddiness, and after a few days a slight but not tenacious scum. The same peculiar odor is also developed here, more especially if the infusion contains a considerable amount of peptone. I do not think that there is any change in the reaction of the fluid; I generally make the infusions faintly alkaline, and after the growth of this organism in it it is faintly alkaline.

These characteristics show that this is a new bacillus, and one which, so far as my knowledge and experience goes, is only found in foul brood. The constant presence in large numbers of a characteristic organism in a disease and its absence elsewhere must, according to our accumulating experience, afford a strong presumption that the organism is the cause of the disease. In the case of foul brood this matter has been completely proved by the following experiments, the details of which will be found in Mr. Cheshire's part of this paper. With a cultivation in milk he sprayed a comb containing a healthy brood, allowing the spray to act only on a particular part of the comb. This part and no other became affected with foul brood. He has also succeeded in infecting adult bees by feeding them with material containing these cultivated bacilli.

I have also had the opportunity of watching the effect of feeding flies with material containing spores and bacilli. I was one day testing some milk in which these bacilli were growing; a large blue-bottle fly settled on it and commenced to eat. I at once put a large glass funnel over the insect, leaving plenty of air. When I came to the laboratory twenty-four hours later, the fly was in the sitting posture on the table and was dead. Its juices were full of these bacilli, as shown by microscopical examination and by cultivation.

Other animals which I have tested are more or less refractory to this bacillus. I have kept cockroaches for days in a box in which was milk containing these bacilli mixed up with sugar. I have also kept them in a box containing a piece of paper which had been thoroughly smeared with the spores. None of them died, but I can not be certain that in either case they ate any of the material, for I never saw them even near it.

I inoculated two mice and one rabbit with a spore-bearing cultivation without effect.

I injected half a syringeful of a spore-bearing cultivation into the dorsal subcutaneous tissue of each of two mice. One of these died in twenty-three hours, the other seemed unaffected, but in the second case I doubt whether the full quantity was introduced. In the case of the mouse which died, the seat of injection and the neighbouring cellular tissue was found to be very œdematous, but no microscopic changes were apparent in the internal organs. Numerous bacilli were found in the œdematous fluid, as also a number of spores which had not been sprouted, and there were also a few bacilli in the blood taken from the heart. This was proved, of course, by cultivation as well as by microscopical examination. On examining sections of the various organs no morbid changes were found, and only very few bacilli were seen in the blood vessels.

At the same time that I injected the mice I injected a syringeful of the same cultivation subcutaneously into a guinea pig. This animal died six days later with extensive necrosis of the muscular tissue and skin and cheesy-looking patches distributed through it. There was no true pus. On making sections of the necrosed tissue numerous bacilli, apparently *Bacillus alvei*, were seen, but there were other bacteria and also micrococci, as of course would be the case on account of the death of the skin. No micro-organisms were seen in the internal organs. It thus remains questionable whether the necrosis was due to the *Bacillus alvei* or not, more especially as I have since injected three guinea pigs subcutaneously with spore-bearing cultivations, but without effect. I must reserve the action of these bacilli on the higher animals for further investigation, as well as several other points of interest in regard to this organism to which I have not here alluded.

I venture to think that when all the evidence brought forward by Mr. Cheshire and myself is carefully weighed no doubt can be entertained that this bacillus is new to science and is the cause of foul brood. Many questions of course still remain open, requiring further investigation into the life history of the disease.

The next investigator to take up a bacteriological treatment of bee diseases was Prof. J. J. Mackenzie, bacteriologist of the provincial board of health of Ontario. The results of this work were published in the Ontario Agricultural College Report for 1892, pages 267–273. At the request of the Bee Keepers' Union of Canada certain things were taken up which had a very practical bearing on the question of eradicating the prevalent disease.

Professor Mackenzie knew of but one disease, probably, and having in hand the work of Cheshire and Cheyne, assumed that the disease found in Canada is the same as that described by Cheyne. This is a natural mistake after the confusion in the diagnosis by Cheshire. It was not the object of this investigation to demonstrate what organism produces the diseased condition, but, assuming that *Bacillus alvei* causes the trouble, to determine what resistance to heat the organism has.

No adequate description, such as would allow us to make any comparisons with *Bacillus alvei*, is included in Professor Mackenzie's paper. We do know, however, or at least have every reason to believe, that European foul brood was not found in Canada at that time and is not prevalent there now. I have been informed personally by Mr. William McEvoy, the veteran inspector of Ontario, that the disease which we now designate as American foul brood is the prevailing disease in Canada. It seems reasonable to suppose, therefore, that the samples taken to Professor Mackenzie by Mr. Holtermann and others did not contain any *Bacillus alvei*.

Professor Mackenzie does not indicate in his paper that he had any difficulty in getting the organism with which he worked to grow on ordinary media. *Bacillus larvæ*, which is present in American foul brood, does not grow in such media, however, so there is but one conclusion to be reached, and that is that he was dealing with some non-pathogenic form and not with *Bacillus larvæ*. Since the bacillus described by Doctor White as *Bacillus A* is found on combs, both diseased and healthy, and somewhat resembles *Bacillus alvei*, it may be that this is what Professor Mackenzie had.

This paper has probably come to the notice of but few bee keepers in the United States, because the report of the agricultural college is not widely distributed. To make it available for comparison, therefore, it is included here.

The Foul Brood Bacillus (B. Alvei); its Vitality and Development.

[From Ontario Agricultural College Report for 1892, pp. 267–273.]

Mr. J. J. Mackenzie, B. A., bacteriologist of the provincial board of health of Ontario, read the following paper:

Gentlemen: At the request of your secretary, Mr. Holtermann, I undertook for your union some investigations on the subject of foul brood, the results of which I propose giving you in this paper. Although it is almost a year now since I undertook this work under the auspices of the Agricultural and Experimental Union, it is by no means exhausted, and there are many points which require to be further elucidated, which I have not had time as yet to touch on, owing to the fact that investigations on foul brood had to be carried on simultaneously with my regular laboratory work. These points I hope to work at next summer, and reserve the privilege of reporting again to your union on the results of further investigation.

The subject of foul brood is an old one to apiarists and an intensely interesting one to Canadian bee keepers, but in reading over the bee journals one can not help being struck with the great want of unanimity amongst bee men as to the disease, how it should be treated, how it is spread, and on many other points. Some would have us believe that the disease arises de novo whenever insanitary conditions prevail; others claim that there is a specific infection and where the disease arises it must have originated from previously existing disease; some claim that the honey is the only method of transmittal; others that it is not, and so on. On every point there seems to be plenty of arguments pro and con.

I have attempted in my work to take hold of some of these controverted points from a bacteriological standpoint in order to aid in coming to some definite conclusion. Some of these points I should consider settled from the results of previous investigation; but as many bee men do not seem prepared to accept this, my work will have value as confirming what has already been done.

Before an association which includes many practical bee keepers it would be superfluous to enter upon a minute account of the clinical features of the disease. Most of you know them better than I do. I certainly would not be prepared to "spot" foul brood in an apiary, although I certainly think I can under the microscope. The infectious character of the disease has been generally accepted for many years, but not until Cheshire and Watson Cheyne worked it out scientifically was it definitely proved. They isolated a bacillus (*Bacillus alvei*) which they found in the diseased brood and which they cultivated on nutrient media for many generations, finally reinfecting perfectly healthy brood from these pure cultures. This evidence to a bacteriologist is absolutely conclusive that *Bacillus alvei* is the specific cause of foul brood. Consequently, when I began my investigations on some samples of diseased brood which were sent me through Mr. Holtermann, I looked at once for *Bacillus alvei*. Microscopically and by means of bacteriological methods I had no difficulty in isolating a bacillus which corresponds in all points to *Bacillus alvei*. It is a bacillus similar to that of Cheshire's in size, produces spores which are somewhat thicker, giving the bacillus a clubbed appearance. On agar jelly it grows rapidly so as to cover the whole surface. In gelatin its growth is very peculiar, shooting out from the infected point in all directions. On potatoes it produces a yellow growth. All these characters show conclusively that it is identical with *Bacillus alvei.* There seems no doubt, therefore, that the foul brood which we have in Ontario is the same disease and produced by the same bacillus as in other places.

Many prominent bee keepers, both here and in the States, however, maintain that wherever unsanitary conditions are allowed to prevail, wherever chilled brood is allowed to putrefy, or decapitated drones are left to decay in the hive foul brood may arise de novo. This is not a new theory, either in bee keeping or in medicine, but unfortunately it is a theory which is not supported by the results of investigation. Diphtheria naturally will develop more readily if unsanitary conditions are present, but it certainly will not develop if the *Bacillus diphtheriæ* is absent. The same is true of other diseases, and consequently when we come to consider such a decidedly infectious disease as foul brood and learn the facts about it which such men as Cheshire have told us we naturally come to the same conclusion. If I were to maintain that a Carniolan queen might lay an egg which would develop into a humble bee, bee men would be inclined to think that not only my bee knowledge, but also my scientific knowledge, was at fault; but yet in all the bee journals I find many prominent bee keepers maintaining that an ordinary microbe which produces putrefaction may become metamorphosed into the specific cause of foul brood. It it is easy enough, however, to combat such an opinion upon a priori grounds, but not quite so easy to offer convincing proof.

In order to do this I thought it worth while to try some experiments. With this end in view I obtained some comb containing chilled brood and endeavored to isolate *Bacillus alvei* from it, but without success.

There were plenty of other bacteria, but none which presented the well-marked morphological characters peculiar to *Bacillus alvei.* Again I had sent to the laboratory a piece of perfectly healthy comb. I killed the brood by chilling. Then I infected some of the cells from a pure culture of *Bacillus alvei.* I allowed all the chilled brood to putrefy in a moist chamber for two weeks, at the end of which time I obtained *Bacillus alvei* again from the cells which had been artificially infected, but could find no traces of it in the other cells. I left this comb in a moist chamber for several months and again examined, but with the same results. In the cells in which *Bacillus alvei* had been placed it was still to be found; in the others it was not present.

It seems to me that an experiment such as the above conclusively shows that there is a distinct difference between foul brood and ordinary putrefaction.

In considering the subject of the vitality of *Bacillus alvei* the first question which naturally arises is its power to resist heat. We know that bacilli which produce spores and those which do not stand in entirely different positions in this regard. The sporeless bacillus is destroyed at a much lower temperature than one which contains spores. Consequently in considering the question of the vitality of *Bacillus alvei,* which produces spores very quickly and easily, we may confine our attention entirely to the vitality of the spore.

This is of special interest, as the question has been repeatedly raised whether it is dangerous to use comb foundation made from foul-broody wax. Does the temperature to which the wax is raised in the manufacture of comb foundation sufficiently destroy the vitality of the spore? Can the spore germinate and infect the brood when once inclosed in the wax?

These questions have been raised by many careful thinkers among bee men, and certainly deserve attention. The second point ought to be considered first, since if surrounding a spore with a film of wax prevents its germination, we need pay no further attention to the question of heat. The crucial test of this would naturally be, supply a healthy colony with comb foundation known to contain the spores and observe the result. This I had hoped to try with the assistance of your secretary, but other work came up which interfered with the carrying out of this experiment and consequently it had to be postponed until next year. However, I was able to perform one experiment which throws some light on the subject. Mr. Holtermann, the secretary of your union, sent me several pounds of very fine wax, such as is used for the manufacture of comb foundation. I cultivated the *Bacillus alvei* upon agar jelly until I had a large quantity of the bacilli containing spores; this was carefully scraped off the jelly and dried first in the air and then over sulphuric acid. The resulting grayish mass was pulverized with a sterilized pestle and mortar, and finally mixed thoroughly with the melted wax kept at a temperature sufficiently low to prevent the immediate destruction of the spores by heat. By this means an enormous number of spores were introduced into the wax. After stirring the wax for some time in order to insure a proper mixing it was allowed to cool. This, as you all know, takes some time when dealing with a considerable quantity. During the cooling I was careful not to disturb the wax.

After it had solidified I set out to discover if I could again obtain my bacillus from the infected wax. If it would germinate in the nutrient media, it certainly would in the bees, and that point was to a certain extent settled. Now I obtained the following results:

From the upper layers of the infected wax I was unable to obtain cultures of the *Bacillus alvei*, either by melting the wax in the nutrient jellies or by allowing particles of the unmelted wax to fall on the surface of these jellies.

From the under layers, however, the results were different; particles of wax placed on nutrient agar in an oven kept at 98° F. became surrounded in twenty-four hours with a luxuriant growth of *Bacillus alvei*. When the wax was melted into the agar or into beef tea, I also obtained the bacillus, consequently it looks as if the mere fact of enveloping the spores with a film of wax was not sufficient to prevent germination. I confess I can not understand how a spore could germinate when surrounded with a film of wax. Spores in germinating require moisture, and if a spore is completely embedded in wax, it can not obtain sufficient moisture to germinate; I would rather believe, therefore, that in this particular experiment the spores had not each an envelope of wax, but that many of them were partially free from wax. Now, if this was the case in my experiment, where I endeavored to make the incorporation of the spores in the wax as thorough as possible, I certainly think it may frequently be the case when foul-broody wax is used and no particular precaution taken. That even when spores are thoroughly surrounded by wax they may not be freed occasionally by the workers is a point which requires further elucidation and upon which I intend to try some experiments next year.

In looking through the bee journals, however, I find it everywhere maintained by foundation makers that they never knew of a case of foul brood originating from foul-broody wax; and I have yet to discover a well authenticated case where this has occurred. What explanation can we offer of this widespread opinion?

I explained to you above that I was unable to cultivate *Bacillus alvei* from the upper layer of the infected wax. Your secretary also sent me a small specimen of wax which he stated he knew to be from foul-broody comb. This I examined repeatedly for foul brood, but was able to obtain it only once. I think we must look to the physical conditions for an explanation of the freedom from infection through comb foundation. The difference in the specific gravity of the bacteria and of melted wax is so great that throughout the process of manufacture the bacteria tend to fall to the bottom. The first refining of the wax must, of course, remove the greater quantity, and the vast majority of the remainder will settle to the bottom during the process of foundation manufacture. But that the simple process of mixing the infected material with the melted wax is not sufficient to prevent germination I think is shown by the results quoted above, where simple fragments of infected wax when placed on agar jelly gave rise to a culture of *Bacillus alvei.*

This question I hope to touch on again after I have had an opportunity of supplying healthy bees with foundation made from infected wax.

The other question is whether the temperature to which wax is raised during foundation making is sufficiently high to destroy the spores of foul brood. In order to decide this question there are several points to be noted. The first is the character of the heat. We know that moist heat will destroy bacteria and their spores much more quickly than dry heat, and Mr. Corneil, of Lindsay, has raised this point several times, claiming that the heat to which the bacteria are exposed in melting wax is not moist heat but dry heat, consequently we must heat to a high temperature and for a long time in order to destroy the spores. The point is undoubtedly well taken, and can only be settled by direct experiment. In order to determine the temperature at which the spores are destroyed in melted wax, I used a method that was first described by Koch. Sterilized silk threads were saturated with a beef-tea culture of *Bacillus alvei* in which there were large numbers of spores. These threads were then allowed to dry and in the dry state were preserved. These dried threads were introduced into the melted wax and allowed to remain in it for a definite time at a fixed temperature. At the end of that time the thread was introduced into the melted agar or into beef tea heated to the melting point of wax, and thoroughly shaken, so as to separate the wax as much as possible from the threads; then the culture medium was rapidly cooled, and the tubes placed in the ordinary cultivating oven kept at 98° F. If I obtained a growth of bacilli, I concluded that the threads had not been sufficiently heated in the wax; if I did not, I concluded that they had been sufficiently heated. The following are my results:

At 212° F. (100° C.):

For one-quarter of an hour: Growth.
For one-half an hour: Growth.
For one hour: Growth.
For one hour and a half: Growth.
For two hours: Growth.
For two hours and a half: No growth.

At 194° F. (90° C.):

For one-half hour: Growth.
For one hour: Growth.
For two hours: Growth.
For three hours: No growth.
For four hours: No Growth.

On the other hand, a temperature of 122° F. (50° C.) did not destroy the spores in twenty-four hours.

I have repeated these experiments several times with the same results, so that I would conclude that to destroy the foul brood in wax it is necessary to heat to a temperature of at least 194° F. for at least three hours. Now the question arises, does this take place during the process of manufacture of comb foundation? In order to get as much data as possible on the subject I wrote to Mr. Larrabee, of Michigan Agricultural College, as he had kindly offered me any assistance in his power. He applied to two prominent foundation makers for information. From their replies it is apparent that, for a short time at any rate, during the refining and purifying of the wax it reaches a temperature quite at or near 212° F. During sheeting, however, it apparently does not reach a temperature much above the melting point, say 175° F. They both seemed to agree that steam heat for too long a time injures the quality of the wax.

In the American Bee Journal, 1891, page 470, we find some statements on the subject in a reply by two prominent foundation makers to an article by Mr. Corneil upon the dangers of infected comb foundation. One of them, Mr. Dadant, states that in refining it is heated for some time at 212° F. and is kept liquid for twenty-four hours. The other, Mr. M. H. Hunt, states that it is kept at the boiling point for six or seven hours. If these are the actual temperatures reached during foundation making, I am inclined to think there is little danger from foul brood in that direction.

I thought it possible that the whole question could be settled by introducing a certain amount of some disinfectant—say beta naphthol—into the melted wax, but my results have not been satisfactory. Apparently even the introduction of 1 per cent beta naphthol into wax did not hasten materially the destruction of the spores. I was able to demonstrate the presence of living spores in wax containing 1 per cent beta naphthol and heated for two hours to 194° F.

From all these facts, and taking into consideration also the physical fact of the settling of the bacilli to the bottom, I should think that with reasonable care in the preparation of comb foundation the dangers of infection from this source would be slight. But that the spores may germinate after being mixed with the wax, I think I have shown.

Why the spores of the *Bacillus alvei* are killed so quickly in the melted wax I am not able to explain, but it may be due to the fact that the wax itself when heated to such a temperature has an antiseptic value. That the spores resist other antiseptics as strongly as do the spores of anthrax I have proved by testing.

Cheshire and others recommend a solution of 2 per cent carbolic acid for disinfecting the hive after removing infected comb, but on actual experiment with the infected silk threads I have found that 2 per cent carbolic acid did not kill the spores in six days. These results are similar to those obtained by Koch for the spores of anthrax, and show that 2 per cent carbolic acid can not be relied on to destroy the spores. However, the question of the value of antiseptics I will take up more in detail later on in this paper.

I would like to say a word or two now on the methods of treating the disease. There are practically two methods: first, the starvation method; second, the method of medicated sirup. Mr. McEvoy's method of treatment, it seems to me, is practically a modification of the starvation method. The first method is widely used both here and in the United States, whilst in England and Europe generally the second method is adhered to.

Considering the vitality of the spores of foul brood, it would seem at first sight useless to try any process which did not recognize as its foundation the destruction of the germ. I find, however, that many prominent bee keepers who have had practical experience with the method of starvation, or Mr. McEvoy's method, accept it as successful. I have not had an opportunity to examine colonies which have been cured in this manner, and so can not say that the bacilli have disappeared. I hope next summer to test this question more fully. We may, however, examine into the rationale of the method. In conversation with Mr. Corneil, of Lindsay, he made a suggestion which may be quite familiar to you all, but which seems to me the only explanation. That suggestion was that either starvation or comb building carried the infected nurses past the period at which they act as nurses and gave them a chance to rid their intestines of the germ. If this is combined with a removal to absolutely clean hives, with new foundation, it may succeed, but I must say that absolute cleanliness in this respect must be insisted on. As I said above, I have not had any opportunity of investigating the results of these methods practically, and so can not speak with certainty.

The fact of the presence of the bacilli in the workers and in the queen bears, to a certain extent, upon this question. Cheshire and others make the statement that the bacilli are found in the intestines of the workers and in the ovaries of the queens. My own experience confirms this. I have found them repeatedly in the workers, and in five queens from infected hives I succeeded in obtaining the bacillus from the ovaries of three. That they are not always present in the ovaries of the queens from diseased colonies is certain; their presence there is apparently accidental. For instance, in the case of one last year's queens in a hive rather badly diseased I was unable to find the bacillus, whilst in a six weeks' queen from a hive in which there were only a few diseased cells I succeeded in finding it.

Cheshire's statement that he found a bacillus in an egg of an infected queen seems to me to require confirmation. I have not been able to find the eggs infected myself, but it is a question which would require very long and careful investigation before one could be able to deny or confirm such a statement.

In the second method of treatment by medication I do not think that an absolute destruction of the spores takes place, any more than in the starvation method. As I have shown above, 2 per cent carbolic acid was not sufficiently strong to destroy the spores, consequently it is not likely that 0.2 per cent (1 part in 500) would be strong enough. I tried 0.2 per cent, but found it quite unsuccessful. Its action then must have another explanation. To test this I made up a sterilized beef broth containing 1 per 500 of carbolic acid, and in it placed my infected silk threads. I found that there was no indication of growth. These threads were then taken out and placed in ordinary sterilized beef broth, and I obtained a luxuriant growth, i. e., the 0.2 per cent carbolic acid in the culture fluid, although it did not destroy the spores, prevented their germination. That, then, is the explanation of the value of carbolated sirup in the treatment of foul brood, it prevents the germination of the spores. The bee journals contain numerous examples of cases where carbolated sirup produced an improvement, but as soon as it was stopped there was a relapse. It is evident that here again, as in the starvation process, there must be combined an extremely thorough cleaning up, so that the best possible results may be obtained from the treatment. Medicated sirup does not destroy the spores, it simply prevents their development and gives the bees a chance to rid themselves of the infection, and in that respect I certainly think resembles the starvation process. Its advantage over that is that it can be carried on for a longer time.

In the course of these experiments I tried another substance which has been much used since Lortet's work on the subject, viz, beta naphthol. I do not think myself, from recent work on this substance, that beta naphthol should be ranked very high as an antiseptic, mainly on account of its insolubility in water. I found, however, that a beef broth containing 1 per 1,000 beta naphthol would not allow spores of *Bacillus alvei* to germinate, and consequently had an equal value with 1 per 500 of carbolic acid. It has an advantage over carbolic acid on account of the disagreeable taste of the latter, and I think would be more acceptable to the bees.

Salicylic acid in sirup has apparently the same effect, but I would not recommend the addition of borax, as Behring has shown that borax lowers considerably the antiseptic value of salicylic acid.

I tested also formic acid in the same way, but my results so far have not been satisfactory, owing to the uncertain strength of my sample of formic acid. I prefer to reserve a report upon it and other substances which I wish to try until later.

Mercuric chloride I have not tested, as I do not think it wise to use it around the hive. The idea of using a 1 per 1,000 solution to spray the diseased combs, as suggested sometimes, is, I think, absurd, and would be a rather serious operation for any living brood.

You will see that I consider all these methods of treatment do not in themselves necessarily presuppose the destruction of the spores, but depend upon the fact that for a longer or shorter period the spores are prevented from germinating, and in this period they are eliminated from the infected bees. Whether the vitality of the bees themselves has an effect upon the elimination or destruction of the spores is a point which would be extremely interesting, but one on which at present we have no definite information. From the results of bacteriological work on other diseases we know that the animal body is engaged in a constant warfare with the disease germs which may be introduced, and this also may be the case in foul brood. Much more extended investigations, however, would be necessary to prove this. It is much safer for apiarists to accept the possibility of a recurrence of the disease after a course of treatment, owing to the lodgment somewhere of some of the spores of *Bacillus alvei*, and by care and cleanliness remove this possibility. To do this the hives and frames in which a foul broody colony has lived must be sterilized, and this may be done in various ways. For the sterilization of material by disinfectants there was a tendency formerly among bacteriologists to run to such disinfectants as corrosive sublimate, carbolic acid, etc., but later work has shown that there are a number of common chemicals which will act just as well, or perhaps better. Corrosive sublimate has lost much of its reputation as a disinfectant within the last few years, and carbolic has been shown to be not nearly so powerful as at first supposed.

For cleaning hives and frames which are suspected to contain the spores of foul brood a hot 10 per cent solution of soft soap is perhaps as effectual as any that can be recommended. A good strong solution of washing soda, when hot, is also very active, destroying the spores in a few minutes. Both these are certainly better than 5 per cent carbolic for disinfecting the hives and frames, as their cleansing properties are so much better than it, and Behring has shown that 5 per cent carbolic requires at least three hours at blood heat to destroy the spores of anthrax. In case the soap or the washing soda is used, however, it must be used as hot as possible. Of course anything which is of no value should be burned.

I trust that in this paper I have thrown a little light upon some of the facts in connection with the disease of foul brood, but, as I stated in the beginning, I reserve the privilege of submitting to you at a future meeting the results of next summer's work.

Before closing I desire to express my thanks to your able secretary, Mr. Holtermann, for the assistance which he has given me, and also to Mr. Corneil, of Lindsay, for advice and for the use of volumes of all the principal bee journals, which he has supplied me with; also to Mr. Larrabee, of Michigan Agricultural College, in connection with the subject of comb foundation.

The next investigation to be considered is that by Prof. F. C. Harrison, professor of bacteriology of the Ontario Agricultural College. Previous to this Dr. William R. Howard published a paper on the subject, but this can be discussed better at a later time. In the paper by Professor Harrison, previously mentioned, the author gives a detailed description of the bacillus with which he worked. The description is as follows:

THE ORGANISM.

Bacillus alvei, Cheshire and W. Cheyne, 1885, from the larvæ of bees suffering from the disease known as foul brood, la loque (Fr.), and faul brut (Ger.).

Morphological characteristics.—In form the organism is a slender bacillus, with ends slightly pointed and rounded. "In the larval juices it is about $\frac{1}{7000}$ of an inch in length and $\frac{1}{20500}$ in breadth. On agar the bacilli vary considerably in size, averaging $\frac{1}{7260}$ inch, some small as $\frac{1}{10000}$ inch, and others as large as $\frac{1}{5000}$ inch. When they have attained the latter size, division of the rod seems to begin. They are always somewhat pointed at their ends. Their average breadth is $\frac{1}{30000}$ inch, ranging from $\frac{1}{35000}$ to $\frac{1}{25000}$ inch (Cheshire and W. Cheyne). Klamann (Bienenwirtschaftliches Centralblatt, Hannover, 1888, pts. 18 and 19) states that a clear space often appears in bacilli with pointed ends. From agar cultures twenty-four hours old, at 37° C., the bacilli average 4 μ in length and 1.0 μ in breadth. On gelatine cultures, grown at 22° C., they are somewhat shorter. They grow singly, but occasionally form chains of various length.

Stains.—With the ordinary aniline stains the bacilli colour rather badly (Eisenberg, Bakteriologische Diagnostik, Hamburg, 1891, p. 298, and Klamann, Bienenwirtschaftliches Centralblatt, Hannover, 1888, pts. 18 and 19). The best stains are methylene blue and methyl violet. The bacilli accept Gram's stain, but the spores are not colored by it. I find the most satisfactory stain in methyl violet.

Capsule.—No capsule has been demonstrated by Welch's method.

Flagella.—The bacilli are actively motile and possess a single flagellum at one pole. The motility of the bacillus is quite pronounced in fresh cultures obtained from bouillon, agar, and gelatine. The flagella stain by Pitfield's, Loefflers's, and Van Ermegen's method.

Spore formation.—Spores are formed by the bacillus, and are large oval bodies averaging in length $\frac{1}{12000}$ inch, and in breadth $\frac{1}{23700}$ of an inch. On agar the spores are arranged in long rows, side by side, and are greater in diameter than the cells from which they are derived. The earliest appearance of spore formation takes place in forty-one hours, at 36° C. (Cheyne), but in some cases it is even sooner. The spores are formed in the center of the rod, and the formation occurs as follows: The rod begins to swell and become spindle-shaped. Occasionally the swelling is more marked at one end than in the center. The spindle-shape increases in size, and the center of the swelling gradually ceases to take the stain. The capsule of the spore is apparently formed within the rod and is not merely the outer part of the rod. In three or four hours the rod is seen to have almost or completely disappeared, although parts of the faint outline of the ordinary bacillus may be noticed.

Germination of spores.—Under favorable conditions the beginning of the germination of the spores takes place in about three hours. The spore loses its oval shape, becomes elongated, and is soon seen to burst through the spore capsule. It then presents the appearance of a short rod, with a pale envelope embracing one end. The rod gradually leaves the spore capsule, and then goes on multiplying as a full-grown bacillus. According to Eisenberg (Bakteriologische Diagnostik, Hamburg, 1891, p. 298) the spores are decolorized by the tubercle bacilli stain, but preparations may be obtained by using the Ziehl-Neilsen stain and alcohol for decolorization. The spores also stain by the method of Neisser.

Polymorphism.—Variations in size and shape may be brought about by growth in acid media, or in media containing different sugars. These variations occur also in the same culture, subjected to exactly similar conditions of growth.

Involution forms.—Abnormal forms are especially abundant when the bacillus is grown on blood serum; peculiar Y-like forms and clubbed shapes are of common occurrence, and relatively few spores are found.

BIOLOGICAL CHARACTERS.

Bouillon.—"In meat infusion at the temperature of the body they grow rapidly, causing muddiness and, after a few days, a slight but not tenacious scum" (Cheshire and W. Cheyne). In bouillon, with a reaction of +0.08 (Report of Convention of American Bacteriologists, Journal American Public Health Association, Vol. XXIII, 1898), at 37° C., there is a slight turbidity in fourteen hours, especially noticeable when the tube is shaken. In twenty-four hours, the liquid is uniformly turbid, with a very fine sediment. In forty-eight hours the turbidity increases and a pellicle commences to form. Reaction of the culture at this time, +0.07. After ninety-six hours the broth is clear, with a pellicle, white, rather massive, and somewhat tenacious. There is also much sediment. Reaction, after ten days' growth, neutral.

Glycerine bouillon.—Media with original reaction of +0.08. At 37° C. the bouillon becomes slightly turbid in twelve hours and quite turbid in twenty-four, with a fine, whitish pellicle on surface, which does not extend to the sides of the tube. If the culture is shaken, the pellicle deposits in flaky masses. The reaction is +1.2. In thirty-six hours the turbidity clears, leaving the media bright, with a smooth, thin, tenacious, and white pellicle on the surface. In many cases the pellice becomes very wrinkled and greasy looking. At the end of eight days the reaction is +2.2, and the bouillon is several shades darker in color, but quite clear. The reaction after fourteen day's growth is +4.2. At 22° C. the same changes occur, but growth is slower. The bacilli are relatively less numerous than in bouillon and are slightly shorter and thicker.

Glucose bouillon.—With a reaction of +2, at 37° C., the broth is more turbid than plain bouillon after fourteen hours' growth; and in twenty-four hours the sediment is heavy and turbidity very marked, but no pellicle. In forty-eight hours the media is opaque and cloudy, and the pellicle is beginning to form. In ninety-six hours the broth is less cloudy, but the sediment is heavier, and a white, thick pellicle is formed. It is often wrinkled, but not quite so much so as that on the glycerine broth. Reaction of broth after ten days' growth, +4.6. The bacilli are occasionally clubbed, and Y-like forms may occur. They average 5 μ in length and may be slightly curved.

Lactose bouillon.—With a reaction of +1.06, at 37° C., the growth resembles that of plain bouillon for the first twenty-four hours; but at the end of forty-eight hours, it is more turbid. In ninety-six hours, a tenacious pellicle forms, less massive than that on glucose broth. Reaction after ten days' growth, +2.4. The bacilli average 3.5 μ in length.

Saccharose bouillon.—With a reaction of +1, at 37° C., the turbidity and sediment are heavier than any of the other bouillons. In forty-eight hours the broth is quite opaque and whitish looking. A heavy sediment is then present, and pellicle formation is just beginning. In ninety-six hours the cloudiness is about the same, but there is an increase of sediment, and the pellicle is thin and membranous. Reaction of media after ten days' growth, +4.04. The bacilli average 5 μ in length.

Gelatine plates.—At 22° C., in twenty-four to thirty-six hours, the colonies are small, round, oval, or lozenge-shaped, with peculiar projections or shoots from one end of the colony, giving it a pear-shaped or tadpole-like appearance, according to the amount of development of the projection. In many cases several of these outgrowths occur from different portions of the colony. By placing a cover glass on the surface of the gelatine and using objective 7, the bacilli may be seen moving around and around the colony and to and fro along the projections. At the end of forty-eight hours the colonies are larger. Fine processes or projections are shooting out into the gelatine in all directions, forming peculiar figures in circles or club-like forms. "It is impossible," says Cheyne, "to give a proper idea of the appearance of the growth. The forms assumed are the most beautiful shaped I have ever seen; but they are very numerous, always retaining the tendency to form curves and circles." After a time the gelatine is liquefied and the beautiful appearance of the colony is destroyed by the liquefaction of the gelatin.

These peculiar shaped colonies are most typical when the germ is taken from the diseased larvæ. After prolonged cultivation on various kinds of media, there is a tendency for the colonies to become round, and the peculiar branching forms are not seen in such numbers. The composition of the gelatine also seems to make a difference in the appearance of the colonies. In gelatine containing 12 per cent gelatine the processes are not so long. The same effect may be brought about by using more peptone in the composition of the media.

Gelatine tubes.—In stick cultures at 20° C. growth occurs all along the line of puncture. On the surface delicate branching or ramifying growth occurs in three days. These outgrowths soon run together and the gelatine is liquefied, first around the line of puncture, and in five days extends over the whole surface. The growth in the depth of the gelatine occurs as a whitish streak all along the needle track, and from this numerous shoots and growths branch out into the gelatine in all directions, giving a haziness to the appearance of the gelatine, which then begins to liquefy. If the inoculation is a heavy one, the shoots are coarse and may have club-shaped extremities, and from these swollen ends fresh shoots may start. Cheyne obtained the most characteristic growth in gelatine containing 3 per cent of peptone as well as 10 per cent gelatine. The whole tube is liquefied in from two to four weeks' growth. The liquid becomes yellowish in color and gives off a peculiar odor. Klamann states that in gelatin acidified with lactic acid the growth is slow and long threads are formed.

Gelatine streak cultures.—In gelatine streak cultures the appearance is very similar to what one sees in stick cultures. The bacilli first grow along the line of inoculation, and then throw out shoots into the surrounding gelatine, producing the appearance noted in the stick culture. The bacilli move to and fro along the channels of liquefied gelatine.

Agar plates.—On agar plates at 37° C. the colonies at the end of eight hours are small and burr-like, with spines protruding in all directions, giving the colony the appearance of a sea urchin. In some cases the projections are from one side or end. At the end of twelve hours the colonies have well-defined projections, visible to the naked eye. The colonies in the depths of the agar are more spiny, the processes being much shorter. On agar plates streaked with a light inoculation most beautiful forms occur. The growth of the bacilli spreads over the surface and branches repeatedly, giving the appearance of seaweed. This appearance is distinctly characteristic; and as the growth is very rapid, this method commends itself for making a quick diagnosis of the presence of the bacillus in larvæ supposed to be diseased.

Potato cultures.—On potatoes the growth differs considerably, according to the reaction and age of the potato. Sometimes a brownish wrinkled growth forms, which gives off a peculiar odor; at other times a dryish yellow layer appears. "The bacilli grow very slowly indeed at 20° C." (Cheyne, Journal of the Royal Microscopical Society, 1885, p. 381). Even at 37° C. they grow slowly.

Milk.—In milk at 37° C. coagulation of the casein occurs in three days. The milk becomes yellowish and gives off a characteristic odor. After several weeks' growth the curd is digested and a whey-like fluid remains.

Blood serum.—On blood serum at 37° C. the growth is rather slow and polymorphic forms are common. "Very long filaments are formed" (Cheshire and W. Cheyne, Journal of the Royal Microscopical Society, 1885, p. 381). These long forms may be from five to ten times as long as the average bacillus growing on gelatine, and consists of single cells. The filaments are often wavy or twisted and of unequal thickness. The extremities of the long, bent rods are often clubbed; and Y-like forms are numerous. Spores are formed very sparingly, and the blood serum is liquefied.

Synthetic media (Uschinsky).—In Uschinsky's medium no growth occurs; but if the medium is neutralized, good growth ensues. The bacilli occur in threads and a pellicle is formed.

Dunham's solution.—The bacilli are small when grown in this solution. No threads form, but there is a slight indol reaction after nine days' growth.

Relation to free oxygen.—Cheyne states that the germs grow most rapidly on the surface of agar and arrange themselves side by side; and they produce spores in this position after a few days' growth. Eisenberg (Bakteriologische Diagnostik, Hamburg, 1891, p. 298) says nothing under the head of aerobiosis. Howard (Foul Brood: Its Natural History and Rational Treatment, Chicago, 1894) writes that, "It grows best under anaerobic conditions; is a facultative aerobe; grows under the mica plate, and in the presence of oxygen the growth is slight and slow." Howard also states that under anaerobic conditions it emits a foul odor resembling that of foul brood. It will be thus seen that Cheyne and Howard do not agree on this point. The former author also says that the characteristic odor is given off under aerobic conditions, whilst Howard states that this smell is emitted under anaerobic conditions. Further, Cheyne states that the bacilli grow with great rapidity on the surface of agar, whereas Howard obtains his best growth under the mica plate, which does not give complete anaerobiosis. Howard's conclusions are thus at variance with Cheyne's, and my own results fully corroborate those of the latter author.

Howard states that the vitality of the spores of *B. alvei* is destroyed when exposed to atmospheric air from twenty-four to thirty-six hours. In making his experiments he took sterilized road dust and mixed it with the dry foul-brood masses from several cells, which were previously dissolved in distilled water. The mixture was worked dry and spread on sheets of paper, and trial cultures were made immediately and at intervals of every twelve hours for three days; and, according to his results, no growth occurred after thirty-six hours. In giving these results, Howard does not state whether he exposed the spores to sunlight or diffused light; nor does he mention the age of the dry foul-brood masses, which he used from several cells. These are points of considerable importance, for, as everyone knows, the disinfecting power of direct sunlight is much greater than diffused light, and the vitality of the spores from foul-brood masses of different ages varies considerably. This, I may add, has been clearly shown by some of my experiments, subsequently described. In my experiments the spores obtained from a pure culture on the surface of agar were spread on cover glasses and placed in a glass chamber, so arranged that a current of air was constantly circulating over them. This chamber was exposed to the ordinary light of a room with six large windows, and a cover glass was taken out every twenty-four hours and tested, to see if the spores would grow. This experiment was continued for one month, and at the end of that time the spores still germinated rapidly. In another experiment, spores spread on cover glasses were exposed to a very diffused light, simulating, as far as possible, the amount of light which would enter a hive. Cover glasses were taken out from time to time and transferred to agar, in order to ascertain if the spores were alive or not. The experiment was begun two years and four months ago, and from the last cover glass taken and placed upon the surface of an agar plate a copious and typical growth of *B. alvei* was obtained. Further, thin strips of filter paper, plunged into a bouillon culture and allowed to dry, were threaded on a wire suspended in a wire basket and so exposed that the air could freely circulate around them in the ordinary light of a room. Trial cultures were made at intervals, and at the expiration of six months the spores from the paper germinated when strips were placed on the surface of agar.

Again, a drop of bouillon containing spores was placed in a sterile tube and allowed to dry; and at the expiration of one hundred and twenty-four hours (thirty-six of which were in sunlight at a temperature varying from 30° to 37° C.) sterile bouillon was added. The tubes were then placed in the incubator, and in less than twenty-four hours a good growth of the germs had taken place.

From these experiments it will be seen that the results are directly at variance with Howard's statement, as they go to show that the vitality of the spores of *B. alvei* is not destroyed by exposure to atmospheric air, with or without sunlight, for even a much longer time than twenty-four to thirty-six hours.

With regard to the aerobiosis of this bacillus, good growth has been obtained in an atmosphere of hydrogen by Novy's method. Buchner's method also gave good results. The growths in the various media are very similar to those produced under aerobic conditions, but with this difference, that the surface growths are, as a rule, whiter in the hydrogen atmosphere. In illuminating gas (water gas) no growth occurred, but the spores were not destroyed by the action of the gas; for when the gas was let out of the Novy jar, good growth ensued on all cultures. In acetylene gas, a restricted growth occurred. In fermentation tubes growth occurred both in the open and in the closed arm of the tubes. No gas was formed, the bouillon in the closed arm was uniformly turbid. Thus *B. alvei* is a facultative anaerobe.

Production of alkali.—In ordinary bouillon a slight amount of ammonia is formed. Control bouillon did not give the Nessler test. In glycerine and the sugar bouillons, there is no trace of ammonia. Cheyne's cultures are faintly alkaline, both before and after inoculation in meat infusion. Klamann states that ammonia is produced.

Acids formed.—A varying amount of acid is formed. All the sugar bouillons give an acid reaction.

Formation of pigment.—On potatoes a yellowish growth is produced; on all other media, the surface growth is white.

Development of odors.—Cheyne states that gelatine cultures give off an odor of stale, but not ammoniacal urine, or what may be better described as a shrimpy smell; and this peculiar odor has been found by Cheshire to be distinctive of diseased larvæ. Klamann and Howard both state that a peculiar odor resembling that of the diseased larvæ may be noticed in artificial cultures.

The effects of desiccation.—I have already noticed, under the head of "Relation to free oxygen," that the spores of *B. alvei* have considerable vitality in withstanding desiccation. My experiments prove conclusively that the spores are extremely hard to kill by desiccation and in this respect resemble those of anthrax, which are known to resist thorough desiccation for a number of years. One experiment which showed this characteristic was as follows: An agar plate completely covered with a typical growth of *B. alvei* was allowed to dry out completely, and was left exposed to the ordinary light of the room for seven months, and at the end of that time, a portion of the film was scraped off with a knife, placed on suitable medium and incubated, with the result that a typical growth immediately ensued.

Spores on cover glasses were exposed to September sunlight (latitude 43°) for varying periods of time, and growth occurred after four, six, and seven hours' exposure. The age of the spores varied from five days to eighteen months; and spores three months old were not killed by seven hours' exposure.

From the symptoms given in this paper the disease with which Professor Harrison worked was doubtless American foul brood. From the discussion of geographical distribution this is also evident, for he says: "I have examined diseased larvæ from Canada, from Europe, * * * Cuba, and thirteen States of the Union, ranging from New York to California and from Michigan to Florida." American foul brood is thus widely distributed, but from all these specimens Professor Harrison obtained a bacillus which he called *Bacillus alvei*. Since we now know that *Bacillus alvei* is found in European foul brood and not in American foul brood, it is evident enough that the germ must have been another bacillus. European foul brood, as far as the author is able to learn, is not found in Canada nor Cuba, and, although now found in several States in the northeastern United States and spreading, is not, as Professor Harrison would have us believe, widely distributed in the United States.

How can this be accounted for? The only way open seems to be in the identification of the bacillus. I do not feel qualified to pass judgment on the accuracy of the description of Professor Harrison, but the matter has been referred to Doctor White, and he assures me that the description just quoted fits the bacillus which is described as *Bacillus A* as well as it does *Bacillus alvei*. If this is true, we can only conclude that Professor Harrison, not knowing of the existence of two diseases, made a serious error in his identification. In no place does he speak of any difficulty in obtaining cultures from American foul brood. For comparison, Doctor White's description of *Bacillus A* (possibly *B. mesentericus*) is here quoted.

BACILLUS A.

(*B. mesentericus?*)

Occurrence.—Found very frequently on combs, on scrapings from hives, and on the bodies of bees, both diseased and healthy.

Gelatin colonies.—Very young colonies show irregular edges, but very soon liquefaction takes place and the colony gives rise to a circular liquefied area, covered with a gray membrane, which later turns brown.

Agar colonies.—Superficial colonies present a very irregular margin consisting of outgrowths taking place in curves. Deep colonies show a filamentous growth having a moss-like appearance.

Morphology.—In the living condition the bacilli appear clear and often granular, arranged singly, in pairs, and in chains. The flagella are distributed over the body. The rods measure from 3μ to 4μ in length, and from 0.9μ to 1.2μ in thickness.

Motility.—The bacilli are only moderately motile.

Spores.—Spores are formed in the middle of the rod.

Gram's stain.—The bacilli take Gram's stain.

Oxygen requirements.—Aërobic and facultatively anaërobic.

Bouillon.—Luxuriant growth in 24 hours, with cloudiness of medium; a gray flocculent membrane is present. Later, the membrane sinks and the medium clears, leaving a heavy, white, flocculent sediment, with a growth of the organisms adhering to the glass at the surface of the medium. Reaction alkaline.

Glucose.—Luxuriant growth takes place in the bulb, with a moderate, flocculent growth in closed arm. The gradual settling of the organisms causes a heavy white sediment to form in the bend of the tube. The reaction is at first slightly acid, but subsequently becomes alkaline. No gas is formed.

Lactose.—Reaction alkaline.

Saccharose.—Reaction alkaline.

Levulose.—Reaction acid.

Maltose.—Reaction acid.

Mannite.—Reaction alkaline.

Potato water.—Reaction alkaline.

Agar slant.—A luxuriant growth takes place on this medium. The growth gradually increases to a moist, glistening one, being then friable and of a grayish brown color.

Serum.—A luxuriant, brownish, glistening, friable growth spreads over the entire surface. No liquefaction is observed.

Potato.—An abundant fleshy growth of a brown color spreads over the entire surface. The water supports a heavy growth. The potato is slightly discolored.

Milk.—Precipitation takes place rapidly, followed by a gradual digestion of the casein, the medium changing from the top downward to a translucent liquid, becoming at last semitransparent and viscid.

Litmus milk.—Precipitation of the casein takes place usually within 24 hours, followed by a gradual peptonization. Reduction of the litmus occurs rapidly, leaving the medium slightly brown; later the blue color will return on exposing the milk to the air by shaking. Reaction alkaline.

Gelatin.—An abundant growth takes place with rapid, infundibuliform liquefaction. A heavy, white, friable membrane is formed on the surface of the liquefied medium. A flocculent sediment lies at the bottom of the clear liquefied portion.

Acid agar.—Growth takes place.

Indol.—None has been observed.

Nitrate.—Reduction to nitrite is positive.

Dr. William R. Howard, of Fort Worth University, Fort Worth, Tex., has published several papers on the bacteriology of bee diseases. In a paper published in 1894 (York Publishing Company, Chicago) he attributed " foul brood " to *Bacillus alvei*. Evidently he was dealing with American foul brood, and we now know that *Bacillus larvæ* is present in that disease.

The same author undertook to determine the cause of pickle brood and described a specific fungus, *Aspergillus pollinis*. No investigator has since been able to find any such fungus in similar specimens.

In 1900 (Gleanings in Bee Culture, p. 121) this author published an account of some brief and entirely inadequate investigations made on what he chose to call "New York Bee Disease, or Black Brood." A specific organism, *Bacillus milii*, is described, but the view is expressed that this is modified, perhaps, by *Bacillus thoracis*. During the investigations of the Department of Agriculture it has been learned from whom Doctor Howard got his specimens, and the same men have furnished specimens which they declare to be of the same diseased condition as those furnished Doctor Howard. These, however, contain *Bacillus alvei*, and the disease is the same as that described by Cheyne, now named European foul brood.

It is most unfortunate for Doctor Howard that in not a single point have his descriptions been verified. Certainly it would seem unwise in him to put out the names *Bacillus milii* and *Bacillus thoracis* as new species without descriptions and after so short an investigation. We can not, therefore, sympathize very much with him when his views are overthrown.

The American bee journals and text-books on apiculture have until recently contained statements to the effect that *Bacillus alvei* is the cause of the disease which has been almost universally called " foul brood." This is due not only to the publications of Mackenzie, Harrison, and Howard, but very largely also to the attempt to determine *Bacillus alvei* by microscopic examination. The best-known case of this is probably the examination of diseased brood made by Mr. Thomas William Cowan, editor of the British Bee Journal. On a visit to Medina, Ohio, Mr. Cowan was shown a sample of diseased brood, and after a microscopic examination he announced that he found *Bacillus alvei*, and that the diseased condition is identical with that found in England. That this ropy type (for such it was) is found in England can not be doubted, but that the germs which Mr. Cowan saw were *Bacillus alvei* may well be doubted. I have taken particular pains to ask Mr. E. R. Root, who was present, whether Mr. Cowan made a cultural examination, and was assured that the microscopic examination was the only one made.

The announcement of this examination in Gleanings in Bee Culture and the A B C of Bee Culture, coupled with the excellent reputation of Mr. Cowan, made this appear convincing to American bee keepers. It must be remembered, however, that at that time no one had questioned the presence of *Bacillus alvei* in American foul brood and on finding bacilli the conclusion that they were *Bacillus alvei* was natural, even though erroneous.

Mr. Edward Bertrand, in his book "Conduite du Rucher," makes a similar announcement, stating that he and Mr. Cowan examined brood described as ropy and found *Bacillus alvei.*

[Mr. DADANT: I have received a letter from Mr. Bertrand. He informs me that they (Mr. Cowan and himself) had examined foul brood, but I know from the tone of the letter that no cultures were made.]

To indicate how much reliance may be placed in microscopic examinations in the absence of cultural tests, let me quote from Sternberg's Text-book of Bacteriology, 1901 edition, pages 13 and 14. It should be borne in mind that this refers to all microscopic examinations of bacteria and not specifically to bee diseases.

The bacteria are also classified according to their biological characters, and it will be necessary to consider the various modes of grouping them from different points of view other than that which relates to their form. This is the more important, inasmuch as we are not able to differentiate species by morphological characters alone. Thus, for example, there are among the spherical bacteria, or micrococci, numerous well-established species which the most expert microscopist could not differentiate by the use of the microscope alone; the same is true of the rod-shaped bacteria. The assumption often made by investigators who are not sufficiently impressed with this fact, that two micro-organisms from different sources, or even from the same source, are the same because stained preparations examined under the microscope look alike, has led to serious errors and to much confusion. As an example of what is meant, we may refer to the pus organisms. Before the introduction of Koch's "plate method" micrococci had been observed in the pus of acute abscesses. Some of these were grouped in chains—streptococci—and some were single, or in pairs, or in groups of four; but whether these were simply different modes of grouping in a single species, or whether the chain micrococci represented a distinct species, was not determined with certainty. That there were in fact four or more distinct species to be found in the pus of acute abscesses was not suspected until Rosenbach and Passet demonstrated that this is the case, and showed that not only is the streptococcus a distinct species, but that among the cocci not associated in chains there are three species which are to be distinguished from each other by their color when grown on the surface of a solid culture medium. One of these has a milk-white color, one is of a lemon-yellow color, while the third is a golden-yellow.

This brings us down to the work of Doctor White. His investigations were begun with Dr. V. A. Moore in 1902, and in January, 1903, a preliminary report was published. During the first year specimens of "black brood" were examined and to the surprise of the investigators *Bacillus alvei* was found in every case. Obviously, then, they were working with the foul brood of Cheshire and Cheyne (European foul brood). In a second short paper by Doctor White a brief note is given concerning some work done on the "ropy type" of foul brood. He recognized that he was dealing with a disease the cause of which had not been described and the disease is called for the time "X brood" and the bacillus, *Bacillus X*. The final results of the investigation appear in Technical Series, No. 14, Bureau of Entomology, under the title "The Bacteria of the Apiary, with Special Reference to Bee Diseases." Doctor White's description of *Bacillus larvæ* is as follows:

BACILLUS LARVÆ.

Occurrence.—Constantly present in diseased brood from colonies affected with American foul brood.

Gelatin.—There is no growth.

Morphology.—It is a slender rod, having a tendency to form in chains. This is especially true when grown in bee-larvæ bouillon.

Motility.—The bacillus is rather sluggishly motile.

Spores.—Spore formation takes place. This can be observed best in the different stages of the disease and decay of the larvæ.

Oxygen requirements.—When Liborius's method is used, the best growth usually appears near to but not on the surface. After a few generations a surface growth may be obtained.

Bouillon.—There is no growth.

Glucose bouillon.—There is no growth.

Lactose.—There is no growth.

Saccharose.—There is no growth.

Agar plate.—There is no growth.

Bee-larvæ agar.—The inoculations must be made with the medium liquefied. The growth takes place near to but rarely on the surface. Cultures must pass through a few generations before a satisfactory surface growth can be secured.

Bee-larvæ agar slant.—On the surface of this medium a thin, gray, nonviscid growth takes place.

Glucose agar.—Slight growth has been observed in the medium. No gas is produced.

Potato.—There is no growth.

Milk.—There is no growth.

Litmus milk.—There is no growth.

Fermentation.—In bee-larvæ bouillon no gas is produced.

Indol.—There is no growth in sugar-free bouillon.

To summarize, then, *Bacillus alvei* is found universally in European foul brood; *Bacillus larvæ* in American foul brood. No specific micro-organisms have been found for the so-called pickle brood or paralysis. Knowledge of the two worst brood diseases is accurate enough to enable us to combat them by applying principles acquired by comparison with results of work with other micro-organisms.

That our knowledge is complete is far from true. Not only is there much to be learned which is of purely scientific interest, but points of the highest practical importance are yet undetermined.

[NOTE.—Several other papers of importance have been issued on this subject which were not discussed at the Inspectors' meeting. They, however, have an important bearing on this subject. Lambotte decided that *Bacillus mesentericus vulgatus* causes "foul brood," or, in other words, that *Bacillus alvei* is but a variety of *Bacillus mesentericus*. His work, however, is far from convincing. The principal point of interest in this regard is that he had great difficulty in getting a growth from the ropy type of foul brood (American foul brood) on ordinary media. Burri in 1904 published an account of his work and found *Bacillus alvei* in a few specimens from Switzerland (indicating that European foul brood is found there), but found another organism which grows with difficulty; the latter is undescribed and unnamed, and it is possible and probable that he worked with *Bacillus larvæ* White. Maassen (1906) found the same difficulty, isolating *Bacillus alvei* in only 13 specimens of diseased brood out of 112 received. He, too, found an organism which could be made to grow on ordinary media only with difficulty and called by him *Bacillus brandenburgiensis*. It is undescribed, so far as is known to the writer. He also claims to have found another organism, *Spirochæte apis* Maassen, but has not established any causal relationship.

These papers all tend to confirm the work of Doctor White. *Bacillus alvei* is not found in the ordinary ropy type of "foul brood," but another organism is; this is probably the *Bacillus larvæ* of Doctor White.

In the face of all these facts several prominent bee men of England are attempting to discredit all this work, the criticism, so far as is known to the writer, being based entirely on comparisons of literature and on an entire lack of investigation. They have, further, misread the papers issued by the Department of Agriculture on this subject. It seems entirely unnecessary, therefore, to review the criticism in detail.—E. F. P.]

EXISTENCE OF BOTH AMERICAN FOUL BROOD AND EUROPEAN FOUL BROOD IN THE SAME COLONY.

Mr. ATCHLEY. Do you think that both diseases, American foul brood and European foul brood, could exist in the same colony?

Doctor PHILLIPS. Reports are sometimes received that a colony is infected with both diseases at the same time, but this is contrary to the experience of those persons most conversant with these conditions. While it may be possible for a colony to have the infection of both diseases at the same time, it is not by any means the rule, and such cases are probably not authentically reported.

Both diseases are found in New York State. The inspectors have to treat both diseases and they treat both in the same way, but they have never found both diseases in the same colony.

GEOGRAPHICAL DISTRIBUTION OF AMERICAN FOUL BROOD.

Mr. DADANT. Is not the American foul brood spread more over the world?

Doctor PHILLIPS. It would seem so from the literature. It is found in almost every State of the Union, while European foul brood is, as far as is known, found only in the States mentioned a while back.

Mr. Dadant. The American foul brood is characterized by the ropy condition. The French name for their common brood disease is "loque," meaning tatters, and this name therefore refers to what we call American foul brood.

Mr. Coggshall. Which of these diseases is the one found in Cuba?

Doctor Phillips. That is the American foul brood. It has the typical ropy character.

EFFECT OF CLIMATE ON VIRULENCE.

Mr. L. F. Juneau (Colorado). I would like to ask if brood diseases are equally bad in all States or has climate anything to do with the virulence of the diseases?

Doctor Phillips. Climate undoubtedly makes a great difference. The American foul brood of California is not anything like the same disease in the East. It is simply terrible in California. Mr. Rankin will tell us about that later in the day. It is the same disease, but its ravages are much worse.

Mr. Juneau. Mr. T. L. Thompson (Colorado) sent some pickle brood to Dr. W. R. Howard, and the latter called it "black brood," but said: "In your State it will not be so bad."

Doctor Phillips. It was probably not European foul brood. That disease has not been found west of the Mississippi River.

ASSOCIATION OF INSPECTORS OF APIARIES.

It was decided that it would be well for the inspectors of apiaries of the various States to be organized in some way to bring about greater cooperation in the work. After discussing the question it was finally decided that Mr. N. E. France, inspector of apiaries for Wisconsin, should act as chairman of a committee on organization and appoint his own associates.

SECOND SESSION, HELD MONDAY AFTERNOON, NOVEMBER 12, 1906.

Doctor Phillips. In the morning session we covered rather thoroughly the scientific side of investigations on bee diseases. That is, of course, important; but when it comes to the practical work on bee disease there are two subjects of much greater importance, namely, methods of treatment and legislation. We will first discuss the treatment of these two brood diseases and then take up the discussion, in so far as we can, of the laws now existing, with suggestions as to the form which a law should have to give the best results and the powers which should be given to the inspectors under the various conditions which may arise. I have, however, a paper that I wish to read first, which was written by Mr. Charles Stewart, of Sammonsville, N. Y., one of the inspectors of that State. I had the pleasure and privilege of spending four weeks in the field with Mr. Stewart last spring, and I feel that I can say that if there are any good inspectors in the United States one of them is Mr. Charles Stewart. Mr. Stewart is exceedingly sorry that he can not be here, and he requested me to read this paper to you.

APIARY INSPECTION IN NEW YORK STATE.

By Chas. Stewart,
Inspector, Third District.

Brother Inspectors: It is with a feeling of regret that I write this paper, knowing that it will be impossible for me to be with you at what must be both a pleasant and profitable meeting.

It is hardly necessary for me to describe European foul brood nor to refer to its entrance into New York State, except to say that it was brought in some years ago by a shipment of bees from one of the Southern States, and just as we were feeling that we had nearly stamped it out and were masters of the situation we discovered that at least one if not two fresh importations had been made in a section of the State where no trouble of this kind formerly existed.

I wish to call your attention to the fact that no bee keeper can feel reasonably safe from infection until every State in the Union is under the surveillance of a keen-eyed inspector who knows every spot of disease in his jurisdiction and allows no bees to be shipped out of such territory. Had the inspectors of New York State not adopted this rule, disease would have spread not only all over our State, but to far distant points, as many, fearing the loss of their apiaries, were eager to sell at a sacrifice. In order not to make this rule a hardship to our people, we have made it a practice to find a buyer within the diseased territory competent to cure the disease and so keep our troubles within our own family.

I wish I had the power to paint to you in words the pathetic picture when four good men and true, who had been bee keepers from boyhood and had large interests to protect, took up this work. I have seen the faces of strong men blanch with fear or turn crimson with anger at the first visit of an inspector, and later, when their bees were saved and their product marketed, the young man sent back to college, their little children cared for, or perhaps the home saved, these same men with tears on their cheek would give one a hand clasp that was far more eloquent than words and possesses a value beyond gold. I question if there is an inspector present to-day who from a mere money point of view would not be better off if he had given his entire time to his own business; yet I honor this American spirit you possess in that, having once started out to accomplish results, you refuse to turn back until the end is attained.

I hardly feel like posing as an instructor to this gathering of inspectors, but will call your attention to a few important points. A question often asked is, "How does the disease spread so rapidly?" I would answer, "By means of infected honey." No field bee from an infected colony goes out with its honey sack so empty of honey that it contains no germs, and on their return many bees mistake their hive and carry disease to their near neighbors in the same apiary, so that it is a common thing to find a badly infected colony and those in the same row infected in proportion to their distance from the source of contagion.

How the disease spread from yard to yard when no robbing took place was for a long time a puzzling question, until I found an apiary of black bees 3 miles from an apiary of golden Italians that were infected. In many colonies of the yard of blacks could be found a sprinkling of the golden Italians and in nearly every case these colonies showed traces of disease. Evidently bees are often driven by stress of weather or some other cause to seek shelter far from home, and thus disease may be spread.

We have found no bees immune from disease, yet some vigorous strains of Italians are nearly so. For years we have recommended the introduction of young Italian queens, but have warned the owner of an infected apiary not to depend on that alone, as it would prove disastrous in localities where the disease has just made its appearance and the bees are mostly black. This method will often prove very successful where European foul brood has existed for some time and lost much of its virulence, but, like the use of drugs, it is not a safe method for the inspector to advocate, while the shaking method has never failed us if done in a thorough manner. Colonies that are found to be diseased late in the season may be cured by taking away all their combs after brood rearing has ceased and giving them clean combs from a healthy colony, as any disease germs that are contained in the honey sack will have been eliminated long before brood rearing commences in the spring.

In conclusion I would say that to be successful as an inspector a man should not only be well versed in the management of bees and bee diseases, but he must be broad minded, even tempered, possess a liberal amount of tact and diplomacy, and be a shrewd judge of human nature. Yes, and even more, he should be able to win the confidence of others and share their burdens, and when the time draws nigh when the working tools of life shall drop from his nerveless clasp he may look back with satisfaction to a life well spent in the service of others.

Doctor PHILLIPS. When the notices were first sent out concerning this meeting I wrote to Mr. Fred A. Parker, of Lompoc, Cal., under the impression that he was inspector of Santa Barbara County. It seems that he has resigned and Santa Barbara County now has no inspector. He has, however, sent a paper, which will now be read:

AMERICAN FOUL BROOD ON THE PACIFIC COAST.

By FRED A. PARKER,

Former Inspector for Santa Barbara County, Cal.

During my term as inspector of apiaries for Santa Barbara County, Cal., in the year 1905, 4,073 colonies of bees were inspected. I discovered 47 cases of American foul brood and found 170 colonies not on movable frames. These were ordered transferred, and in some instances I did the work myself. Every case of foul brood was either burned or treated by the shaking method. Five were burned, being too weak in numbers to treat. Preparatory to burning, I would dig a hole about 2 feet deep and build a fire in it, then throw in the frames containing the diseased brood. After the fire did its work the hole was filled with dirt to prevent bees from getting diseased honey, if any might have been left unconsumed. If any comb was attached to the hives the latter were placed on the fire in the hole and when the interior was a mass of flames they were removed with a shovel, hoe, or other long-handled tool and water thrown on to extinguish the flames if the wood had caught fire. The bees were shaken into an empty hive and allowed to build comb on the lid for three days, when they were shaken onto frames with starters and allowed to proceed. The comb was scraped from the lid and the lid scorched. This treatment, if carefully performed, is successful in about nine-tenths of the cases treated. Bee keepers are generally too careless in handling the diseased combs, thus giving other bees an opportunity to steal a load of infected honey.

I have read many statements to the effect that queens do not carry the infection, but my experience has convinced me otherwise. I had shaken six diseased colonies in my own apiary in 1902 and four were completely cured. While I was equally careful in handling these cases the disease reappeared in two of them. I shook them again, and again in due time the disease appeared. This caused me to suspect that the queens were defective, and to test it I exchanged them with the queens of two perfectly healthy colonies, shaking the diseased stock again. In both cases the cure was complete, while the disease appeared in the brood of the formerly healthy colonies. This appears to me to demonstrate beyond doubt that the ovaries of queens are occasionally infected, that their eggs transmit the germs of American foul brood, and that the disease will develop in any colony to which they are introduced. If this occurs in one-third of the cases or one-tenth, it will pay to requeen in every case, unless you have an especially valuable queen you want to save, in which case it may pay to experiment. For that reason I now practice requeening every colony treated for American foul brood.

My experience with drugs has been unsatisfactory in every case. I have tried carbolic, rosemary, Bingham's sulphur plan (as outlined in Gleanings in Bee Culture, April 15, 1902), the formaldehyde spray plan (Gleanings in Bee Culture, December 1, 1903), and naphthol, but while all these drugs have the effect of checking the disease and preventing its spread over the combs as long as used, none of them cures it, regardless of the duration or persistence of its application.

I have not tried the formalin-gas plan, nor do I intend to try it, or any other drug treatment, so long as the shaking treatment will cure. While destruction of frames and combs is expensive, it is to my mind cheaper in the end than experimenting with every new cure that is exploited in the bee journals. After trying these you are forced to resort to the shaking treatment to make the cure complete, so why not use it at first and save the trouble and expense? So long as honey contains spores, so long will drugs fail, because they can not reach and destroy the spores. Even if a temporary cure could be effected the disease would reappear when the bees began feeding the larva this germ-laden honey. Nothing short of removing all the combs will make the cure permanent.

As an apiarist I have had experience in many infected apiaries, and in every yard where the disease has ever been, with one exception, a few cases develop every season, and will continue to do so until these old combs are retired. If a whole apiary is to be treated, it pays to save the wax and honey, but I do not believe in bothering with them if only a few hives are to be treated; it does not pay to take the trouble. Of course progress is desirable, and I would not discourage anyone who wants to experiment with drug treatments, but I believe if any good is ever derived therefrom, it will come from the work of experiment stations or trained scientists, who have the means and time to devote to it and do not have to depend on apiculture for a living.

American foul brood seems to act differently here than in most places. The question may arise, Is it American foul brood? It has the sunken, perforated cappings and the foul, glue-like odor, and it ropes from one-eighth to several inches. I have seen many cases where the brood chamber was badly affected with foul brood, but when a honey flow came, the queen moved up and not one cell of disease appeared. I have known these bees to cast strong swarms, which proved to be entirely healthy.

Again, I have known American foul brood to disappear without any treatment whatever. Mr. B. Dickens, one of the most intelligent and observing apiarists, had marked a colony for treatment. Not being able to attend to it for several weeks, he was surprised when he did open it to find every trace of the disease gone. I had the same experience this season. The most amazing case of this character, however, was the experience of Mr. W. J. Oates (now my business partner) in 1903. He purchased an apiary of 30 colonies, nearly every colony being badly affected with foul brood. The former owner, Mr. J. H. McGee, desired to get rid of the colonies, not caring to go to the trouble of shaking them. Mr. Oates treated the whole apiary by the shaking treatment. As soon as there was sealed brood in the hives, it was seen that disease had developed in about three-fourths of them. I examined these colonies myself, and if they did not have the disease after the shaking, then I never saw a case of American foul brood. Mr. Oates did nothing more to them, and, becoming disgusted with the proposition, he sold out to Mr. F. S. Moorehead and went to Nevada. The year 1904 was a poor season here, and honey was extracted from these hives once, I think. Nothing was done for the disease. In 1905 I inspected these bees, expecting to find them reeking with disease, but to my surprise I could not find a single case of foul brood; it had completely disappeared. Mr. Oates was surprised when informed of this, but he managed this apiary that season on the shares, and no disease developed. I had occasion to look through this apiary just last week, and not one case of disease exists there to-day. That is a case I can not understand, unless it is that by the shaking the bees were relieved of all diseased honey, and, being shaken in the fall, the queens ceased laying entirely later, and the bees cleaned out all infection. But I am unable to account for the wholesale reappearance of the disease, unless the treatment was carried out in a careless manner. I am certain that the circumstances occurred just as related. The Simmins plan is not a drug plan, and I intend to test it next season, if I find any American foul brood.

Sometimes disease spreads quite rapidly here, infecting one-half or more of the colonies in two seasons. Then I know of some apiaries where a few cases have existed for years without any perceptible increase. I know of one instance where an apiary was entirely destroyed by the disease in one season. Whether our climatic conditions have anything to do with the matter I do not know, but it is a fact that foul brood as it exists here is of a very erratic nature. Furthermore, it is dangerous, and a relentless war should be waged against it until it is exterminated.

A paper entitled "The appointment of inspectors," by Fred A. Parker, of California, was then read, in which the writer showed that the work of the inspector is far from easy. Many bee keepers criticize the work of the inspector as soon as their apiaries are examined, and fault is found with inspection and the inspectors. It is the duty of the bee keeper to uphold the inspector as long as he is doing honest work for the bee-keeping industry. The salary paid an inspector is in most cases smaller than the income he could make by remaining at home and doing the required work in his own apiary, so that inspection is usually done at a financial loss to the inspector.

Mr. J. M. Rankin (California). It has been my privilege since May, 1905, to be in touch with bee-disease work on the Pacific coast. During this time I have visited many diseased apiaries throughout the State of California.

Few eastern people have an adequate conception of the bee-keeping industry in California. It is not an uncommon thing for one man to own 4,000 colonies of bees. This, of course, puts the business on an entirely different footing than in the East. In the same way, conditions of disease are also different. The control of American foul brood among so many colonies becomes a much more difficult proposition than it is where the bee keeper owns only fifty to seventy-five colonies. There seems to be no doubt, also, that the American foul brood is much more virulent in California than in the East. Whether this is due to some climatic condition or not, I do not know. I have seen an apiary showing only slight infection in February become almost a total wreck in August. In California, also, the bees fly nearly 300 out of the 365 days in the year, and the honey flow in most parts of the State is of comparatively short duration. This makes conditions favorable for more rapid infection than in colder climates where the bees are confined to their hives during about half of the year.

Under such conditions you can readily see that treating the disease is difficult. It must be done at exactly the right time and under favorable conditions or the treatment is worse than useless. Some of the best inspectors in California use the shaking treatment, and all of them shake twice, as well as disinfect the contaminated hives. There are some few men who do not believe in treating by this method and who burn all diseased colonies, only saving hives when these are in good condition. In counties where bees can be bought for 50 cents a swarm it may not be a bad plan to destroy all diseased colonies, as this is certainly an effective treatment if the burning is complete.

A treatment very favorably thought of by some is that of thoroughly boiling all diseased material. A large tank is used and the diseased colonies, after having been sulphured the night before, are carried to the tank and all the combs thrown in. After all the wax is melted, the frames are removed from the tank and placed on the fire under the tank as fuel. This is certainly an effective way of eradicating the disease and can be recommended more highly than the burning plan, as by this means the wax is not destroyed.

California has the county system of inspection, and probably the smallest number of colonies which one inspector has to look after is 30,000. From that number the colonies run up to 150,000 in a single county.

Doctor PHILLIPS. What Mr. Rankin has just said is in line with my own observation during the middle of the summer. I visited one apiary in Ventura County, with Mr. A. G. Edmondson, the inspector for that county, and he showed me 151 hives. Two years ago this apiary was in the hands of a competent bee keeper and no disease was present. Ventura County is so large that the inspector can cover only one half in one year and the other half the next year. When we examined the apiary we found 15 healthy colonies and 136 hives in which the bees were dead or nearly so.

TREATMENT FOR BEE DISEASES.

In discussing the methods of treatment, it would be a good plan to call on each of the inspectors present and get each one to tell what method he employs. We should hear first from Mr. N. E. France, inspector from Wisconsin. He is the oldest inspector in the United States in point of service.

Mr. FRANCE. Referring to the paper which was just read, I have tried some of the methods of using drugs in the apiaries of competent bee keepers and invariably all these methods are failures in Wisconsin. The fumigating with formalin seemed for a time to check the disease, as did also some of the other drugs, but in the end they all are failures. The one method that has given universal satisfaction we owe to the oldest inspector in America, Mr. William McEvoy, of Ontario, and it has often been termed the "McEvoy method." The plan is to remove the bees from the infection and keep them away long enough to use up whatever infected honey there is in the stomach of the bee.

I am not satisfied to stop with finding disease in a yard and immediately prescribing treatment. In fact, I seldom, after looking over the yard and finding the disease, begin to prescribe treatment, for I feel that we are not yet ready for it. What is the use of treating when some neighbors might have diseased colonies? Take a wide circuit; then treat at once all colonies having disease. This has sometimes vexed the bee keepers, for they want me to stay and show them what to do at once, but I tell them that I see no good in treating colonies while leaving another source of infection.

I try first to instruct the owner of the bees to be careful in his management. If, in my judgment, he is one who keeps the apiary clean, and if I can depend upon him, I sit down and go over the "McEvoy" plan with him very carefully, asking him from time to time if he understands it. If he says that he does, I say: "Now, I am your student; tell me what to do. When you can tell me what you are going to do, I will trust it to you." In nearly all such cases they have treated it without my assistance, and cured it. I can not recommend anything better than the "McEvoy" plan.

Doctor PHILLIPS. There is just one thing I should wish to add to that. The treatment of taking bees from the infected combs was originated in 1769 by Schirach, as nearly as I can find out, and if we are going back to give credit to the originator of this plan, Mr. McEvoy is not the man to get that credit.

Mr. G. W. YORK (Illinois). Was not the plan original with Mr. McEvoy?

Doctor PHILLIPS. It was probably original with him, but it was advocated long before in many European works.

Mr. SMITH. The ground has been thoroughly covered by Mr. France. Two years ago Mr. France said to me: "Now, Smith, I have tried almost everything, but I find the 'McEvoy' plan the best. My advice is to use the 'McEvoy' treatment, as I have done." I have only had one case this year where I have had to make a second transfer, and I found that to be due to infection from a neighbor's colony that I did not get to treat the first time, but which subsequently was treated, and the bees were all right. I have no trouble, and I have great confidence in shaking. I don't alarm the bees. I shall give my method. In treating a diseased colony I use an extra hive, to which the bees are to be transferred, and an additional empty hive, in which I place the infected frames after the bees are shaken from them. The last mentioned is covered with a cloth to prevent other bees from robbing. First I move the old infected hive back, and in its place put a clean hive containing clean frames, with strips of foundation. The frames are lifted from the old hive, shaken in front of the new hive, and then covered up in the third hive, which is used to store infected frames. This is all done in the middle of the day. If there is no honey in the field, the colony should be fed well at night.

Mr. J. Q. STONE (Illinois). How do you treat the old hive?

Mr. SMITH. I either burn out the hive, paint it with kerosene oil and have it burned out, or wash it in strong salt water.

Mr. FRED MUTH (Ohio). When you shake the bees, they carry over honey, do they not?

Mr. SMITH. I set the hive right on the ground. I do not jar the frames hard enough to jar out the honey.

Mr. MUTH. You shake them off during the middle of the day. Is it not better along toward evening?

Mr. Smith. If you wait till evening you will never get through.

Mr. Muth. Do you use smoke in that operation?

Mr. Smith. I use no smoke.

Mr. Muth. How long do you keep the bees on the strips of foundation; do you feed them right away?

Mr. Smith. Yes.

Mr. Muth. You don't believe in starving them at all?

Mr. Smith. No, because the bees coming from the fields are loaded with honey.

Mr. Muth. Do I understand that the bees have these bacteria all over them?

Doctor Phillips. Yes; they have the contamination on them. When they are shaken they of course have it all over them, and when they are shaken off they doubtless take the bacteria with them.

The McEvoy system is the radical treatment of shaking twice, which the majority of bee keepers do not use.

Mr. York. If I mistake not, Mr. McEvoy recommends the second shaking.

Doctor Phillips. He recommends the second shaking after the bees begin to drop from starvation.

Question. What do you do with the unhatched brood in the infected hive?

Mr. Smith. My recommendation is to destroy the whole thing.

EFFECT OF REQUEENING ON DISEASE.

Mr. Dadant. Has removing the queens any value in treating the two diseases? Alexander, Simmins, and others have recommended removing the queens. Is this of any value in either disease?

Doctor Phillips. As has been stated before to-day, I spent four weeks last spring with the inspectors of New York State in the field. Both American foul brood and European foul brood are found in that State, but practically the same method of treatment is advocated by the inspectors for both diseases. Colonies found to be diseased are shaken according to the method which has been described several times in this meeting.

In order to save any healthy brood which is found in colonies infected with disease, the sealed brood from several colonies, four to eight, is piled up in hive bodies above a weak colony which is diseased. In seven to ten days all the brood which is worth saving will have emerged and the weak colony will have been changed to one strong enough to treat. This colony is then treated by the shaking method as were the others. There is no necessity of waiting more than ten days, for brood which was unsealed when the brood was first attacked will scarcely be fed sufficiently to emerge.

In addition to this treatment, the inspectors recommend the introduction of young, vigorous Italian queens from good stock. It has been shown repeatedly that Italian bees are less liable to disease than most of the black bees, especially of degenerate stock, as is so much of the black stock when no attention is paid to improvement. In a pamphlet issued in 1903 by the inspectors of New York the introduction of Italian brood was recommended. This is not advocated as a cure, however, but merely as a means of protecting the colony against future infection.

Reference has been made to the introduction of Italian queens as a method of curing disease, and to this method the name of Mr. Alexander is attached. In the article in which Mr. Alexander first advocated the plan he says, in part:

"How to rid your apiary of black brood" (By E. W. Alexander).[a]

This cure is on the line of introducing new blood into the apiary, * * * Go to every diseased colony you have and build it up either by giving frames of maturing brood or uniting two or more until you have them fairly strong. After this, go over every one and remove the queen; then in nine days go over them again, and be sure to destroy every maturing queen cell or virgin, if any have hatched. Then go to your breeding queen and take enough of her newly hatched larvæ to rear enough queen cells from to supply each one of your diseased queenless colonies with a ripe queen cell or virgin just hatched. These are to be introduced to your diseased colonies on the twentieth day after you have removed their old queen, and not one hour sooner, for upon this very point your whole success depends; for your young queen must not commence to lay until three or four days after the last of the old brood is hatched, or twenty-seven days from the time you remove the old queen. If you are very careful about this matter of time between the last of the old brood hatching and the young queen commencing to lay, you will find the bees will clean out their breeding combs for this young queen, so that she will fill them with as fine healthy brood as a hive ever contained. This I have seen in several hundred hives, and have never seen a cell of the disease in a hive after being treated as above described.

It is not necessary to remove any of the combs or honey from the diseased colony; neither is it necessary to disinfect anything about the hive. Simply remove the old queen, and be sure the young queen does not commence to lay until three or four days after the old brood is all hatched. This treatment with young Italian queens is a perfect cure for black brood.

In regard to those old queens that were formerly in your old hives, I think it best to kill them when you first take them from their colonies—not that the queen is responsible for the disease, for I am sure she is not; but a young Italian queen that has been reared from a choice honey-gathering strain is worth so much more to you that I can not advise saving these old queens.

I have experimented along this line considerably, and found, after the colony has been without a queen twenty-seven days, as above directed, it will usually be safe to give them one of these old queens, and the cure will be the same. Still, there have been exceptions, so I advise killing them at once.

The essential point in the treatment is to allow several days to elapse after the emergence of the last of the healthy brood before the queen begins to lay.

[a] Gleanings in Bee Culture, November 1, 1905.

There are several points in this treatment and its successful application by Mr. Alexander which may well claim our attention. In the first place, the scales formed by the dried larvæ of European foul brood are less adhesive than are those formed when American foul brood is present. It is therefore easier for the bees to clean out the cells, and in most cases, at any rate, a strong colony would do this. This is one point, then, in favor of the Alexander treatment of European foul brood.

Mr. Alexander's apiary is located in a portion of New York State (Delanson, Schenectady County) where European foul brood has been prevalent for several years. It is a matter of common observation that this disease becomes less virulent in any given locality within a few years, and it is very probable that this plan might be successful in Mr Alexander's apiary and not in localities where the disease is just appearing. At any rate, it is unwise to advocate its use in new regions when there is an established remedy—the shaking method.

The hives used by Mr. Alexander seem to me to have a decided bearing on this subject. They are several inches shorter than the Langstroth hive, and, as a result, in the spring, when European foul brood usually appears, there is not a large supply of honey on hand. This, taken into consideration with the fact that very little honey comes in before August 1 in that locality, is very significant. The hive is not full of infected honey, and consequently when the bees clean out the combs they get all the infected material present. That this method would be successful in a moderate-sized hive—e. g., a 10-frame Langstroth—may well be doubted, for in the twenty-seven days during which the colony is left queenless many cells containing contaminated honey would be left untouched. Either we must advocate very small hives or advise against the Alexander method as a cure.

The New York inspectors say that the publication of the Alexander plan has been a great detriment to bee keepers.

Mr. FRANCE. I visited a yard last year where there were 22 infected colonies. The owner wished to save some new drawn-out combs that were on hives free from the disease. As an experiment we used foundation with half of the colonies and in the others we put the new combs. Eleven had to be treated again, while the others, right in the same yard, did not. You can kill the germs in the honey, but you have to boil it until it is as black as molasses to do it.

Mr. LOUIS SCHOLL (Texas). I do not know that I can say much about treatment in Texas. We do not rely on the shaking treatment at all. Whenever we have had foul brood we have tried something as radical as could be practiced—that is, the burning of the diseased colonies. There is one trouble that we have here in shaking the bees, and that is that if we treat the bees during the honey flow there is so much danger of shaking out the honey and starting the disease again in that way. The other thing with which we have to contend is robbing. During a honey flow there is a good deal of inside robbing almost all the time. Until we find something that is absolutely sure and absolutely a good thing we shall resort to the burning of colonies whenever we find them infected. The way we use the fire treatment is to inspect the yards and then toward evening we dig a pit about 10 feet wide, according to the number of colonies to be treated, and build a brush fire. By the time we have that burning well we go to the colonies that are to be "treated" and use sulphur in a smoker. The entrance is smoked a little, and this kills all the bees. We go from one colony to another to kill the bees, to keep them from leaving the hives in handling; we know that no live bees can escape from those colonies. We remove the combs and burn them, then the bottom boards and the covers are treated over the flames. The hive bodies are stacked on a single bottom board, and from a small can of kerosene we pour just a little oil from the top down the sides; by throwing in some dry grass or anything of that kind, which has been lighted first, the fire will start at the bottom and the hive bodies will act as a chimney. In that way we scorch the hive bodies for a few minutes. As soon as these have been scorched sufficiently we close up the top with a bottom board or cover and close the entrance of the hive with earth; then we leave them for a little while for what we call "steaming."

Mr. Anderson. Is there any way of safely detecting American foul brood before the cells are broken, and how long is it after it is sealed before the cap is broken? That is a question I have been discussing at home, and I would like to know if there is a way that it can be detected. For instance, if you have not treated a colony successfully, or suppose American foul brood has been in your locality and you are waiting for it, can you catch it before all the larvæ are exposed?

If there are only two or three diseased cells in a colony and if you cut those out, will the disease go any farther? I have read that if the cell cappings are broken and you take out those particular cells you will never see the disease again in that colony. I have heard an inspector say that he can tell the disease in his own apiary. He claims that there is a way to tell it before the capping is broken, and he says he can take away the disease then and it will not reappear. I know he can, because he has proved it. He can tell where foul brood is before he can actually see it. He further says that the larvæ are killed, but do not show it for forty-two days afterwards. Now, I want to know if anyone else has found such to be the case.

Doctor Phillips. I think his record stands alone.

Mr. Anderson. I know this: If you cut this foul brood out before there is another exposure, you won't get it in that colony unless it is carried from somewhere else. I have proved that.

Doctor Phillips. As far as the forty-two days' time is concerned, I have no faith in it, because in most cases inside of forty-two days the colony would be dead. I have seen that demonstrated.

Mr. Holekamp. I might ask how early can the disease be discovered?

Doctor Phillips. Not sooner than the ropiness of the larvæ becomes evident. I never saw a sample of diseased brood from Texas, but, assuming for the moment that the conditions in this State are similar to those in California, the method described in the East is not going to work in Texas. It will work where the disease is not virulent. The same thing holds true for European foul brood. Where it has existed for five years it is easily treated, and the Alexander treatment is sometimes successful, but it is not when the disease first appears in a locality. As you know, European foul brood started in New York and is spreading to the Vermont line. You will find a great difference in the type of disease in Schoharie County and on the Vermont line. The same thing seems to hold in a different way for the American foul brood. The disease is much more easy to combat in the East than in the West. I visited California this summer. Inspectors there have proved to their satisfaction that Eastern methods are not satisfactory, and they told me that it is necessary to burn out the hives. Mr. Smith does not burn his hives, and the inspector in New York does not burn hives; they insist, however, that no honey and no wax cells remain in the hives and that the hives be clean. That does not prove satisfactory in California. We know that this one disease is a very different proposition under different climatic conditions, and in discussing treatment it is necessary to bring out this point. In discussing treatment in bee journals writers forget or do not realize that the plans which they advocate may not do in different places. As Mr. Parker said in his paper, the eastern treatment will cure nine-tenths, but the other tenth has to be taken care of. The disease seems to be much more virulent in the western part of the United States than in the eastern part.

Mr. L. Scholl. Our conditions are the same here as in California, I am sure. We have tried some of the shaking treatments, but they were unsatisfactory. On account of the character of the disease here, we think we are on the safe side in using the burning method until we can find something better. While Mr. Smith and others gave their method of shaking the bees, I wish to put the question whether these treatments would work west of the Mississippi River, and that is why we have been practicing such radical measures here. My brother, who is here from the Agricultural and Mechanical College of Bryan, Tex., working for Professor Conradi, has been conducting experiments on this shaking treatment, and you might get him to tell you something about it.

Mr. Ernest Scholl (Texas). I am glad to be called upon, because I have been paying close attention to the shaking treatment, and as soon as Mr. J. Q. Smith mentioned his method of shaking but once, I thought surely he is dealing with different conditions or it must have been an accident that he succeeded. My work has been mostly in the northern part of the State, but in one case I had some work in the central part. I thought I would try some experiments. We tried shaking once, but it would not work; the disease appeared just as badly as ever. We tried shaking twice; that worked better, so that shows that shaking once does not work here. I have tried many other experiments, and am still on the go, but this is the only point I want to bring out. Shaking once is not sucessful in Texas, and I don't think it ever will be. I don't see how Mr. Smith can be successful in treating, because the bees gorge themselves with honey. Down here, as soon as you open a hive the bees will run to the cells and, consequently, shaking once would not work; and, as my brother said, there is always some honey taken up and the bees carry it into the new hive.

Mr. Juneau. Mr. Smith's plan is satisfactory in Colorado. We shake our bees there, but we smoke them a little bit and we shake only when a honey flow is on. The honey will sometimes drip on the wings of the bees, but it is very seldom that foul brood starts again. I have been an inspector there for a number of years, and the general way is to shake the bees hard. We shake them a little bit differently. We put paper down and we shake when the honey flow is on and we save nearly all the brood—that is, the healthy brood—and let it stay twenty-one days. The reason for letting it stay so long is because there is honey around and the bees hatching out will use it. Not only do the inspectors instruct that shaking be practiced, but the State association has issued pamphlets, in which this treatment is explained, to be given by the inspector to each man who has foul brood.

Mr. D. C. Milam (Uvalde County, Tex.). In our locality we are governed by conditions. If the conditions are not favorable for shaking, we burn the bees, frames, and all. If the conditions are favorable, shaking is all right. Last May I shook five colonies in one apiary for experiment, and week before last I went there and they were all right, but honey was not coming in fast.

I wish to speak of another thing. In this apiary I watched especially to see if there was any disease of the unsealed brood and I found none. Two years ago I found the disease both in the sealed and unsealed brood, and the question comes up: Have we both diseases, the European and the American foul brood? I began to hunt for another disease attacking sealed brood, and I found it that year; but I looked further, and in 65 colonies which I shook off last spring you could not find disease in any unsealed brood. Last fall a year ago I went to one apiary that had several colonies in which the sealed brood was diseased. I told the family what they could do. I said: "You will either have to fight this disease and take care of the colonies through the winter or you can burn them up." I will say they were not bee keepers, and they said just to burn up everything. I agreed to this, but said that there were two colonies in the apiary that had only a few cells diseased, and I would experiment on them—that I would take them under my own management. I burned the rest, but I kept those two colonies until this spring. This spring they became weak and I set one colony on top of the other. Last week I went back there, although I had examined them some time ago, and they had starved to death.

One shaking, I am sure, will do under favorable conditions, but if the bees are not gathering honey, I would not advise shaking.

MEDICATION.

Mr. Dadant. Has anyone ever tried feeding medicated sirup? The reason I ask the question is because some people succeed with drugs.

Mr. Smith. Mr. Reynolds was the first man in Illinois who imported Italian queens. He said that after foul brood got into his bees and destroyed them he heard of a remedy that could be obtained at the drug stores, and the next time he transferred his bees he used this and he had good luck with them.

Mr. Dadant. After shaking them?

Mr. Smith. Yes, sir; and he ordered some of this drug from St. Louis just a short time ago. He said he was going to feed it to the bees next spring for fear they would develop the disease again.

Mr. Udo Toepperwein (Texas). It is a good idea to feed the bees sugar and naphthol beta.

Mr. Atchley. As Mr. Scholl has already stated, I don't believe treatment will eradicate foul brood in Texas. I have seen a few people that have experimented this season in shaking bees. We have never been able to determine results in shaking in one season. I have had the disease disappear in the summer and fall and the next year the colonies would be diseased again. Another point, in Texas bees are too cheap to treat. We can burn them and buy other colonies to replace them with less expense.

PICKLE BROOD.

Mr. SMITH. Is there anyone present whose bees have been suffering from pickle brood?

Mr. DADANT. Mine have, and I used oil of eucalyptus. I thought I had foul brood and I afterwards discovered that it was pickle brood. About every four days I fed some oil of eucalyptus and in three weeks there was no trace of the disease.

Doctor PHILLIPS. Would not that disease have disappeared without the use of drugs?

Mr. DADANT. I doubt it. I asked another bee keeper to try the same thing and the result was the same.

Doctor PHILLIPS. We have no proof that pickle brood is at all infectious. Oil of eucalyptus is a disinfectant; therefore I was wondering what effect it had.

Mr. HOLEKAMP. One of the members of the Missouri State Bee Keepers' Association, who was about 20 miles from St. Louis, asked me to come over and help with his bees. He said last spring that his bees were in a terrible condition; he was very busy and did not know what to do. A good many of the colonies were in bad condition. He put a tablespoonful of carbolic acid in a quart of water and sprinkled his bees with this. He told me they were all well except two colonies. He said he did not look at them. I looked at them and they were clean. He told me that he had colonies that had gathered in five days a super full of honey. He had about 10 square miles of Spanish heather, but these colonies that had been affected did not make any surplus, so there must have been some disease.

Doctor PHILLIPS. It might have been pickle brood. Pickle brood is sometimes pretty bad, but it will disappear.

EXPENSE OF TREATMENT.

Doctor PHILLIPS. Is it so expensive to treat bees? How much does the colony lose by shaking during the honey flow?

Mr. ANDERSON. We lose a honey crop. Take all that brood away from a colony and all that remains is the live bees. For ten days there is no brood started to take the place of what has been removed.

Mr. JUNEAU. It is altogether different in our country (Colorado). We shake bees, and they act just like a new swarm. I have had as high as two or three swarms from those that have been shaken, if they were ordinarily good strong colonies, and I believe it will do just as well to shake a colony during a honey flow as any time. It makes no difference.

Doctor PHILLIPS. That is the point I was about to mention. I know that in Colorado they sometimes shake bees whether there is disease or not, because they claim the bees do better. You talk about shaking bees being a very expensive operation, but you do not need any brood during the honey flow, and the time makes a great difference.

Mr. York. There is one thing to be taken into consideration. Bees are worth less per colony in Texas and California than in the East. When you talk to a man here about burning 30 colonies, it does not take all his bees.

Dr. Phillips. I do not know about Texas, but I do know that farther west an eradication of 50 colonies to many of the bee keepers of the West is not a serious proposition. The western bee keeper's normal increase is more than his loss, so it is not like the loss to a small bee keeper.

Mr. Atchley. In Texas we hardly ever find an apiary in which every colony has the disease; therefore, when we burn the affected colonies we have enough left to rebuild the apiary.

Mr. Rankin. In considering this matter of bee disease and bee inspection one sometimes wonders if the ideal inspector exists. It would seem that bee inspectors are born, not made. The fact that a man knows bee disease and its treatment does not indicate that he is necessarily a good inspector. The most successful inspectors of whom I know are men who not only know bee disease thoroughly, but also have the ability to handle the bee keeper whose bees they are inspecting. The successful bee inspector, then, must first of all be able to diagnose the disease and know it under all its varying conditions. Next, he must know its treatment and management under every condition which may arise; he must know every condition on which the success of the treatment depends. Then, last, but also of vital importance, he must be able to use tact in the handling of the men whom he is appointed to help. He must know from the appearance of a man and from the first words exchanged just how to proceed with that particular individual to secure the best results.

Let me add a word in defense of the inspectors. I know 14 of those in California personally, and among them are some very exceptional men. They are not all equally successful, although I believe they all know bee diseases thoroughly, but among the entire number I do not know a single man who is serving as bee inspector merely for the money he receives for the work. Let us give credit to whom credit is due. These men are doing good work, and it is through these men that the bee keepers must look for the suppression of bee diseases under the present system. Give them your support and encouragement, but never under any consideration criticize them in public in a way which would interfere with the work on bee disease. The laws provide for the removal of an incompetent man, and if a man is not competent to serve as an inspector let him be removed and a man put in his place who is competent, but under no circumstances subject an inspector to the criticism of the bee keepers of the community or of the bee-keeping press. This is unwise, for it gives the public a prejudice against inspection rather than against the individual inspector, while those few deserving of censure are perhaps unaffected.

BOILING HONEY FROM DISEASED COLONIES.

Mr. Muth. Mr. France has said that you can not kill the germs in honey until you boil and boil until the life is all out.

Mr. Rankin. All you have to do is to make a hot fire and the honey will boil. Of course you have got to boil it sufficiently long to kill the germs.

Mr. Muth. How large is the tank reservoir?

Mr. Rankin. Big enough to hold your combs; as Abraham Lincoln said of your legs, they must be long enough to reach the ground. The tank used by one bee keeper is 6 feet square and 4 feet high, and you would be surprised to see the amount it will take care of.

Mr. Theis (Wis.). Are the frames destroyed then?

Mr. Rankin. Yes; we never use any secondhand frames.

Mr. J. A. Rouse (Mo.). I would like to ask if that water does not get too thick?

Mr. Rankin. Not at all.

Mr. Rouse. How do you get rid of the honey? I tried that plan and found that honey and wax hung with the frames until they did not look like frames.

Mr. Atchley. Mr. Rankin's treatment is similar to ours except that we burn. The labor for digging ditches is very cheap. It would only cost us $5 to get ten ditches, and in each ditch we can burn 30 or 40 colonies. Our treatment is something like your California treatment, except that it is not so complicated and is less work.

Mr. Rankin. That is another phase of the proposition. Conditions are different in that also. In California you can not hire a man to do the work for less than $80 per month.

Doctor Phillips. We have gone over the subject of treatment thoroughly, and I think all persons here have arrived at about the same conclusion; that is, that it will not do for a man who has a few colonies in one part of the United States to write to our bee journals and tell us all what to do. We want to know what he is talking about. The vast majority of the men who write to-day know nothing about the varying conditions. What will work in one little county in the East will not work in the West, and vice versa, the methods of the West will not work in the East. Suppose that Mr. Scholl should sit down here and tell everybody in the United States to burn their bees.

Treatment depends upon the locality. Locality is an important factor, but what we have to do is to find out in what respect the locality is different, whether it is in climatic conditions or in the conditions of the honey flow. We are in just as much ignorance when we attribute difference to "locality" as if we did not recognize any difference. We must get down to the point where we know the individual factors involved. I anticipate that when some of the discussions that have been carried on this afternoon are read, they will open the eyes of some people that think they have had some experience with disease. We have men from the East and West who have different conditions to contend with. That is one reason why I have been in favor of an inspectors' meeting. Here we get on a common ground. Conditions from different parts of the country are discussed in a way that you can not obtain practically in any other way.

I have copies here of the laws relating to foul-brood inspection now in force. Some of these are deficient and others have valuable points which ought to be brought out. It seems that the best thing to do is to put a copy of them in the hands of every man who is an inspector, with a list of questions taking up the points which are covered by the laws, and ask each one to express an opinion concerning them. Then all that expert testimony should be collected and put on record, so that people interested in future changes of legislation may read it. If there is anyone here that would suggest how this subject should be handled, I should like to hear from him.

After some discussion, it was finally decided that the Bureau of Entomology be asked to prepare a list of questions to be sent to all the inspectors. (The future action in regard to this is discussed in the preface).

Mr. France then read the following paper:

THE HISTORY OF BEE DISEASE INSPECTION IN WISCONSIN.

By N. E. France,
Inspector of Apiaries for Wisconsin.

From 1870 to 1886 bee keeping was one of the profitable agricultural pursuits in Wisconsin. There was no limit to the bee pasturage of white clover, besides miles of basswood timber and large areas of wild flowers. Comb honey in all kinds of packages sold for from 25 to 30 cents a pound, queen bees for from \$3 to \$10, and full colonies were from \$10 up.

In 1886 one Wisconsin bee keeper received \$10,000 in cash from his 1,400 colonies, and started the first bank of Jefferson, Wis. Another apiary of 250 colonies yielded in 1882 29,000 pounds of honey; in

1884 30,000 pounds, and in 1886, with 240 colonies, it yielded 25,000 pounds. This bee keeper also became a partner in a bank. Another apiary of 175 colonies in 1886 yielded 32,725 pounds of honey and in 1891 the bees were all dead with foul brood. Another apiary of 200 colonies in 1900 yielded 21,000 pounds of honey, but in 1904 all the bees were dead. Another apiary of 50 colonies in 1897 yielded 3,500 pounds, but in 1900 all the bees were dead. Another apiary of 26 colonies in 1899 yielded 2,500 pounds of honey and in 1901 all the bees were dead. Thus I could enumerate a pageful of similar sad results of foul brood.

About this time the State Bee Keepers' Association voted to delegate to the president of the association the securing of proper laws for the eradication of this disease. With little help from the bee keepers, he had to see his efforts turned down. Two years later I was delegated as before, but without the personal help of our members the bill was ridiculed and lost. While before the legislative committee I learned better what must be done, and two years later a committee of all the officers of the State Bee Keepers' Association was delegated to act, with the promise that each State member would do his part. The committee got figures of facts about Wisconsin bee keeping and furnished each association member with copies of the same, with the request that each one see personally the member of the legislature from his district. Many members did as requested and our entire committee appeared before the first legislative committee and made good progress. When the last State committee on State appropriations was to consider our bill I was alone. Several other bills calling for aid were turned down before I had a hearing. I gave the committee these facts to consider: (1) There are 10,535 farms in Wisconsin, having 106,090 colonies of bees, which produce in one year 2,677,100 pounds of honey. (2) There are more than twice as many pounds of honey produced each year in Wisconsin as there are head of cattle or sheep. (3) One year's honey crop in Wisconsin would load 13 freight cars, or if placed all in full-weight pound section boxes, touching each other, a sweet honey walk 4¼ inches wide would reach 181¼ miles—more than the distance across the State. (4) The valuation of Wisconsin bees and products amounts each year to more than the appropriation made by the State for several State institutions. (5) The State Horticultural Society receives over ten times more aid from the State than the bees do, yet over three times as many pounds of honey as bushels of apples are produced. (6) Over 10,500 Wisconsin taxpayers and voters who send representatives to the legislature are bee keepers and ask to be reasonably protected by law to save the bees.

After I was excused from the committee room the committee voted unanimously to recommend the bill for passage. It soon became a law, and an inspector was appointed in the person of the writer. Owing to false statements in the papers regarding the new office created, I met with all kinds of difficulties, such as being met at the gate with a shotgun and bull dog. At other times I was ordered from the premises with a pitchfork raised over my head, but each time I quietly explained why I was there, what I intended to do, and read the law, "or refuse to allow the inspector of apiaries to inspect such apiary, honey, or appliances shall be fined not less than $50 nor more than $100, or be imprisoned in the county jail not less than one month nor more than two months." Before going away I saw the apiary cleaned up in proper shape, the owner well pleased, and was requested, whenever in that part of the State, to call and see them. Now, when I am called to inspect or treat an apiary the bee keeper is glad to leave his other work and meet me at the train, take me to the desired place, help me, and even take his team to aid inspecting the neighborhood. Everyone who has once been through the treating process will never need State aid again, but will take care of his own bees in the future.

Several times the disease has been almost stamped out of Wisconsin, when newly imported cases have appeared, and before owners know what the trouble is several apiaries are affected. I hope that soon every State will have laws on diseases of bees, and that no one can sell or ship bees without a health certificate similar to that required for farm stock in Wisconsin.

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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.

ISSUED JULY 18, 1907.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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TRANSFORMATION OF PERIODICAL CICADA (TIBICEN SEPTENDECIM).

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
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.

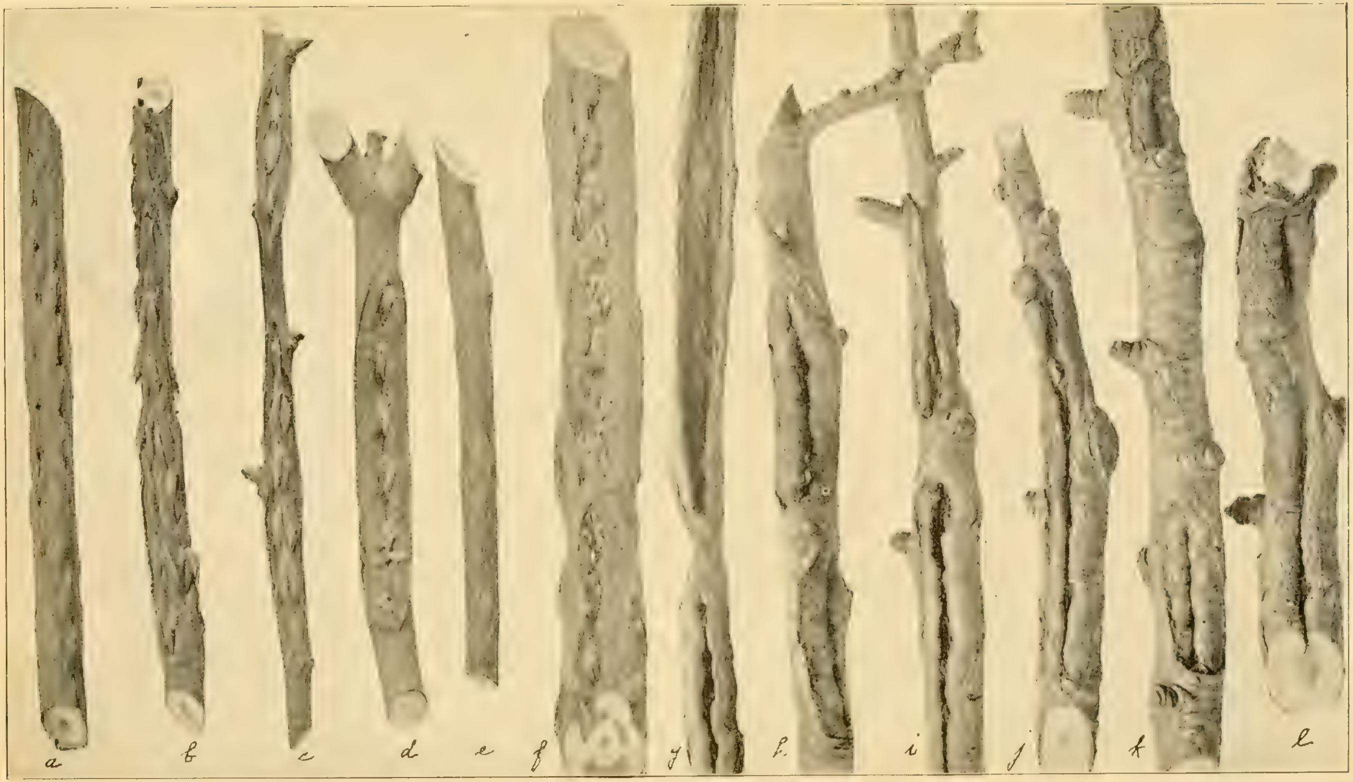
Following briefly the history of the insect, the young ant-like larva, hatching from the egg a few weeks after the latter has been laid, escapes from the wounded limb, falls lightly to the ground, and quickly burrows out of sight, forming for itself a little subterranean chamber or cell over some rootlet, 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*, *c*, and *f*, Condition four months later in maple; *c*, Wounds healed in one season; *e*, 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.)

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 Professer 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. I, 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 char-

[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.

acteristics 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] 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.

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.

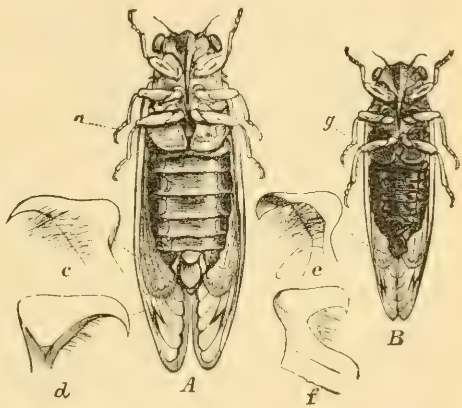


FIG. 1.—The periodical Cicada: *A*, male of typical form, natural size; *c*, *d*, genital hooks enlarged; *g*, singing apparatus, natural size: *B*, male of the small form (*cassinii*), natural size; *e*, *f*, genital hooks, enlarged. (After Riley and Hagen.)

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		1849
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.

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-

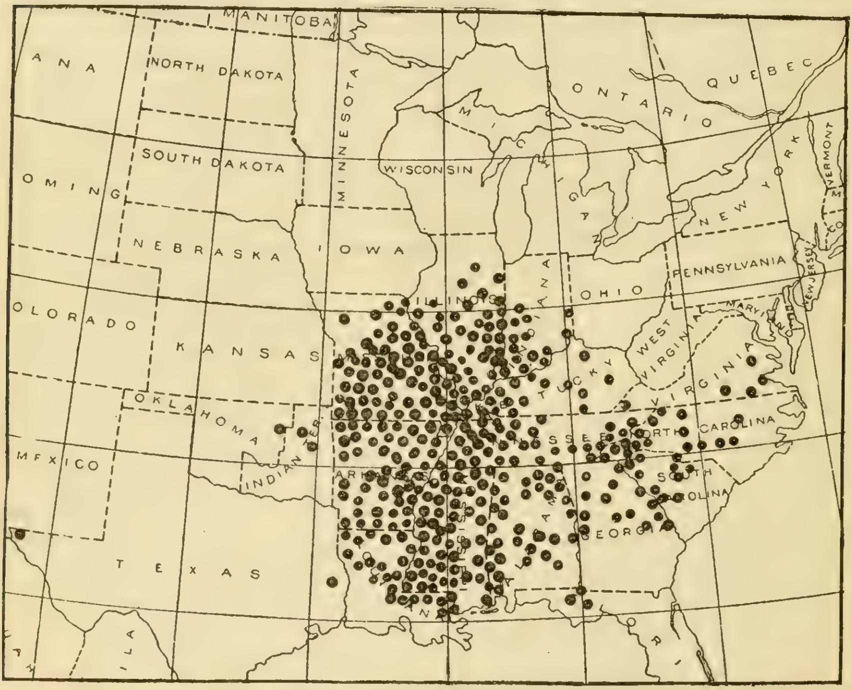


FIG. 2.—Map showing distribution of the broods of the 13-year race.

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

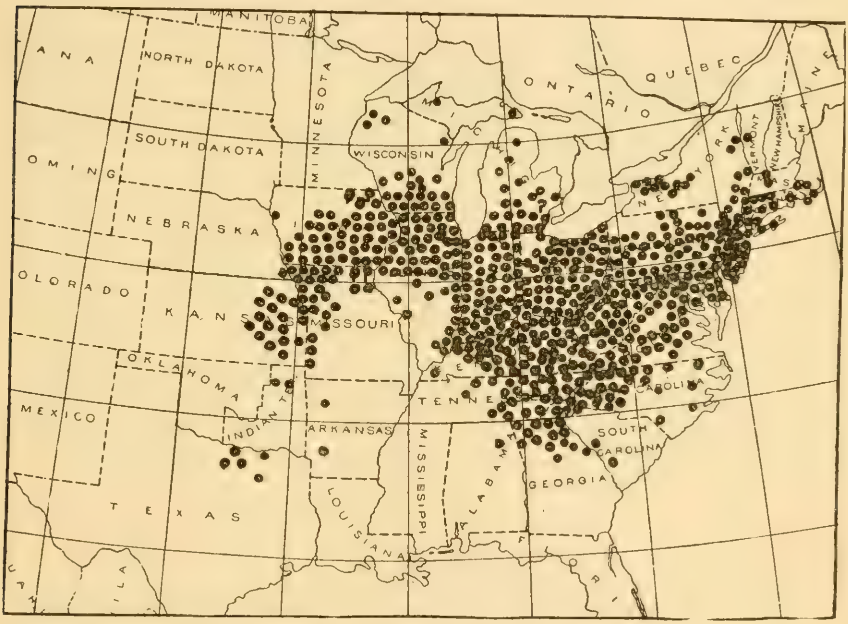


FIG. 3.—Map showing distribution of the broods of the 17-year race.

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.

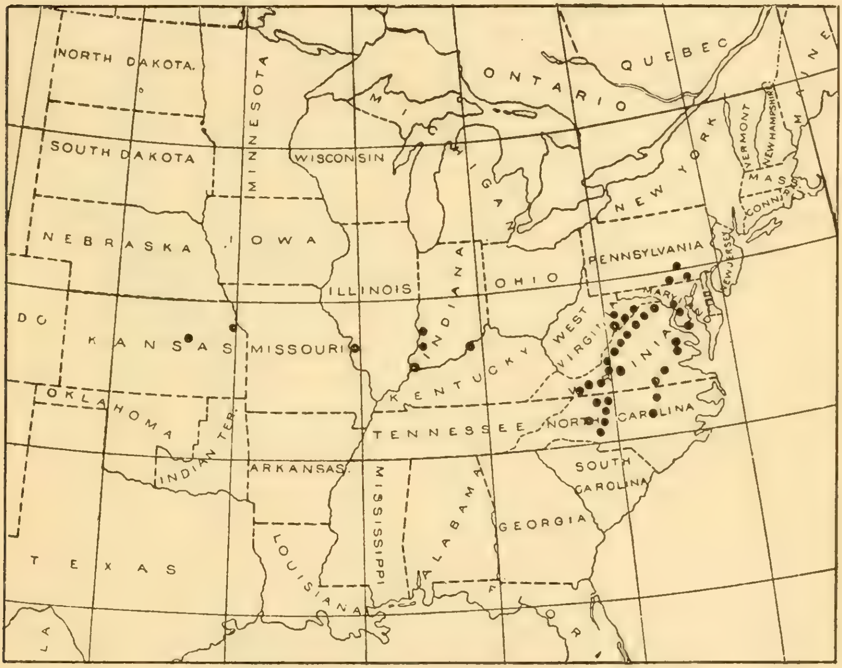


FIG. 4.—Map showing distribution of Brood I, 1910.

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

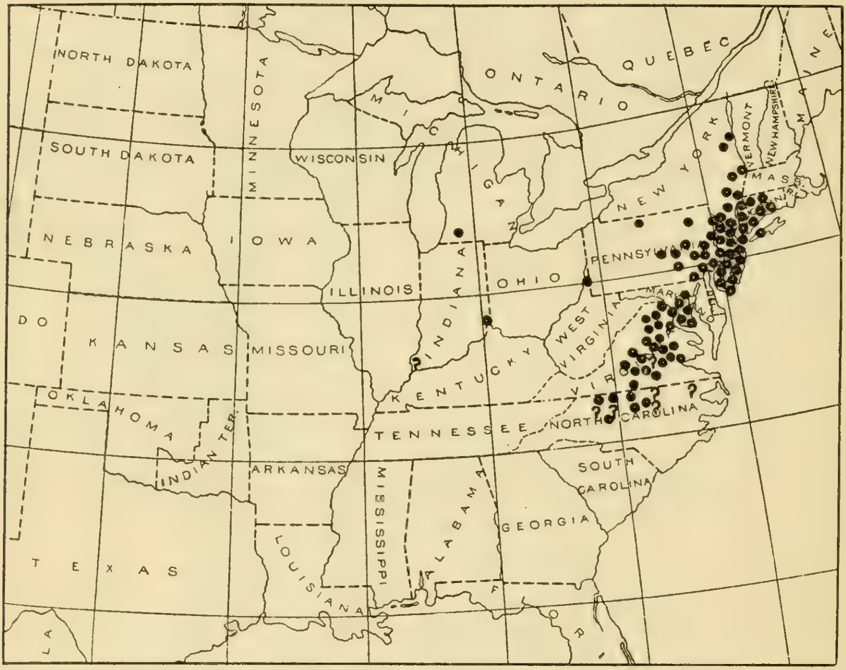


FIG. 5.—Map showing distribution of Brood II, 1911.

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,

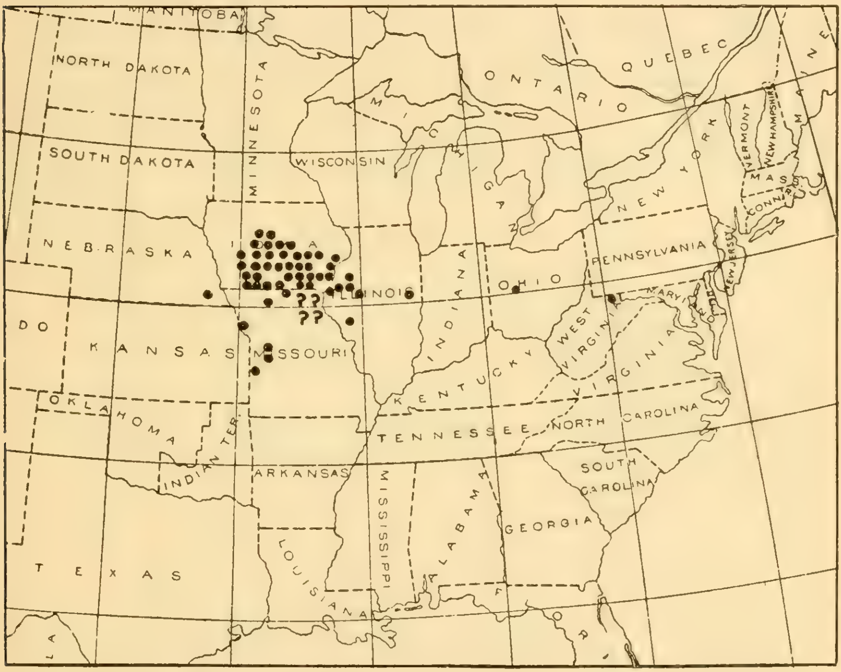


FIG. 6.—Map showing distribution of Brood III, 1912.

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.

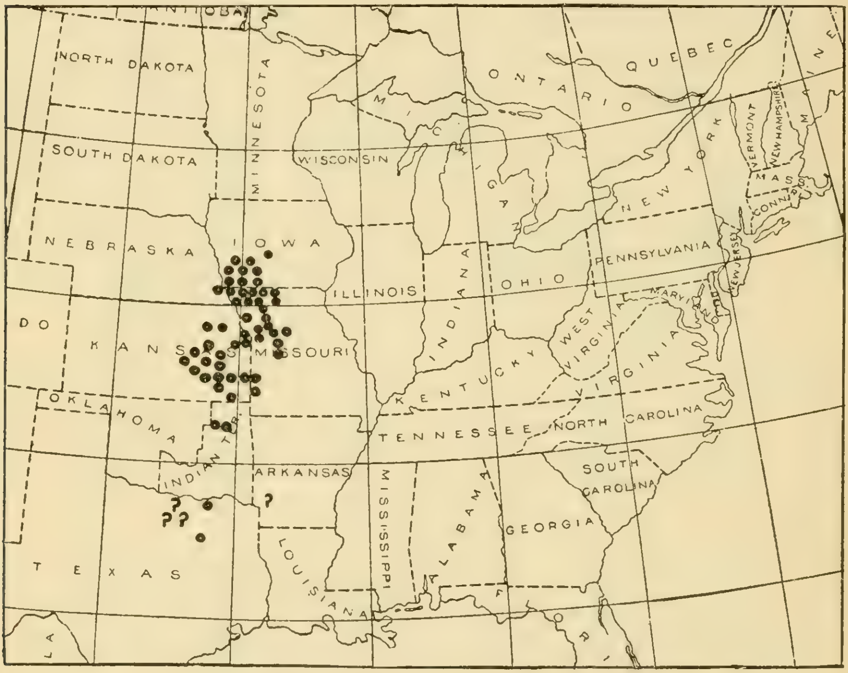


FIG. 7.—Map showing distribution of Brood IV, 1913.

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, Kanawha, 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,

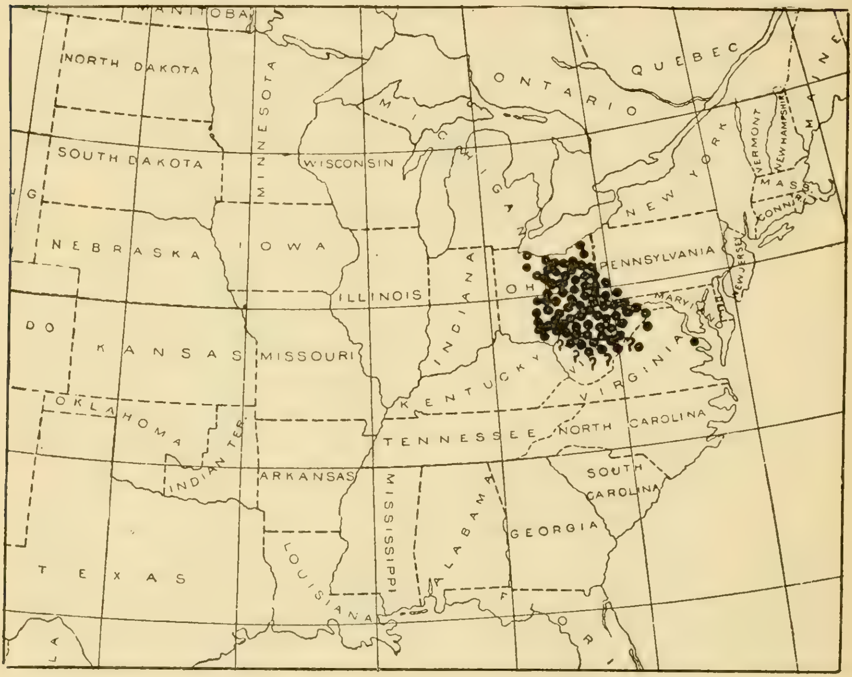


Fig. 8.—Map showing distribution of Brood V, 1914.

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

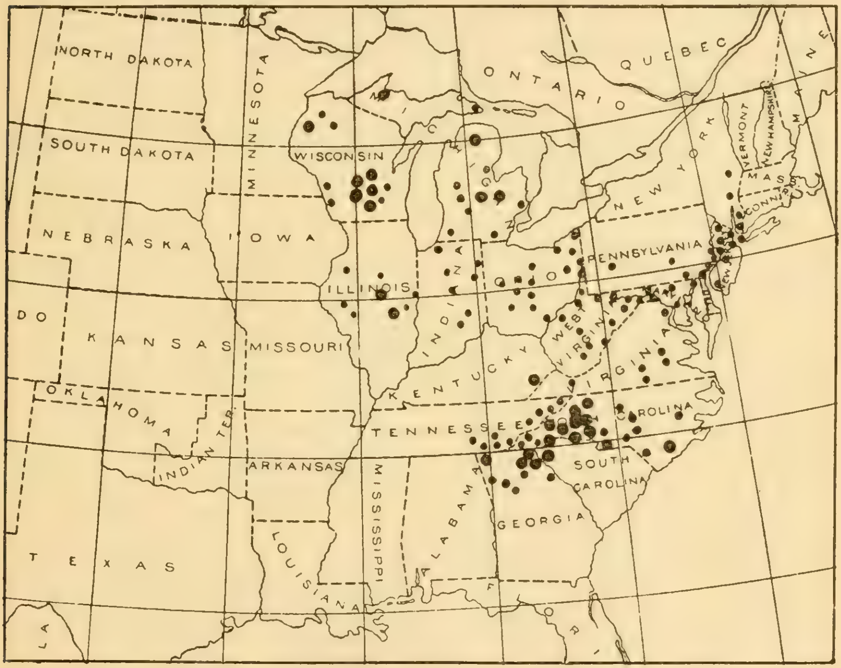


FIG. 9.—Map showing distribution of Brood VI, 1915.

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?.

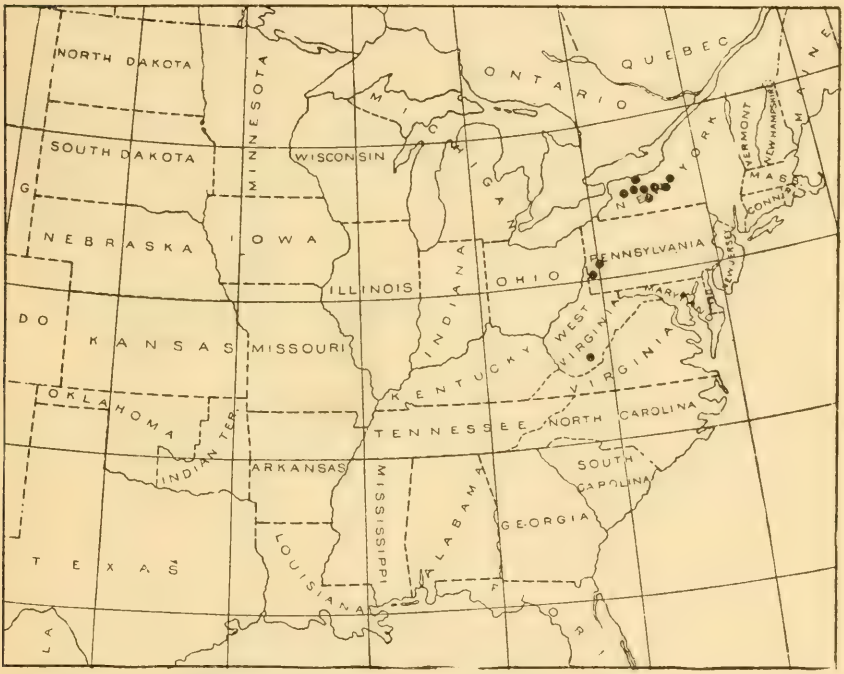


Fig. 10.—Map showing distribution of Brood VII, 1916.

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

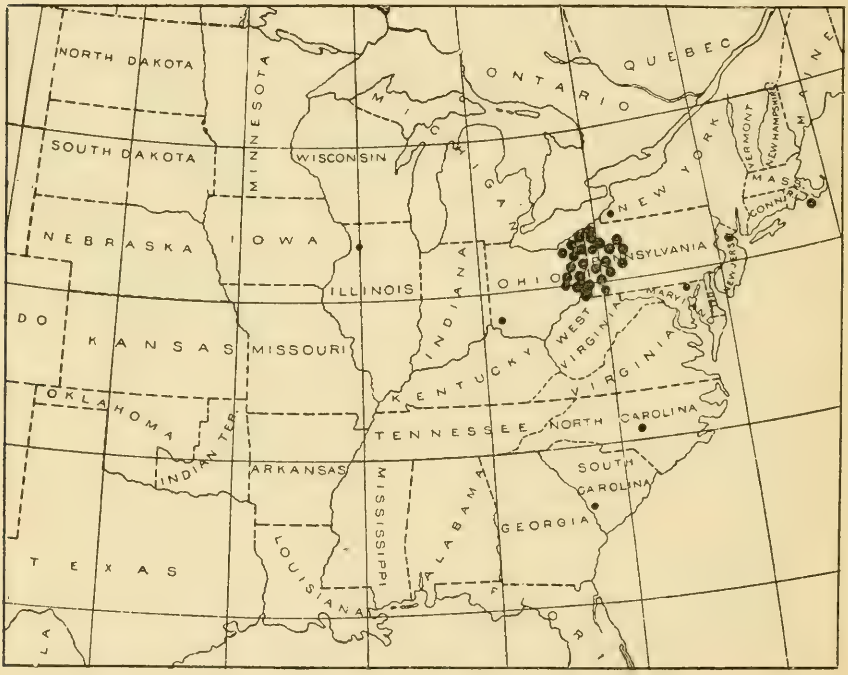


FIG. 11.—Map showing distribution of Brood VIII, 1917.

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*,*

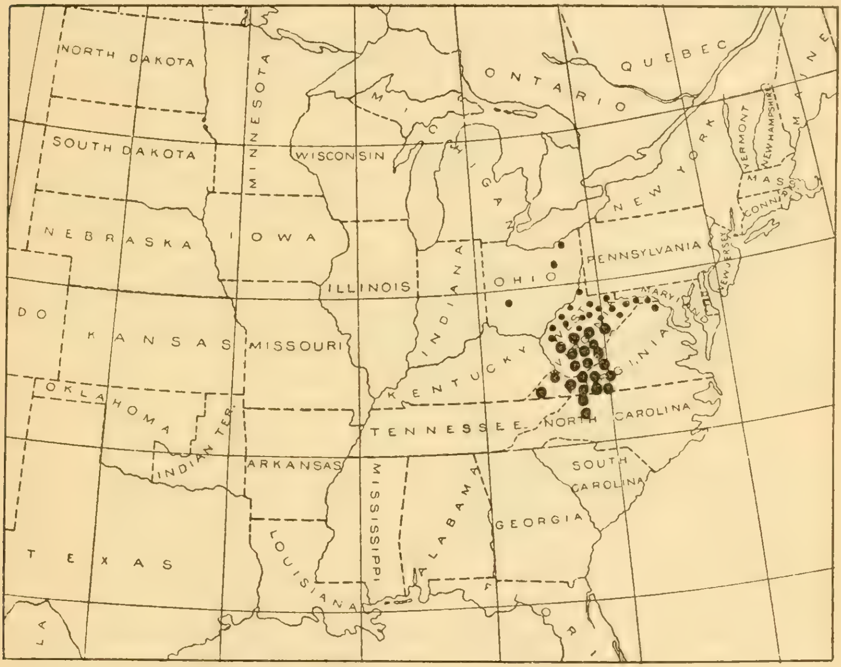


FIG. 12.—Map showing distribution of Brood IX, 1918.

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 Virginia, 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

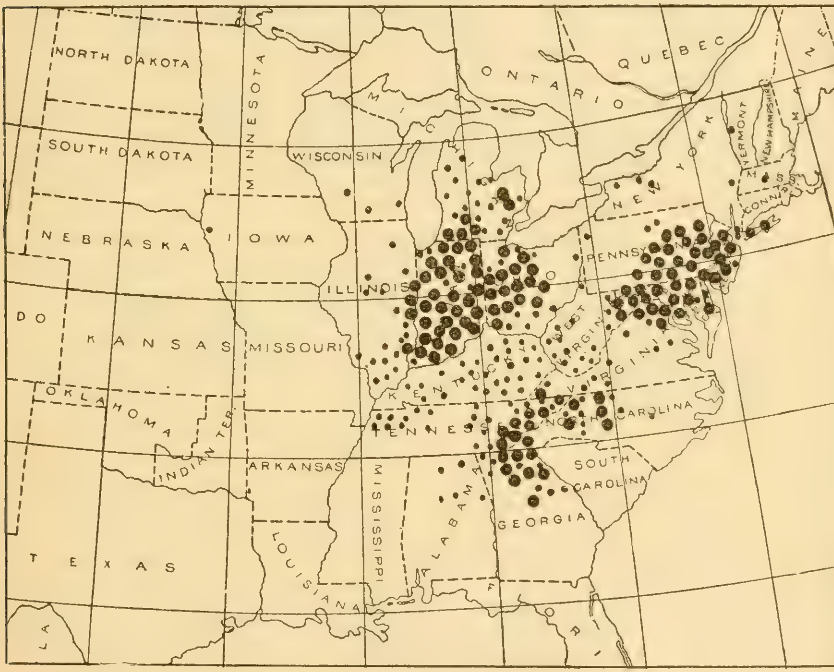


FIG. 13.—Map showing distribution of Brood X, 1919.

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, _Hampshire_,* _Hardy_,* Harrison,* _Jefferson_,* Lincoln, Logan, McDowell, Mason, _Mineral_,* Mingo, Monroe, _Morgan_, Ohio, Pocahontas, Preston,* _Putnam_, Raleigh, Roane, Tucker,* Wayne.

WISCONSIN.—Dane, (Sauk).

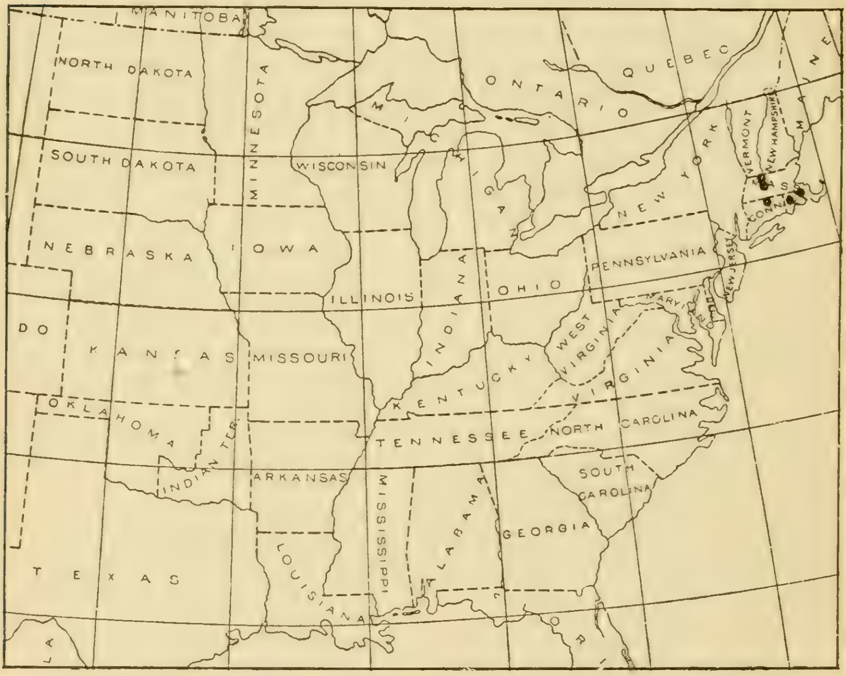


FIG. 14.—Map showing distribution of Brood XI, 1920.

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:

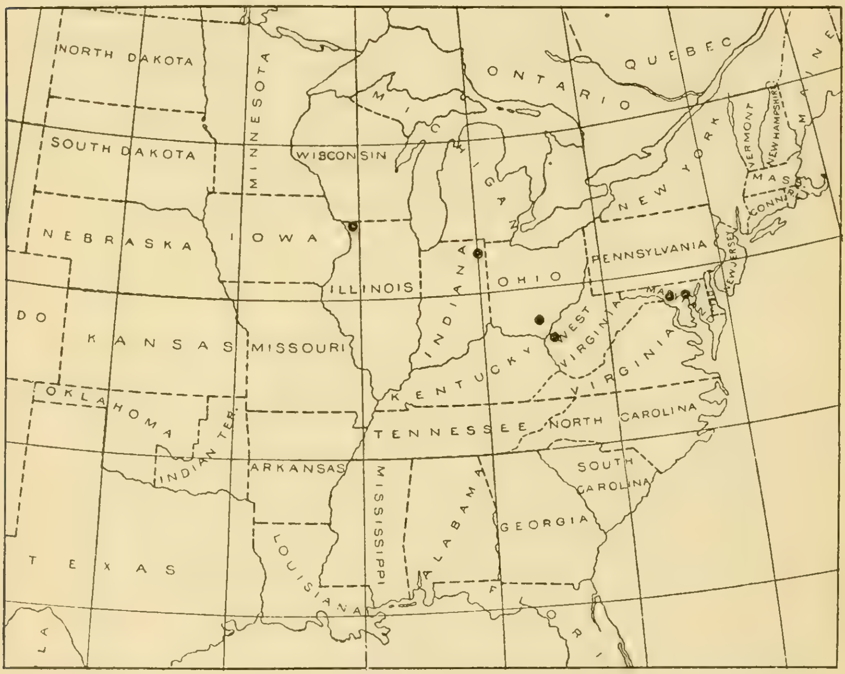


FIG. 15.—Map showing distribution of Brood XII, 1921.

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

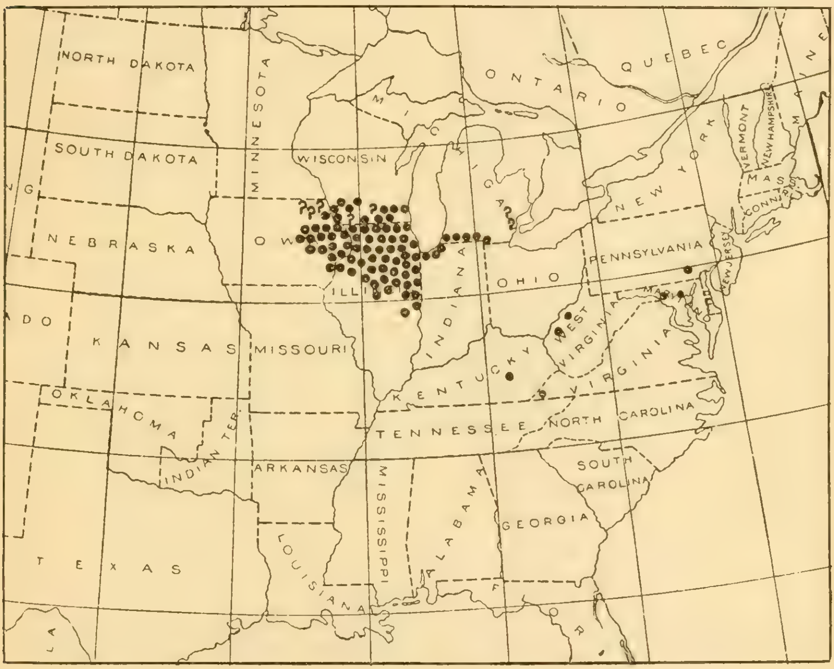


FIG. 16.—Map showing distribution of Brood XIII, 1922.

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

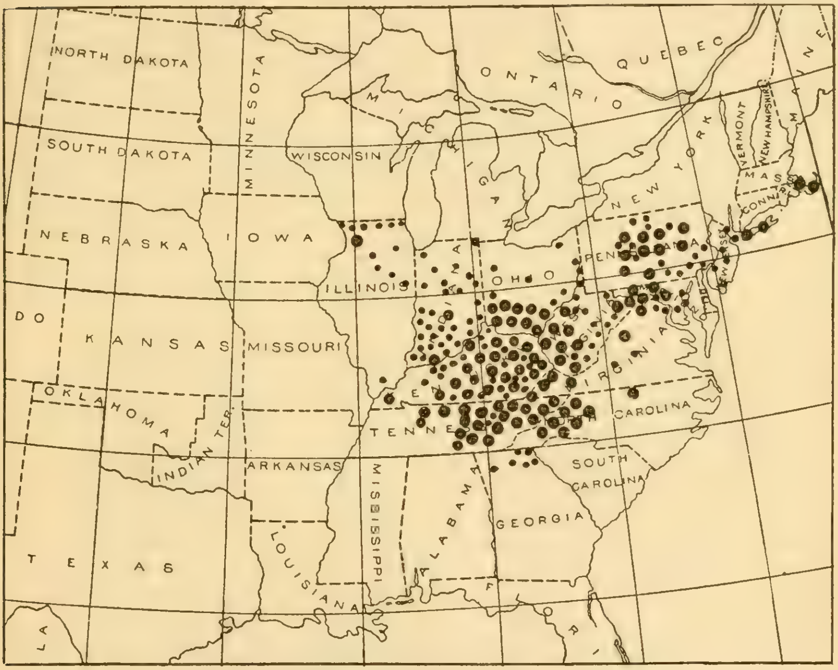


FIG. 17.—Map showing distribution of Brood XIV, 1923.

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

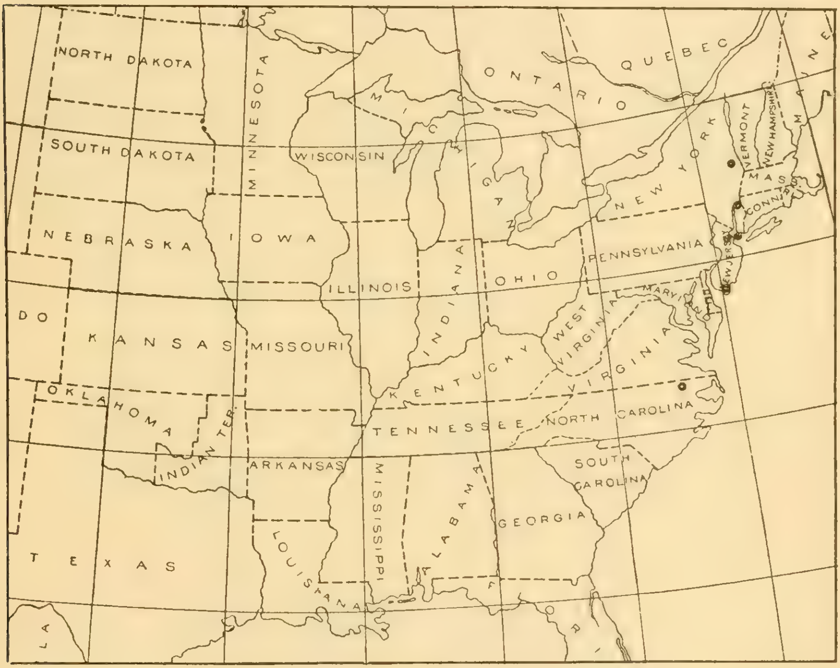


FIG. 18.—Map showing distribution of Brood XV, 1907.

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 occur-

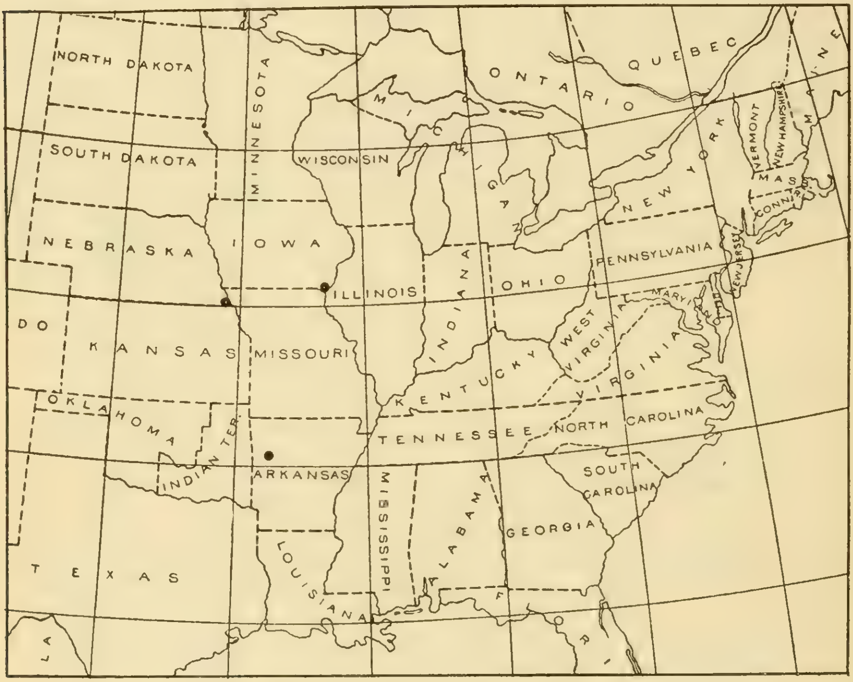


FIG. 19.—Map showing distribution of Brood XVI, 1908.

ring 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.

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*.

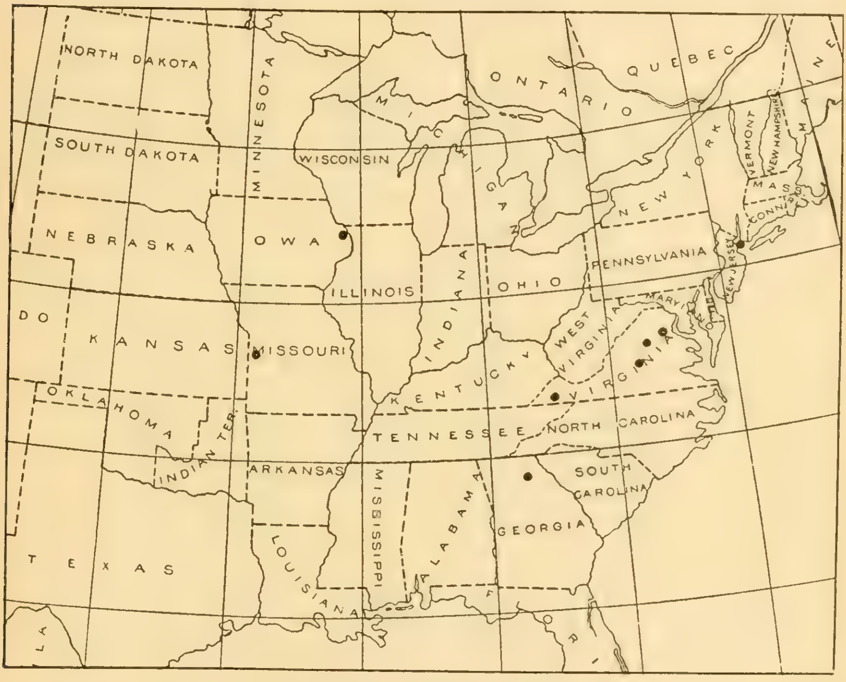


FIG. 20.—Map showing distribution of Brood XVII, 1909.

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.

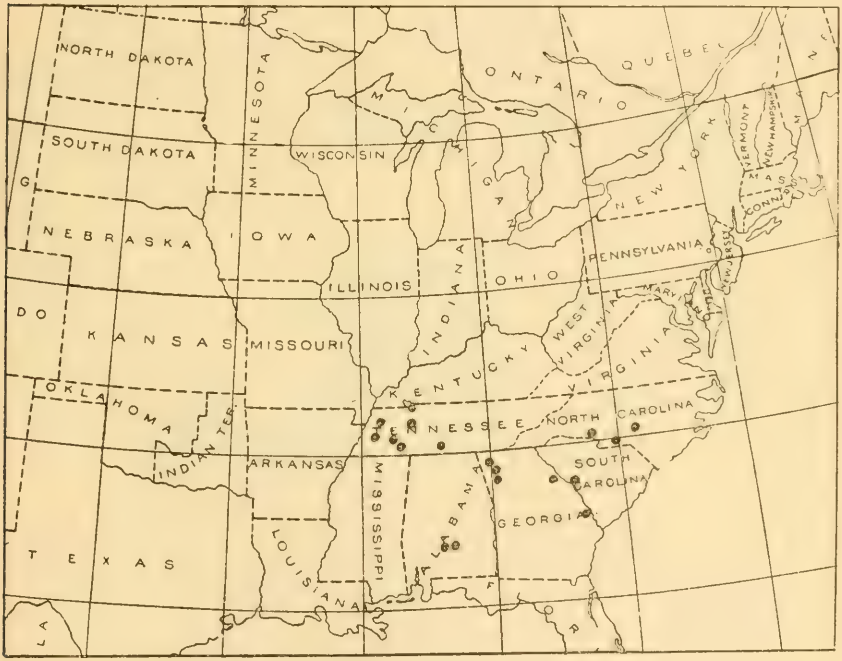


FIG. 21.—Map showing distribution of Brood XVIII, 1919.

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.)

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.

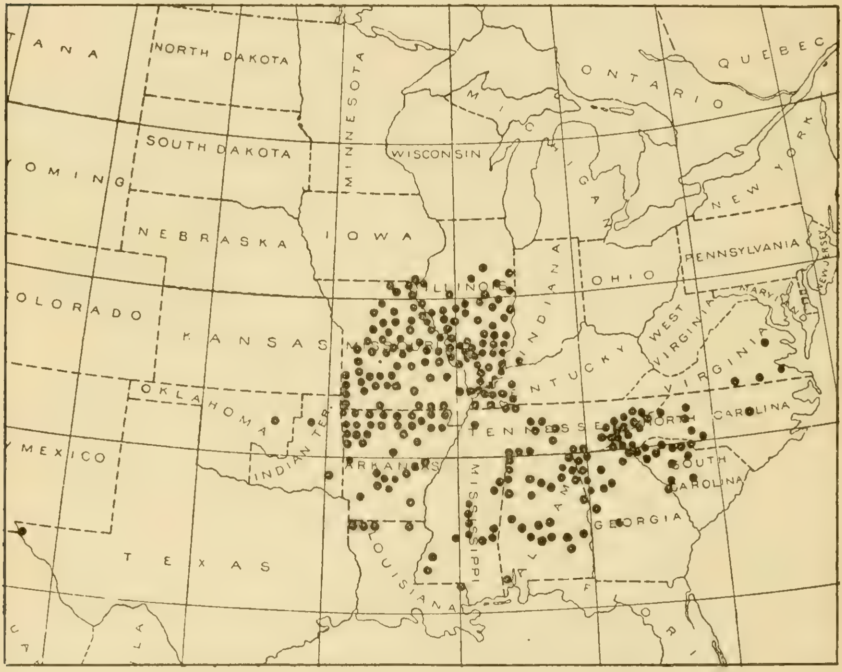


FIG. 22.—Map showing distribution of Brood XIX, 1907

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.

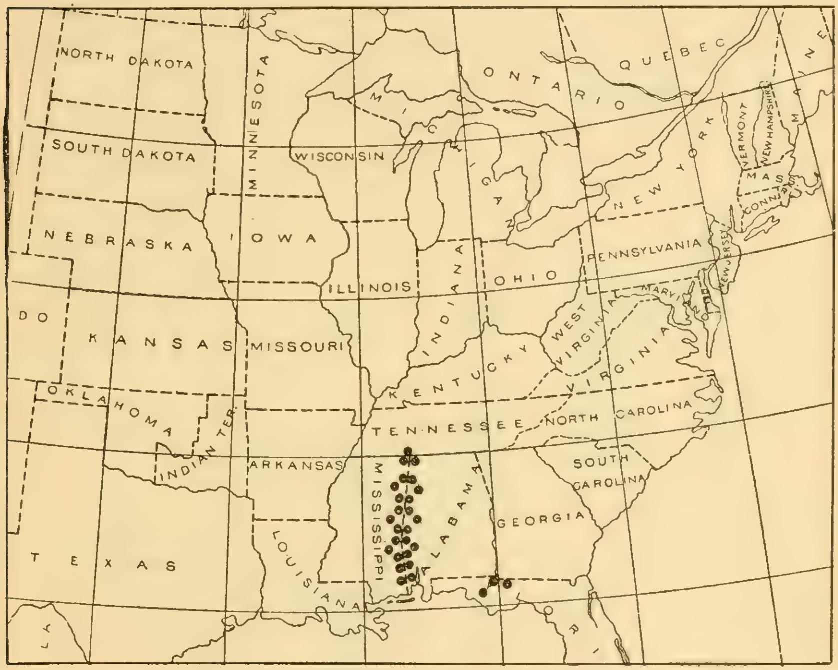


FIG. 24.—Map showing distribution of Brood XXI, 1909.

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

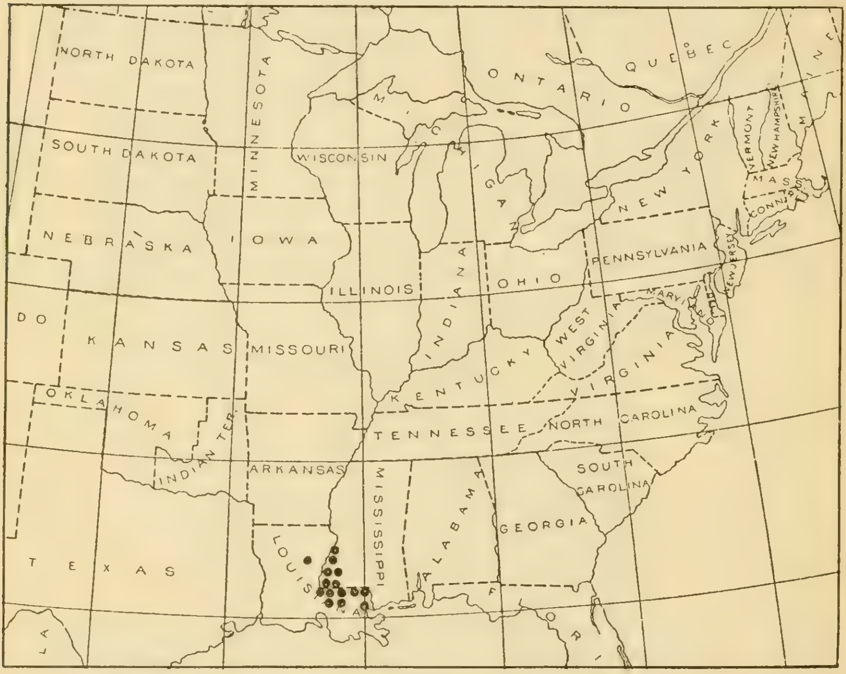


FIG. 25.—Map showing distribution of Brood XXII, 1910.

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

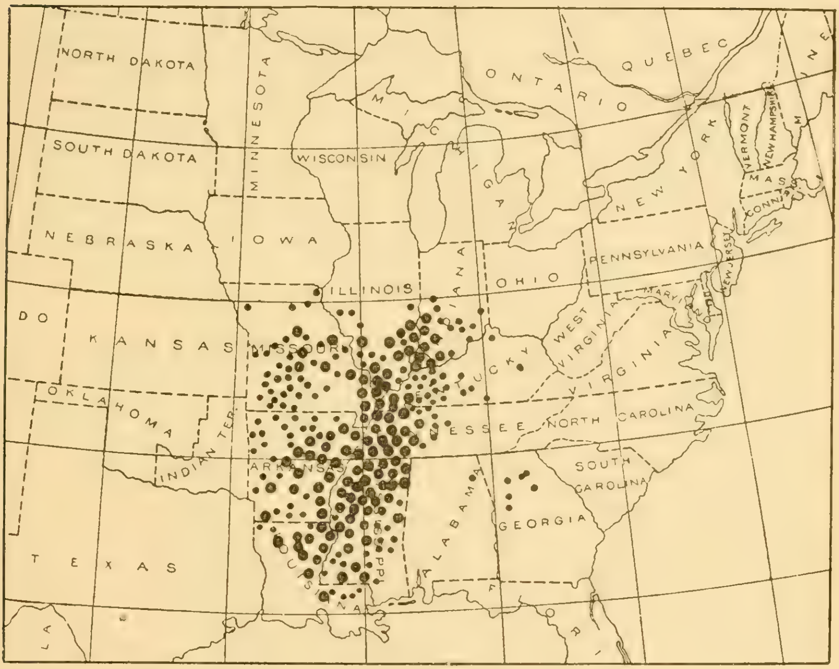


FIG. 26.—Map showing distribution of Brood XXIII, 1911.

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.

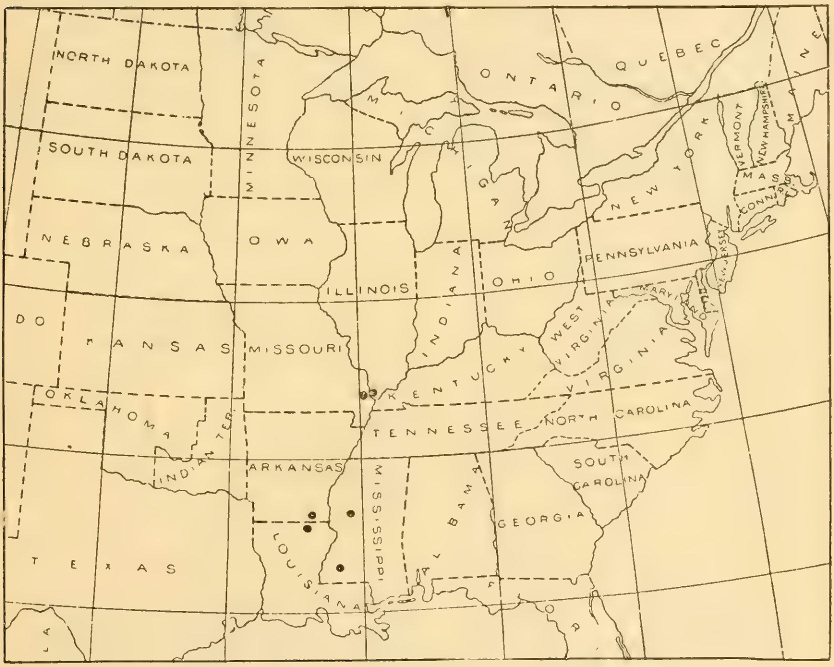


FIG. 27.—Map showing distribution of Brood XXIV, 1912.

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 Mississippi 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.— (?).

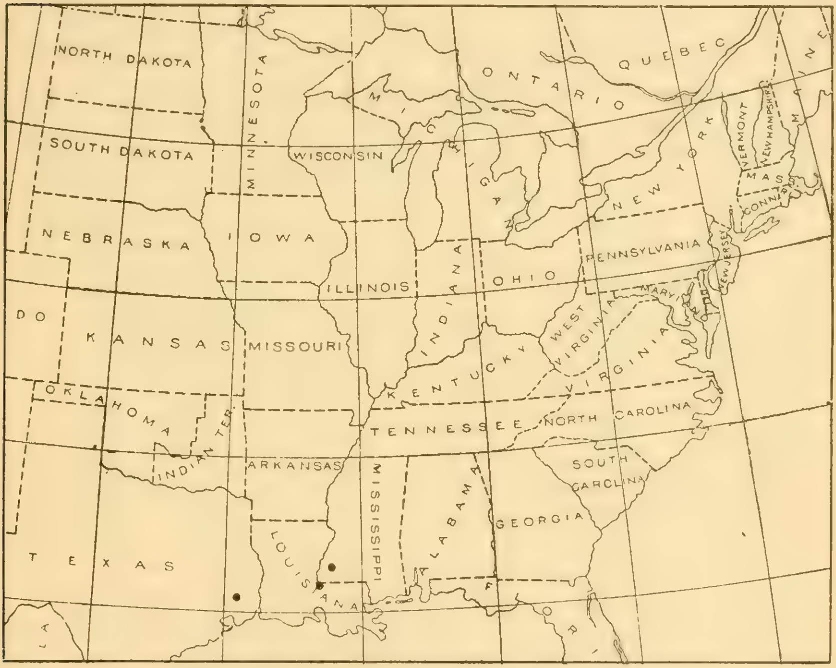


FIG. 28.—Map showing distribution of Brood XXVI, 1914.

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

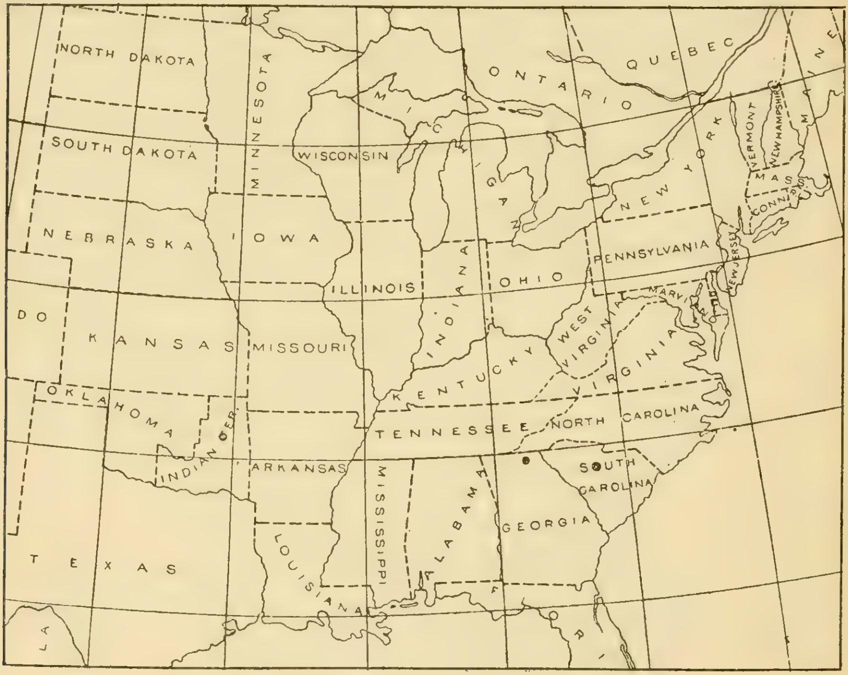


FIG. 29.—Map showing distribution of Brood XXIX, 1917.

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.

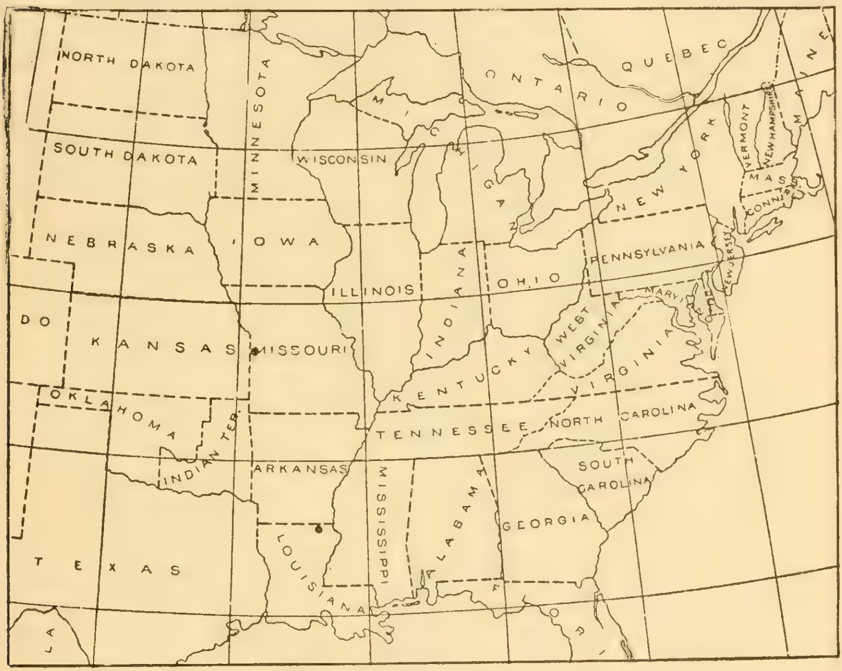


FIG. 30.—Map showing distribution of Brood XXX, 1918.

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.

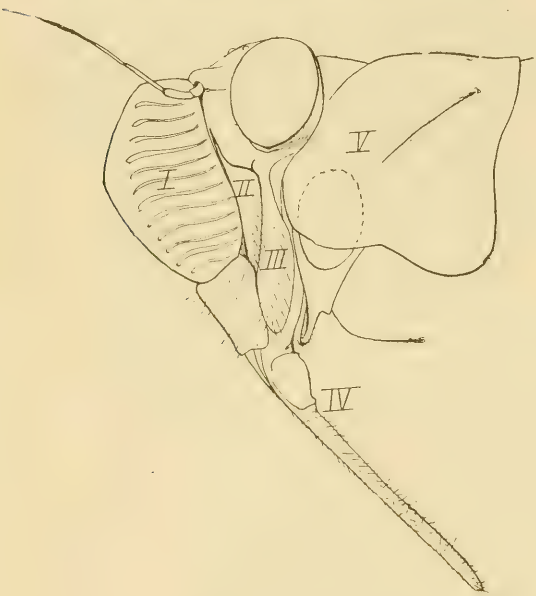


FIG. 31.—Head and prothorax of Cicada, lateral view, showing parts in normal position. For description, see fig. 33. (Author's illustration.)

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.

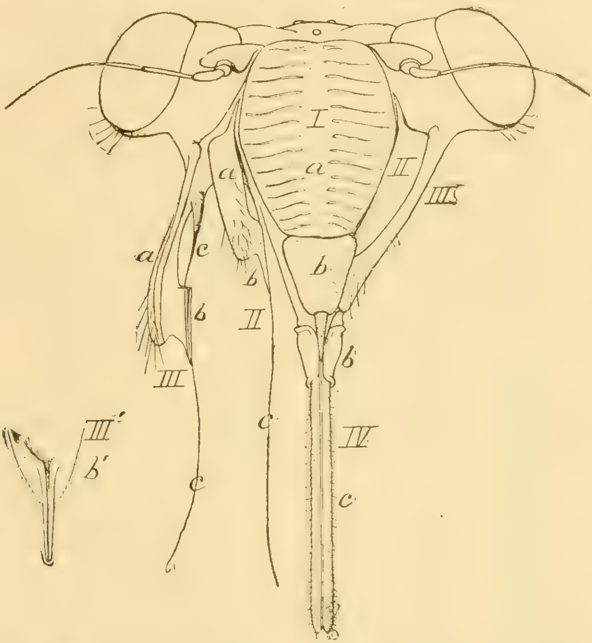


FIG. 32.—Head of Cicada, front view, showing the normal position of mouth parts on the left, and with the mandible and maxilla drawn out on the right. For description, see fig. 33. (Author's illustration.)

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

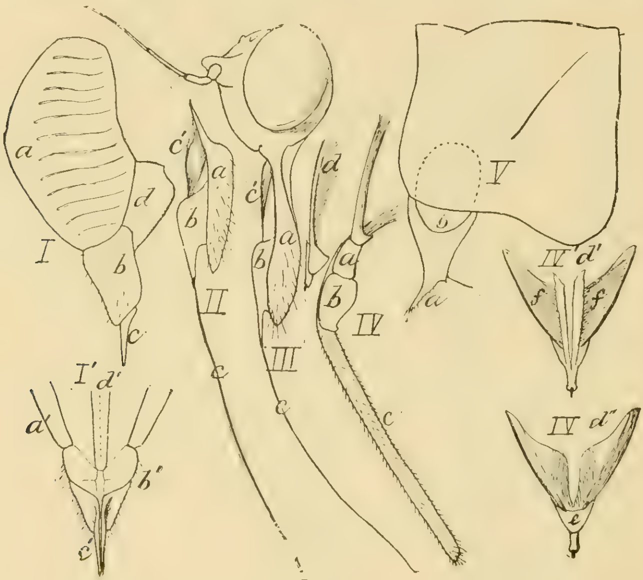


FIG. 33.—Head and prothorax of Cicada, lateral view, with parts separated to show structure: I, *a*, clypeus, *b* and *c*, labrum, *d*, epipharynx; I′, same from beneath; II, mandible, *a*, base, *b*, sheath for seta, *c*, mandibular seta, *c*′, muscular base of latter; III, maxilla with parts similarly 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.

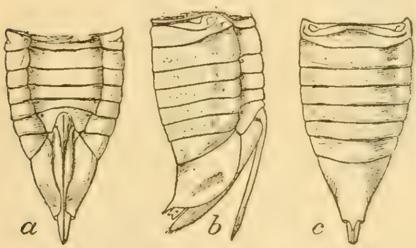


FIG. 35.—Abdomen of female Cicada showing ovipositor and attachments: *a*, ventral, *b*, lateral, and *c*, dorsal view. (Author's illustration.)

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-

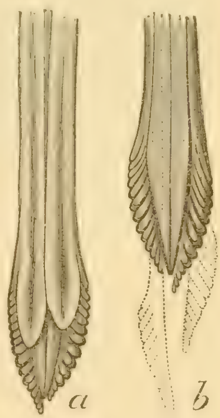


FIG. 36.—Tip of ovipositor of Cicada, much enlarged: *a*, from above, *b*, from beneath, with dotted portion to show the alternating motion of the side pieces. (Author's illustration.)

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.

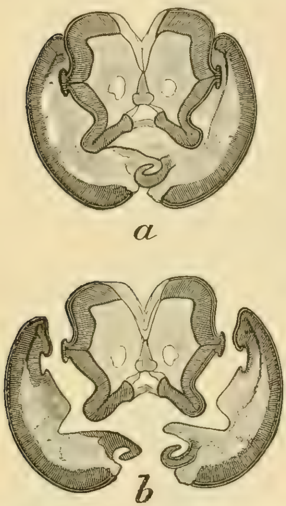


FIG. 37.—Cross section of ovipositor of Cicada: *a*, with parts attached in natural position; *b*, separated to show interlocking tongues and grooves. (Author's illustration.)

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]

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[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.

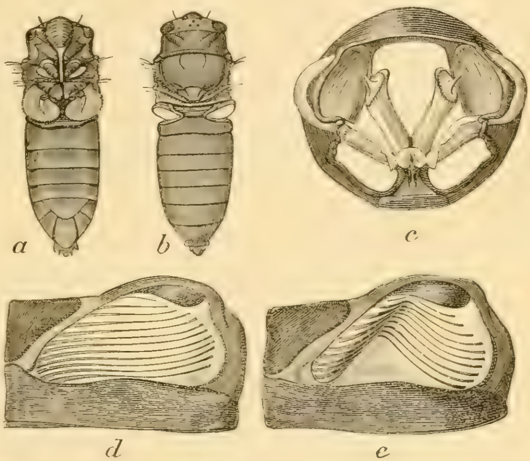

FIG. 38.—The musical apparatus of the periodical Cicada: *a*, view from beneath, showing the plates (light colored) covering the sounding disks; *b*, dorsal view, the timbals showing as light-colored areas; *c*, section at base of abdomen, showing attachment of large muscles to timbals; *d*, timbal greatly 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 $1\frac{1}{4}$ 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.

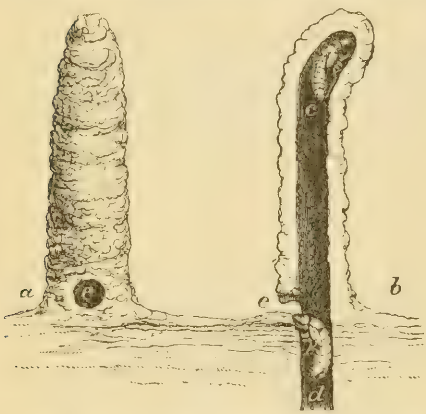

FIG. 39. Pupal galleries of the Cicada: *a*, front view; *e*, orifice; *b*, section; *c*, pupa awaiting time of change; *d*, pupa ready to transform. (After Riley.)

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 3½ 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

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[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:

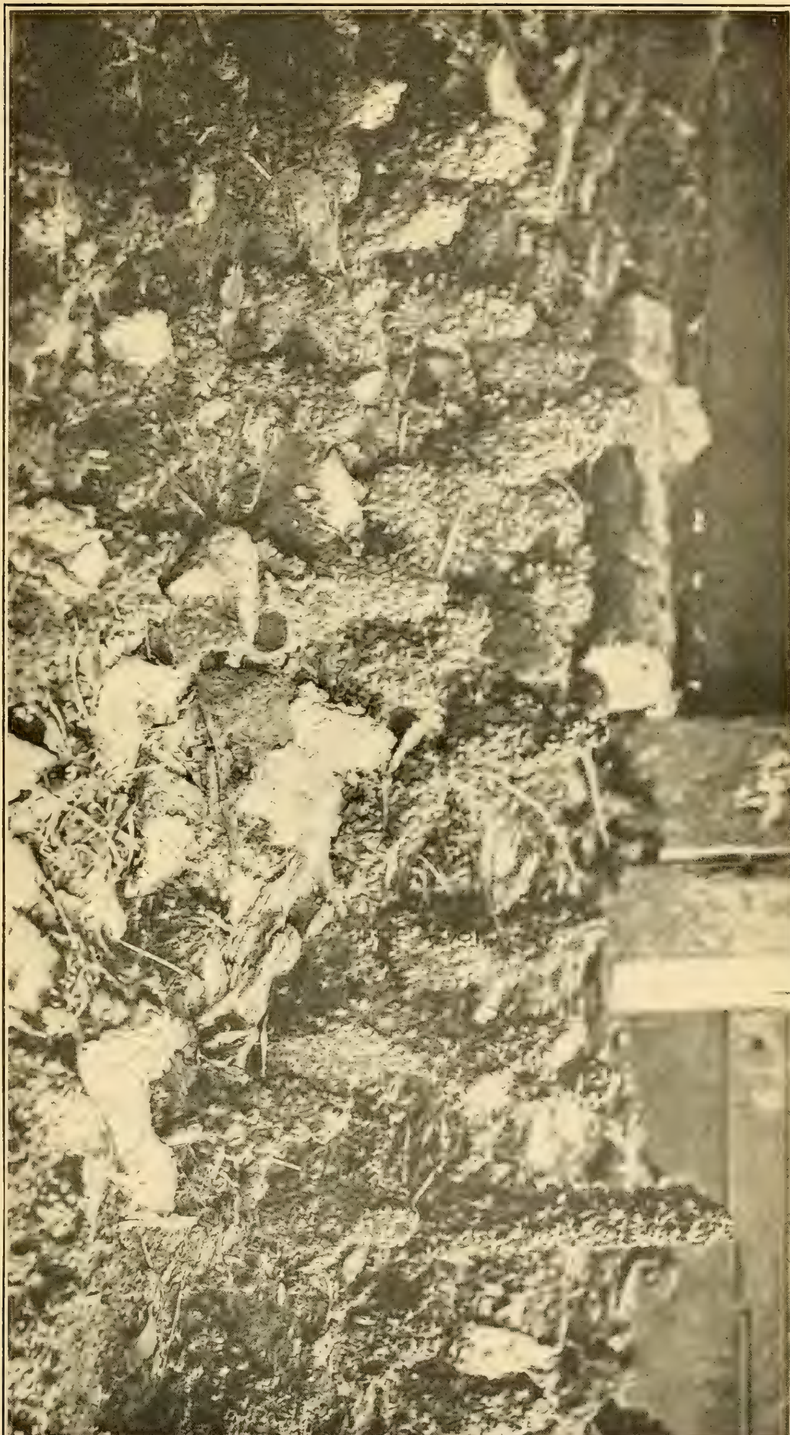
On the 4th of May, 1894, while in the woods on the summit of South Mountain, at Nyack, N. Y., I came upon a spot that had recently been burnt over. On this area I observed vast quantities of the Cicada structures, entirely closed, averaging about 2½ inches in height, the aggregation ending at the very 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 $1\frac{1}{2}$ 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:

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[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.

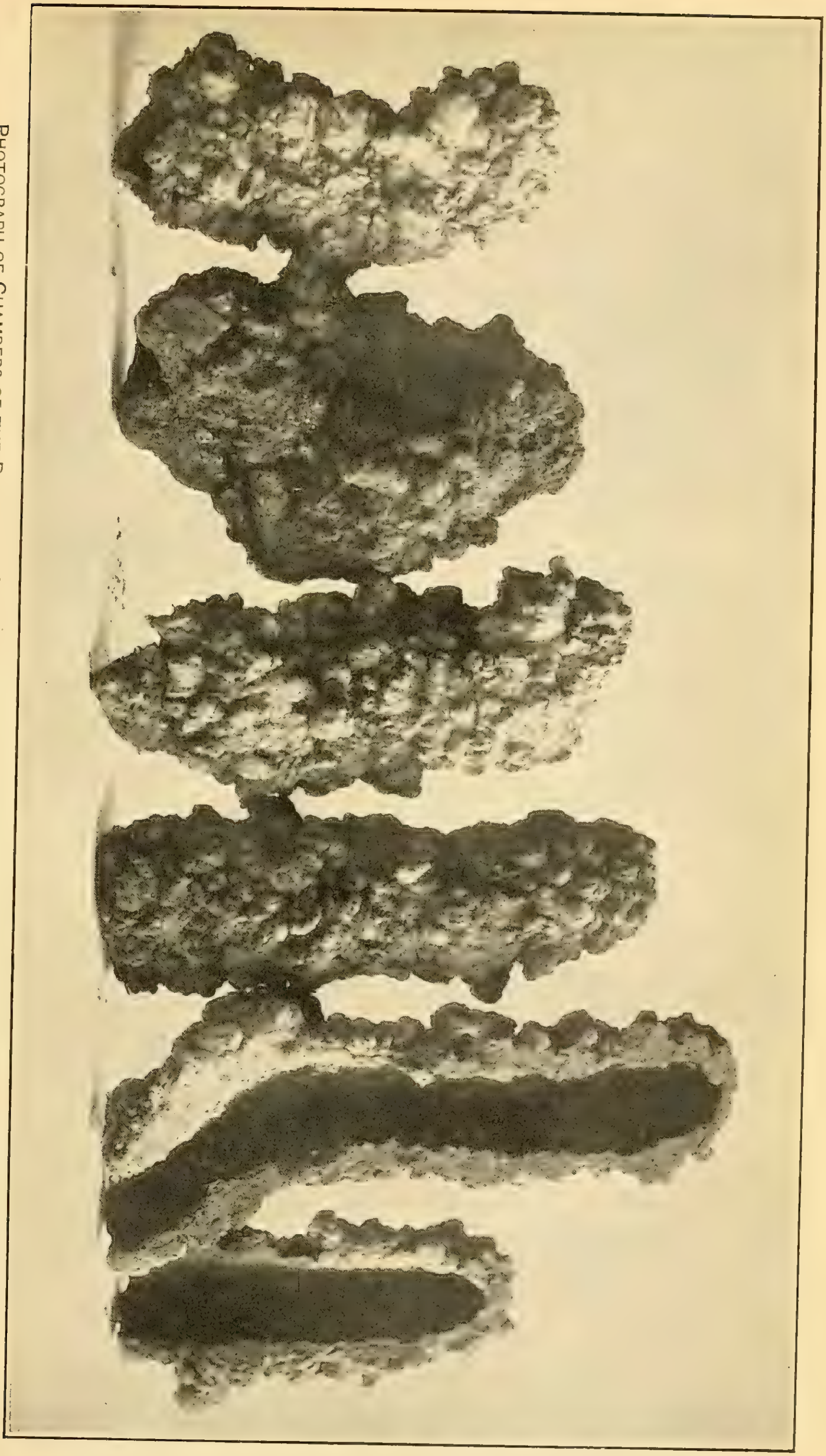
Accepting the theory proposed by Mr. Lander for the condition found to exist in the Nyack region, Doctor Love does not deem it entirely adequate, as he says:

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 "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

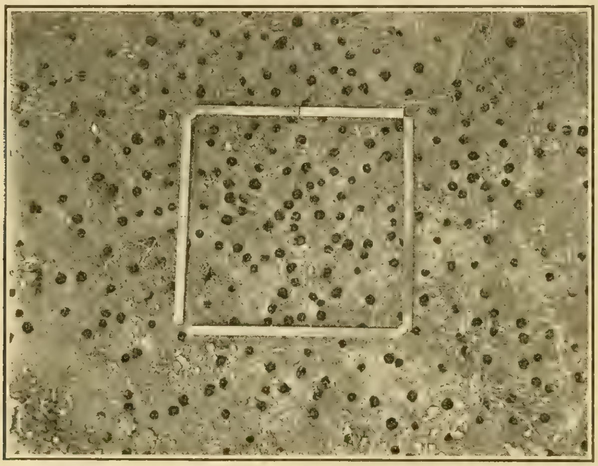
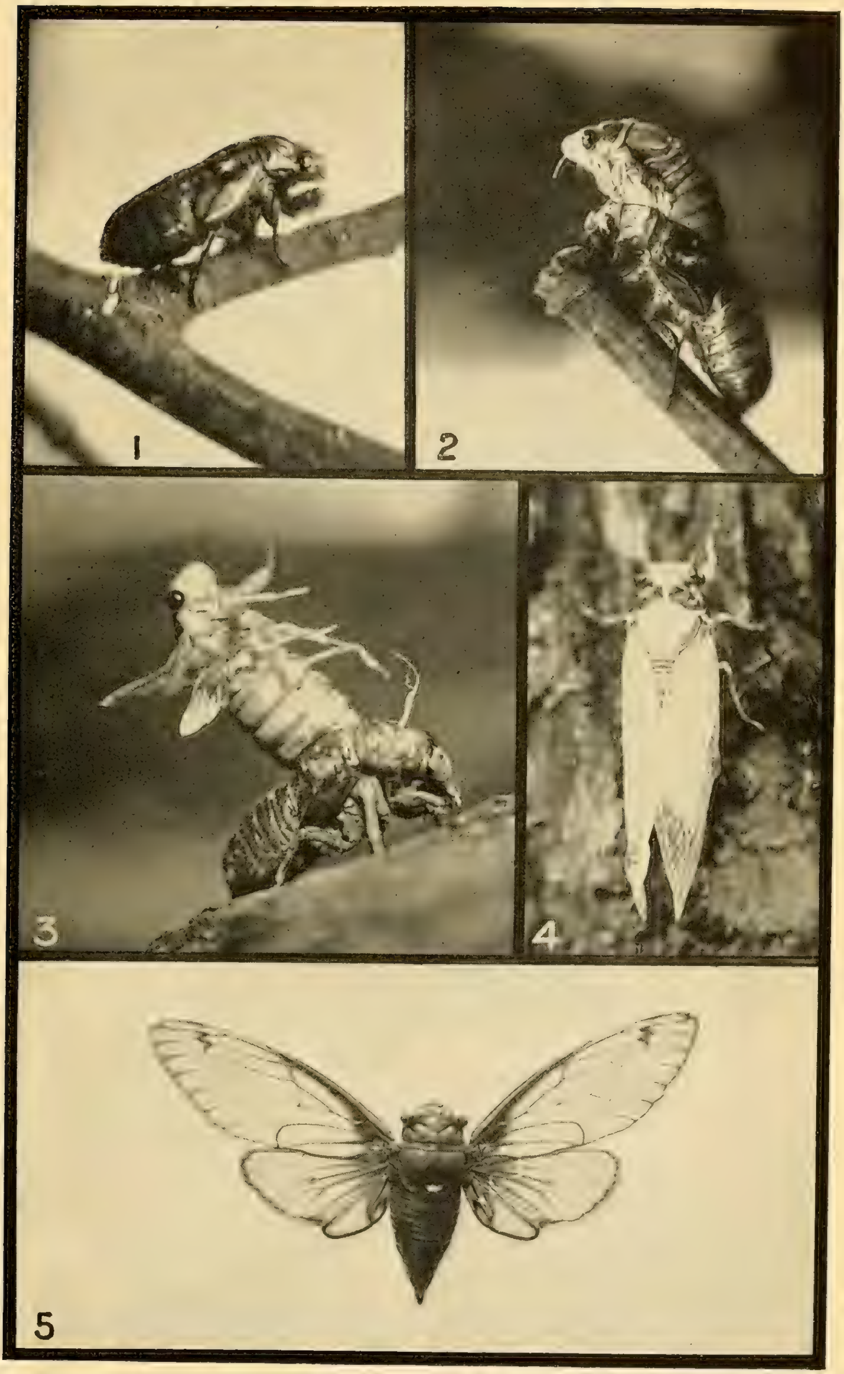


FIG. 40.—Exit holes of the periodical Cicada at surface of soil. The rule shows the large number of holes occurring, in this instance, in a square foot of ground

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

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[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 fomale 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

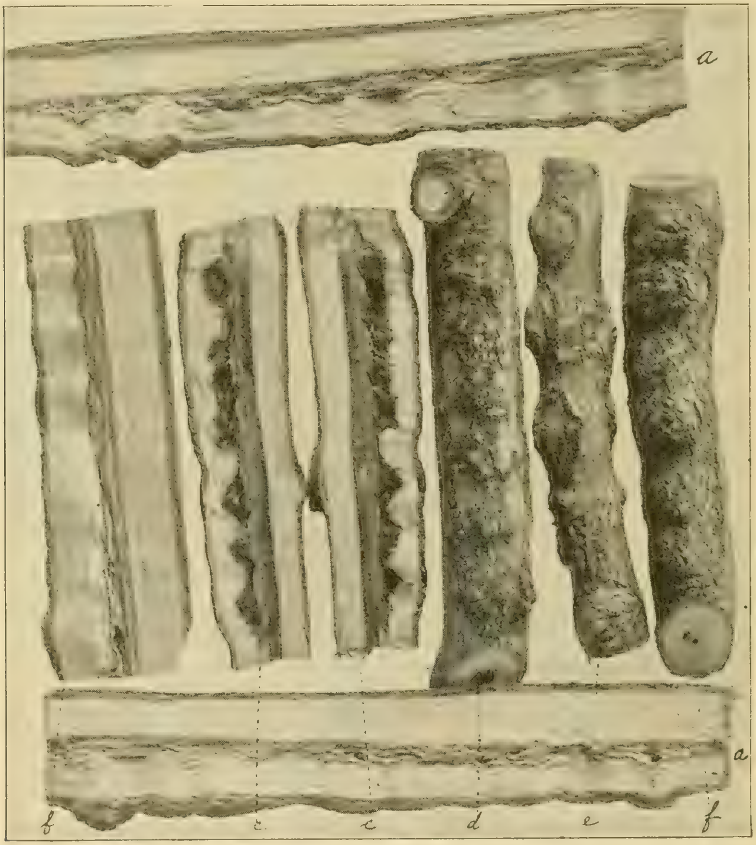

Fig. 43.—Periodical Cicada scars in hard-maple twigs after seventeen years. (Hopkins.)

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

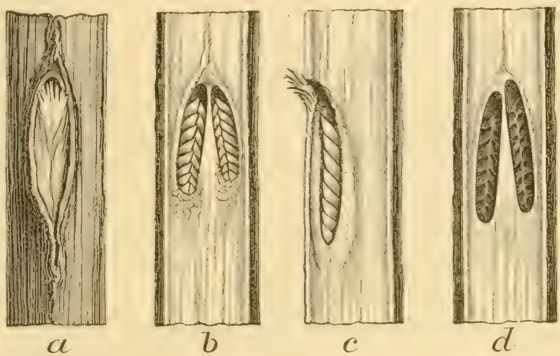

FIG. 44.—Egg nest of the periodical Cicada: *a*, recent puncture, front view; *b*, same, surface removed to show arrangement of eggs, from above; *c*, same, side view; *d*, egg cavity exposed after eggs are removed, and showing the sculpture left by the ovipositor. All enlarged (after Riley).

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.

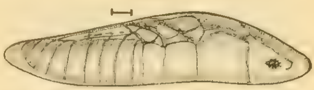
FIG. 45.—Egg of periodical Cicada, much enlarged, showing young about to be disclosed. (Author's illustration.)

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.

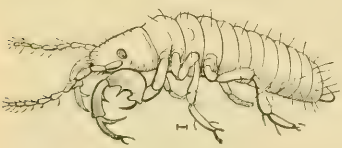

FIG. 46.—Newly hatched larva, greatly enlarged. (After Riley.)

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

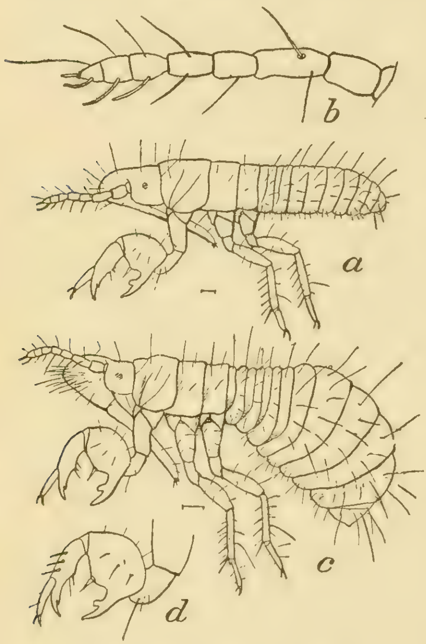

FIG. 47.—First larval stage: *a*, newly hatched larva; *b*, antenna of same; *c*, larva eighteen months old; *d*, enlarged anterior leg of same. (Author's illustration.)

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.

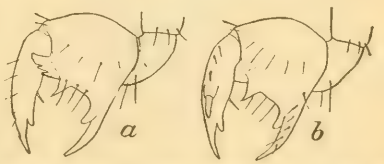

FIG. 48.—Second larval stage: *a*, anterior leg, outer face; *b*, same, inner face. (Author's illustration.)

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 noticeable; 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.

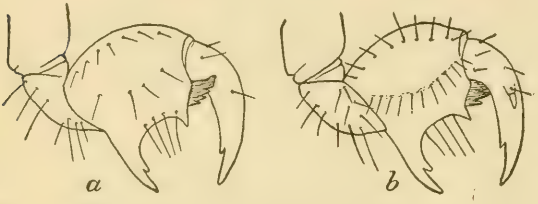

FIG. 49.—Third larval stage: *a*, anterior leg, outer face; *b*, same, inner face. (Author's illustration.)

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.)

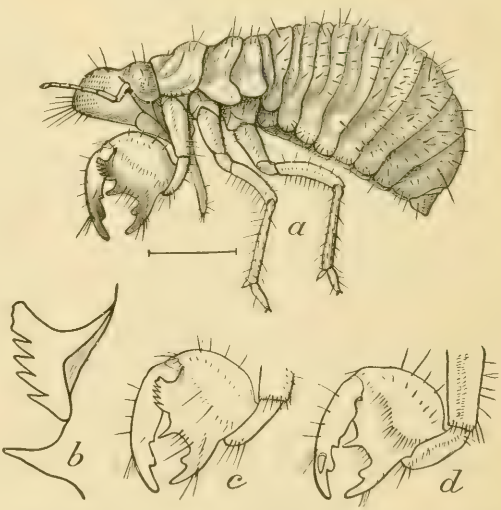

FIG. 50.—Fourth larval stage: *a*, full grown larva, much enlarged; *b*, outline of femoral comb; *c*, anterior leg, outer face; *d*, same, inner face. (Author's illustration.)

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.

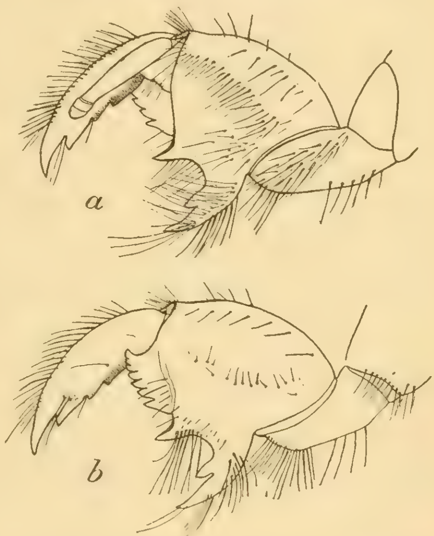

FIG. 51.—First pupal stage: *a*, anterior leg, inner face, showing tarsus bent back against the tibia, *b*, same, outer face. (Author's illustration.)

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 $1\frac{1}{2}$ 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.

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[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.

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).

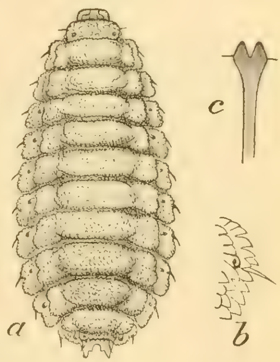

Fig. 52.—Cecidomyiid egg parasite of the periodical Cicada: Larva, much enlarged, with anatomical details at side. (Original.)

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.

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.

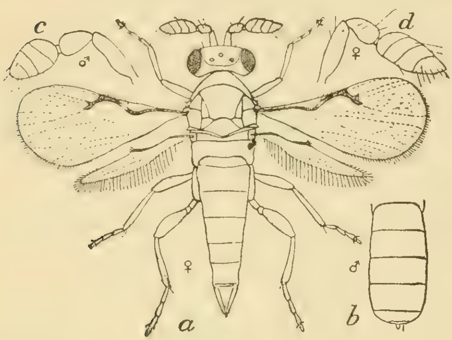

Fig. 53.—Egg parasite, *Lathromeris cicadæ: a*, female; *b*, abdomen of male; *c*, antenna of male; *d*, antenna of female. All greatly enlarged (original.)

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

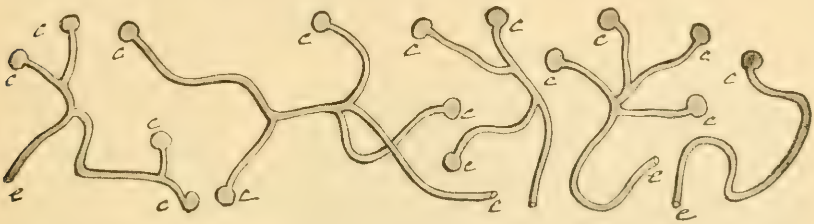

FIG. 55.—Burrows of *Sphecius speciosus: e, e, e,* main entrance; *c, c, c, c,* chambers for larvæ and their food. Greatly reduced (after Riley).

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."

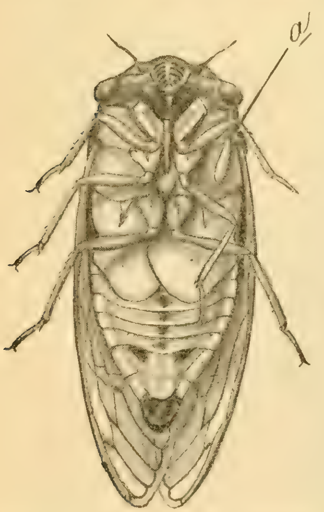

FIG. 56. Adult Cicada with Sphecius egg attached at *a*. Natural size (after Riley).

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).

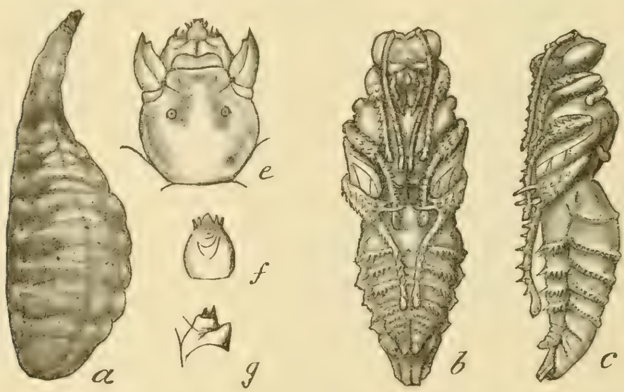

FIG. 58.—*Sphecius speciosus*: *a*, larva; *b*, pupa, from below; *c*, same, from side, natural size; *e*, head of larva; *f*, labium of same; *g*, maxilla of same. Enlarged (after Riley).

[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.

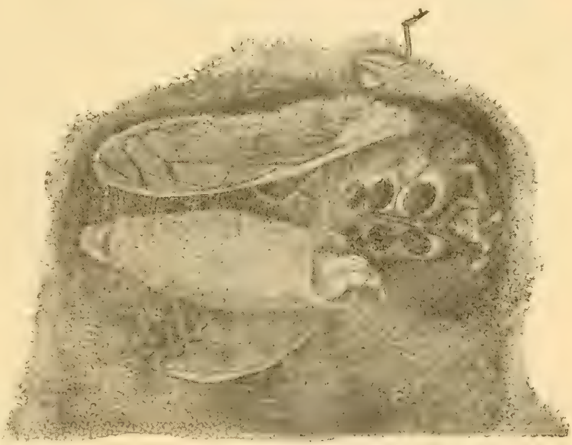

FIG. 59.—Larva of Sphecius spinning its cocoon. Natural size (after Riley).

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 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 $1\frac{1}{2}$ 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.

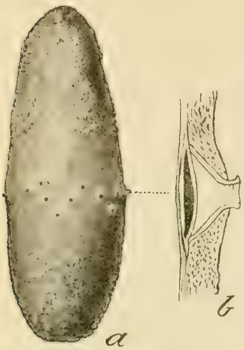

FIG. 60.—*a*, cocoon of Sphecius, natural size; *b*, enlarged section of pore. (After Riley.)

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

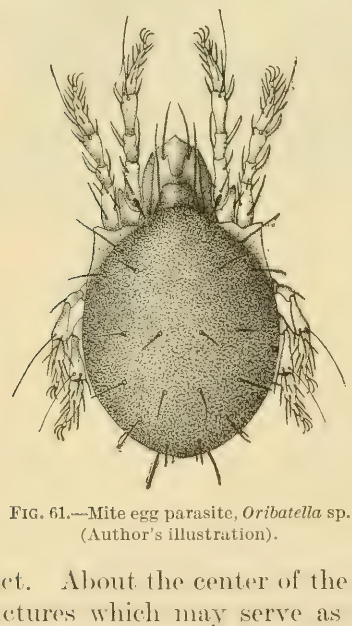
FIG. 61.—Mite egg parasite, *Oribatella* sp. (Author's illustration).

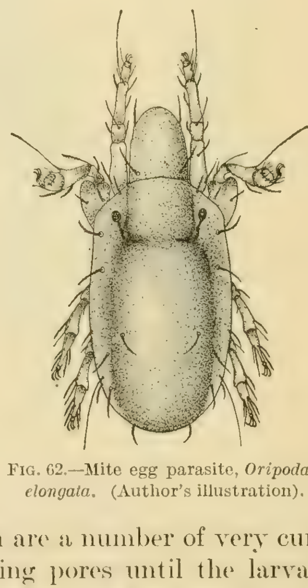
FIG. 62.—Mite egg parasite, *Oripoda elongata*. (Author's illustration).

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*).

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 cankerworm, 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.

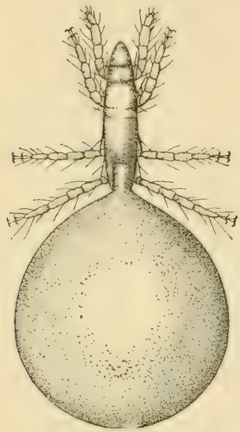
Fig. 64.—Mite egg parasite, *Pediculoides ventricosus*. (Author's illustration.)

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.

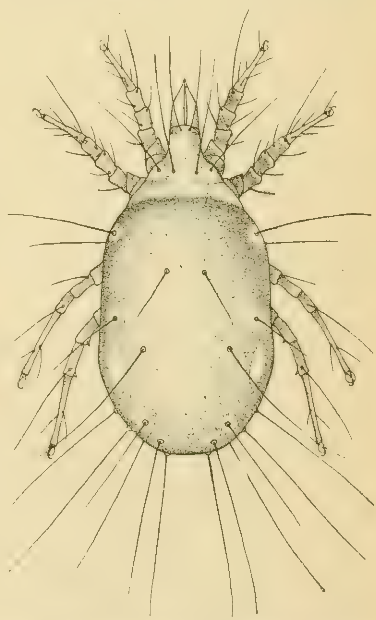
Fig. 65.—Mite egg parasite, *Tyroglyphus cocciphilus*. (Author's illustration.)

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

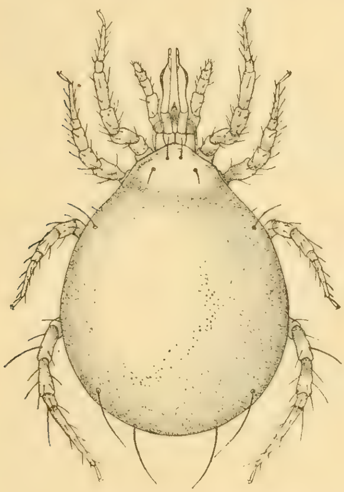

FIG. 66.—Mite egg parasite, *Iphis ovalis*. (Author's illustration.)

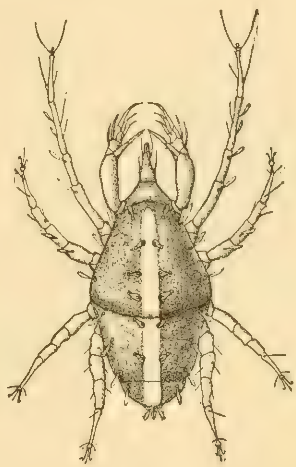

FIG. 67.—*Cheyletus* sp., mite egg parasite of Cicada. (Author's illustration.)

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.

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:

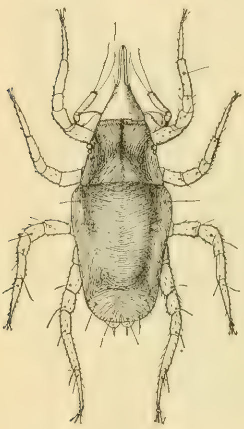

FIG. 68.—*Bdella* sp., mite parasite of eggs of Cicada. Greatly enlarged (author's illustration).

[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 amer-*

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[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.

icanus (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.

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.

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[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 ferti-

[a] Proc. 15th Ann. Mtg. Assn. Economic Entomologists, Bul. 40, Bur. Ent., p. 75.

lizers, 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.

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 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

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[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

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[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

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[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.]

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[a] Synonym of *Sphecius speciosus.*

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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.]

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[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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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY—BULLETIN No. 72.

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

INFORMATION CONCERNING

THE NORTH AMERICAN FEVER TICK,

WITH NOTES ON OTHER SPECIES.

BY

W. D. HUNTER AND W. A. HOOKER.

ISSUED NOVEMBER 2, 1907.

WASHINGTON:
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R. P. Currie, *assistant in charge of editorial work.*
Mabel Colcord, *librarian.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., June 19, 1907.

Sir: I have the honor to transmit herewith a manuscript prepared by Messrs. W. D. Hunter and W. A. Hooker of this Bureau. The manuscript is a study of the life history and habits of the North American fever tick, together with notes on other species. The work upon which this bulletin is based was begun in July, 1905, after practically all of the directors of the southern experiment stations had brought to the attention of this Bureau the necessity of additional work on the important parasite which transmits Texas or splenetic fever of cattle. Prof. H. A. Morgan, director of the Tennessee Experiment Station, has given valuable advice during the progress of the work. The paper contains information of great value in the practical work of tick eradication. I therefore recommend that it be issued as Bulletin No. 72 of this Bureau.

Respectfully,

C. L. Marlatt,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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INTRODUCTORY.

It is safe to state that no more important problem than the eradication of the cattle tick (*Margaropus*[a] *annulatus* Say) confronts the farmers of any country. Not only the cattle-raising industry, but the whole economic condition of a large section of country is affected. The tick, without any but the most limited power of locomotion, and for all practical purposes dependent upon cattle for its existence and dissemination, presents a problem in eradication of a hopeful nature. Cattle are under the control of man. Therefore, the problem is quite different from that involved with other pests, like the boll weevil, which by flight spread over large areas of land. In the one case absolute eradication is possible and in the other it is out of the question. In fact the possibility of the total extermination of the tick in this country is by no means visionary. It was foreseen originally, probably, by Dr. Cooper Curtice, who wrote as follows in 1896: "I look most eagerly for the cleansing of even a certain portion of the infected territory under the direct intention of man, for it opens the way to pushing the tick back to the Spanish Isles and Mexico, and liberating cattle from disease and pests and the farmer from untold money losses. Let your war cry be, Death to the ticks."[b]

In view of these facts it is evident that the most complete knowledge of the habits and life history of the tick is of the utmost importance. All means of eradication must depend upon such knowledge, and improvements in present methods must depend upon additional information regarding the tick. Dr. Cooper Curtice, who will be quoted frequently, because he has been among the foremost in the study of the problem, has written as follows: "To the scientist studying the tick to learn its life history, habits, form, and anatomy,

[a] Neumann has shown that the generic name Boophilus of Curtice must, in obedience to the zoological law of priority, fall as a synonym of the earlier name, Margaropus of Karsch.

[b] Journ. Comp. Med. and Vet. Archives, Vol. XVII, p. 655.

the fact that these animals are pests to the stockman throughout the greater part of the year is of very little importance, while the latter cares little about such matters if he can only learn how to rid his cattle of them. Yet it is only by learning the life history that remedies to prevent them can be applied intelligently, and the fact that the knowledge attained is of practical value adds a double interest to their study."[a]

In view of the evident importance of the work it is surprising that so little has been done in this country. In 1892, about a year previous to the issuance of Smith and Kilborne's epoch-making bulletin demonstrating the tick transmission of fever, Dr. Cooper Curtice published the first data regarding the life history of the cattle tick as Bulletin 24 of the Texas Agricultural Experiment Station. It was accompanied by excellent illustrations. The value of this work will be understood from the fact that it was of a pioneer character, and that all subsequent work has depended upon it. Nevertheless, it was of a preliminary nature and merely outlined matters that must eventually receive the most careful investigations.

Prof. H. A. Morgan, principally in bulletins 51 and 56 of the Louisiana Experiment Station, has added greatly to our knowledge of the cattle tick as well as other species. His work has such practical bearings that it has been the chief indication of the value of life-history studies in pointing out successful methods of eradication. Recently Messrs. Wilmon Newell and M. S. Dougherty, of the Louisiana crop-pest commission, have published a valuable contribution which still further shows how every fact relating to the tick can be utilized in combating it.

The above are the principal publications by American workers. There are many others which also contribute important facts. Among these are Connaway's, Schroeder and Cotton's, Ransom's, and others. In other countries excellent work has been done on related forms. In South Africa Prof. C. P. Lounsbury has made scholarly studies of *Margaropus* (*Boophilus*) *decoloratus* and many other species. In Argentina, Dr. F. Lahille has recently published the results of some of the most exhaustive work on ticks that has been done. These works, with others, are listed in the bibliography at the end of this bulletin.

Notwithstanding the studies that have been conducted in this country, it must be stated that our knowledge of the tick is far short of what it should be. There is a lack of knowledge of local variations, due to climatic influences, as well as such matters as dissemination. To supply this deficiency, the Bureau of Entomology, in cooperation with the officers of several experiment stations, has undertaken a

[a] Tex. Agr. Exp. Sta. Bul. 24, p. 238.

careful study of the tick. Some of the results of practical bearing are given in the following pages and others will be published from time to time.

The writers desire to express their thanks to Prof. H. A. Morgan, director of the Tennessee Agricultural Experiment Station, for many most valuable and courteous suggestions in the course of this work. He has turned over to the writers many of his original notes and has generously assisted in numerous other ways.

LOSSES OCCASIONED BY THE CATTLE TICK.

Undoubtedly the popular idea of the damage caused by the cattle tick concerns itself with the actual death of cattle from the disease transmitted by the tick. Although this is a very important matter and would fully justify the most energetic attempts toward the eradication of the tick, it is really unimportant in comparison with the other losses. Mr. August Mayer, a practical cattle breeder of Shreveport, La., and Dr. J. R. Mohler, of the Bureau of Animal Industry of this Department, have made most careful, comprehensive estimates of the losses caused by ticks. The following summary is taken largely from their writings:

1. Loss by death from disease in young animals and those removed from temporarily tick-free localities (as, for instance, in cities) to places where they become infested. The enormous loss under this heading will be understood when it is recalled that every bovine animal in the tick area must suffer an attack of fever if it becomes infested with ticks. In an instance that came to the attention of the writers, 39 out of 40 calves dropped in a city died of tick fever when removed to an infested pasture.

2. Loss in weakened condition and stunted growth caused by the fever.

3. Loss by gross tick infestation. At the present time (March, 1907) hundreds of cattle in south Texas are dying from gross infestation resulting from a mild winter. In extreme cases, Mr. Mayer estimates that as many as 200 pounds of blood may be withdrawn from the host during a single season. This makes a gain in weight impossible even in the best of pastures. Moreover, Prof. H. A. Morgan and other observers believe that gross infestation and the consequent general debility induce acute attack of fever even in animals ordinarily immune.

4. The tick makes hazardous the importation of pure-bred cattle. This prevents the upbuilding of southern cattle and at the same time largely deprives the northern breeder of a market that he should have. Moreover, the inability of the southern breeder to exhibit his stock in

the north and of the northern breeder to exhibit his in the tick area is a handicap, the importance of which will be readily seen.

5. The necessary restrictions in the shipping of southern cattle also handicap the breeder and affect the price.

6. The maintenance of the quarantine involves considerable annual expense for the protection of the cattle owners north of the line.

7. Minor losses may be grouped as follows: (*a*) In Texas, especially, the tick induces the attack of the screw-worm fly (*Chrysomyia macellaria* Fab.); (*b*) there seems to be, as pointed out by Mr. Mayer, a considerable interference with the fecundity of infested cows; (*c*) the railroads are put to the expense of disinfecting cars and maintaining separate pens and the stockman to the expense of dipping—items which react on the price that southern cattle bring.

All the losses that have been mentioned total approximately $100,000,000 each year. At present the loss, as indicated by Doctor Mohler, amounts annually to at least 10 per cent of the value of the cattle. The quality of the animals is the lowest and the loss is greatest in the regions where the natural conditions without the tick should produce the finest cattle with the least loss. But the damage may be better expressed by the statement that the tick makes profitable production practically impossible in the South. Any successful system of agriculture must rest upon a diversification of crops, and this, in turn, depends upon animal husbandry to maintain the fertility of the soil. Therefore, until the tick is eradicated or placed under control, a rational system of agriculture in the infested area is out of the question, and that achievement would mean almost as much to the North as to the South.

THE LIFE HISTORY OF TICKS IN GENERAL.

The following general statement regarding the life history of ticks is taken from Salmon and Stiles:[a]

Ticks are temporary parasites, attacking mammals, birds, and reptiles. They do not appear to be so strictly confined to certain hosts as do parasites in general. Still, this may be more of an apparent than a real rule. Certain it is that, although a given tick may be found occasionally on animals which are very dissimilar (dog ticks have, for instance, been found on snakes), still the various species show a decided predilection for certain hosts.

The parasites copulate during the period of parasitism [b] and suck the blood from their hosts. The female grows to a large size and eventually drops to the ground and

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[a] Seventeenth Ann. Rept. Bureau of Animal Industry, U. S. Dept. Agric., p. 398.

[b] This is not invariable. *Amblyomma americanum* sometimes copulates soon after the second molt, but before it has gained a host. It is likely that other species also occasionally do so.—W. D. H. and W. A. H.

lays numerous eggs, which are usually more or less clustered together. The larva upon hatching possesses three pairs of legs, the fourth pair being added during the first molt. Either the hexapod or the octopod form may attack its host.

From the foregoing it will be seen that the cattle tick, like other ticks, passes through the following stages: Egg, larva (six-legged form), nymph, and adult.

The eggs are nearly round, dark brown in color, and deposited in large masses, held together by the gummy secretion with which the female coats each egg as it is deposited. The next stage, known as the seed tick, differs remarkably from the later stages in the fact that six instead of eight legs are present. The stigmata are located between the second and third coxæ, just anterior to the third coxæ, and problematic indications are seen between the first and second coxæ. No distinct genital or anal opening can be seen in this stage. The anterior legs are much larger than the others. They are waved violently through the air when the seed ticks are disturbed either by the approach of a host or in any other way. After some time the seed tick molts and the next, or nymphal stage, is provided with eight legs. The absence of the genital opening will differentiate this stage from the following one. Ticks in the nymphal stage are frequently referred to in the South as "yearling ticks." After a second molt the adult form is reached. Copulation then takes place, and after engorgement the female drops to the ground for the purpose of depositing eggs.

THE LIFE HISTORY OF THE CATTLE TICK.

As pointed out by Morgan the most important fact about the cattle tick (*Margaropus annulatus* Say), from the standpoint of practical control, is that the time of development on the animal is always shorter than the total of the preoviposition, oviposition, and incubation periods. This gives the farmer an opportunity to free his cattle and pastures of ticks by the same process of rotation. As a foundation for the surest and most economical procedure an accurate knowledge of the variations of the periods in the life history of the tick under different conditions is absolutely essential. Our effort in this bulletin is in a measure to supply this information. The work has been principally to obtain data necessary in the pasture eradication and feedlot systems of eradication. We have consequently studied the development of the tick both during its existence on the animal, by means of a steer procured for that purpose, and during its life, under various conditions, when not attached to the host.

PERIOD PREVIOUS TO OVIPOSITION.

The cattle tick, like other species, passes through a distinct period between the time of dropping from the host and the beginning of oviposition. When the tick drops, the eggs are not ready to be deposited, but must pass from the ovary through the oviduct. (See fig. 1.) Thus there is a definite physiological basis for a period which has a very practical bearing on plans of eradication that depend upon a knowledge of the exact time to be allowed in removing cattle from one inclosure to another. Lahille has used the term "prootoquie" for this period, but we shall refer to it merely as the preoviposition period.

FIG. 1.—Genital apparatus of *Margaropus microplus: a*, Position of eggs at time of dropping of tick from host; *b*, position of eggs when oviposition begins. Highly magnified (redrawn from Lahille).

As will be seen from Table I the preoviposition period ranges from 2 to 40 days, depending upon temperature. In the summer it averages between 3 and 4 days, and in winter over 20 days.

It might be supposed that the data in the table referred to show a preoviposition period longer than normal on account of the removal of the ticks artificially. However, only ticks about to drop were selected, and repeated tests with ticks actually dropped showed that the method followed gives the natural preoviposition period.

OVIPOSITION PERIOD.

As will be seen from Table I, the period occupied in oviposition ranges from 6 to 70 days, depending upon the temperature. In the summer it averages 10 or 11 days, while in the winter it is two or three times as long.

TABLE I.—*Oviposition of Margaropus annulatus, July, 1905, to July, 1906, at Dallas, Tex.*

When collected.	Number of ticks.	Preoviposition period.			Oviposition period.			Period from dropping to end of oviposition.			Number of eggs per tick.		
		Maximum.	Minimum.	Weighted average.	Maximum.	Minimum.	Weighted average.	Maximum.	Minimum.	Weighted average.	Maximum.	Minimum.	Weighted average.
1905.		*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Eggs.*	*Eggs.*	*Eggs.*
July 21	18	3	2	2.9	13	6	8.2	14	8	11.0	3,806	515	1,185
Aug. 3	4	5	3	3.5	11	7	9.0	13	11	11.8	2,228	1,466	1,971
Sept. 18	10	4	3	3.4	18	12	15.0	20	14	17.0	....	....	....
Sept. 27	6	3	3	3.0	19	19	19.0	21	21	21.0	3,875	2,365	2,576
Oct. 12	15	6	4	5.1	44	21	30.7	48	21	32.0	2,311	694	1,795
Nov. 6	15	15	10	11.9	64	21	39.9	79	33	50.8	2,689	805	1,891
Dec. 6	14	41	21	28.6	70	20	42.6	90	55	71.0	3,946	464	1,779
1906.													
Feb. 6	8	39	18	21.8	47	8	29.8	58	26	50.5	2,134	147	695
Feb. 21	9	40	13	18.7	41	30	38.9	53	38	47.8	3,496	10	2,009
Mar. 23	10	10	9	9.8	29	12	23.4	38	21	30.2	2,437	1,118	1,941
Apr. 6	10	6	3	4.8	25	17	21.8	30	20	25.7	2,260	1,281	1,658
Apr. 20	10	6	5	5.4	18	11	15.6	22	16	20.0	3,412	2,197	2,891
May 4	10	10	6	7.8	17	11	14.6	24	18	21.4	2,676	1,701	2,251
May 22	10	6	4	4.3	15	10	12.6	18	15	16.4	3,180	1,391	2,250
June 5	10	5	3	3.5	13	9	10.9	15	12	13.4	2,881	152	1,802
June 20	10	4	3	3.5	14	9	11.7	16	8	14.2	2,467	843	1,950
July 2	10	5	3	3.9	14	9	11.0	16	12	13.9	2,292	1,135	1,837
July 13	10	4	3	3.1	13	7	10.4	13	8	12.5	2,397	1,666	2,068
Total	189	......	......	......	......	......	......	......	......	......	....	....	32,499
Average	......	......	......	......	......	......	......	......	......	......	....	....	1,911.7

From Table I the following important, practical data are obtained:

1. The preoviposition period ranges from about 3 days in summer to as many as 28 days in winter.

2. The oviposition period ranges from between 8 and 9 days in summer to 42 days in winter.

3. The total period from dropping to the end of oviposition ranges from 11 days in summer to 71 days in winter.

It should be noted that Table I gives the total period from dropping to the end of oviposition based upon the weighted averages of the preoviposition and the oviposition periods. Therefore the maximum total period may be somewhat longer than indicated, as, for instance, in cases where either the preoviposition or the oviposition for some reason are prolonged beyond the average.

EGG STAGE.

The eggs are generally elliptical, but vary in shape on account of pressure and drying. In color they are at first honey-yellow, but soon change to a deep yellowish brown. They are shiny and smooth. The average size in a lot of 10, measured by a micrometer, was 0.54 by 0.42 mm. About the middle of the incubation period in many species a whitish spot appears on the eggs and becomes more conspicuous as the time for hatching approaches. This spot is located toward one end and seems to be due to the excretion of the embryo. In *Margaropus annulatus* it is very conspicuous and is a certain indication of viability.

The act of oviposition is most interesting. This process was referred to by Dr. Cooper Curtice.[a] An analogous operation in *Ixodes ricinus* has recently been carefully described and illustrated by Wheler,[b] and was earlier noted by Lewis.[c] One of our associates, Mr. R. A. Cushman, has observed the operation. The following description is based upon his notes:

When oviposition is about to take place the capitulum is bent downward toward the genital aperture. This exposes a delicate, viscid membrane between the capitulum and the scutum. The membrane becomes distended and is projected out over the capitulum in two rounded lobes, practically covering it. This process is repeated several times before the egg is finally ejected, the membrane being extruded and retracted alternately while the capitulum is lowered and raised. Finally the white, membranous ovipositor is extended, turning inside out, until it touches the distended membrane. The capitulum is now completely hidden. As soon as the ovipositor and membrane have come in contact the former slowly recedes, leaving the egg adhering to and partially enveloped by the membrane. The egg remains in this position for a varying length of time. Then the membrane is withdrawn, rolling the egg along for a short distance on the dorsal surface of the capitulum. At the same time the capitulum is raised. Then the processes of distention and contraction of the membrane and lowering and raising of the capitulum are repeated several times, the egg being finally completely coated by the viscid substance from the membrane and being finally pushed back and deposited on the anterior edge of the scutum. Each egg is laid in this manner, the tick backing slowly away and leaving the mass of eggs in front of her. The actual time consumed by the tick in laying a single egg is about 30 seconds, while the removal of the egg and the resting period consume from one to several minutes, a much longer resting period being taken at intervals between lots of from 10 to 50 eggs. It has been impossible for us with the means at our command to demonstrate the "paired, racemose glands" of the membranous sac referred to by Curtice. As far as we have been able to see, the substance with which the eggs are coated is secreted from numerous minute glands scattered over the surface.

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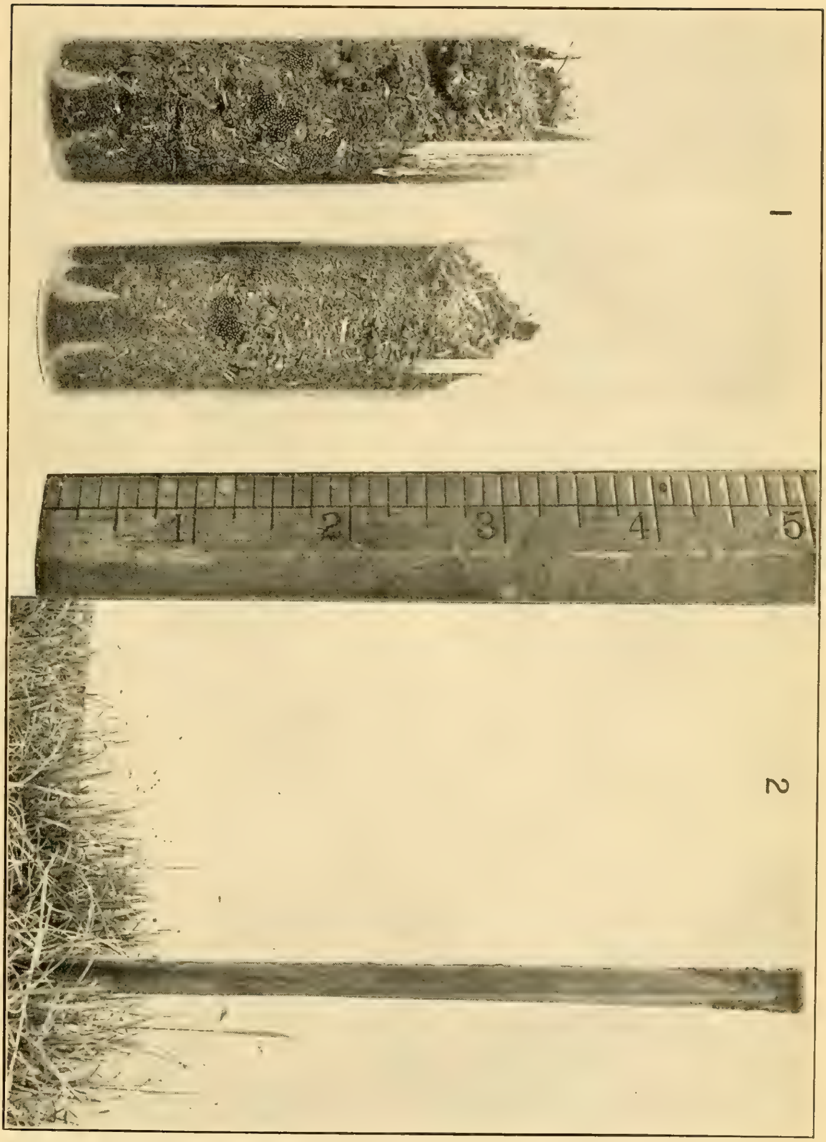
[a] Tex. Agr. Exp. Sta., Bul. 24, p. 242.

[b] Journ. Agric. Sci., 1906, p. 405.

[c] Proc. Roy. Micros. Soc., 1892.



THE NORTH AMERICAN FEVER TICK.

Fig. 1.—Eggs of *Margaropus annulatus* deposited under stable litter. Fig. 2.—Seed ticks of Margaropus bunched on grass and stake. (Original.)

THE NORTH AMERICAN FEVER TICK.

Fig. 1.—Steer used in experimental work. Fig. 2.—Arrangement for obtaining data on incubation. (Original.)

In the manner described a mass of eggs grows steadily in front of the tick, while its body becomes correspondingly smaller as the process proceeds. The gummy secretion holds the eggs together so that the mass looks not unlike a large accumulation of minute brown beads.

The number of eggs deposited varies greatly with the size of the female. The highest number recorded in our experiments was 3,806.[a] The average of 189 ticks under various conditions was 1911.7, and this probably very closely approximates the average under natural conditions. The daily average, of course, varies also. The maximum is generally reached from 7 to 9 days after deposition begins. The highest number for any 24-hour period was 826. The average for 20 ticks was 144.

INCUBATION.

Most important means of control of the cattle tick depend upon taking advantage of the fact that eggs remain on the ground for a considerable time before hatching. Provided there are no seed ticks present, it is perfectly safe to allow cattle in areas in which ticks may be dropped from them, as, for instance, in fields under cultivation for one crop season, if the animals are removed before hatching takes place. It will be seen that this has an important bearing on the process of relieving cattle of ticks by placing them for limited periods in different tick-free inclosures. Accordingly we have made an especial effort to obtain data regarding the period occupied in incubation under different conditions and in different seasons.

In 1905 a number of experiments to determine the length of the incubation period were conducted, the eggs being placed in paper pill boxes. Subsequent work showed that this arrangement gives more rapid development of the embryo than takes place under normal conditions. Especially is the period shortened when an abundance of moisture is furnished. In these experiments in July and August the eggs hatched in from 17 to 21 days, and during September in from 25 to 44 days. These results are of value only in showing how the incubation period may be shortened under extreme conditions, which must rarely or never occur in nature.

No eggs deposited in October, 1905, hatched before April 10, 1906, a period of over 170 days.

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[a] The greatest number found by H. A. Morgan was 3,198 (La. Agr. Exp. Sta., Bul. 51, p. 242), but Newell and Dougherty record 4,124 in one instance (La. Crop Pest Comm., Circ. 10, p. 23).

In 1906 a more extended series of experiments was instituted. In the first series, consisting of 59 lots deposited from February 20 to September 21, eggs were kept in pill boxes. As has been pointed out, this method accelerates incubation further than natural conditions are likely to. The following is a summary of the results of these experiments:

Eggs deposited in March hatched in 74 days.
Eggs deposited in April hatched in 43 to 53 days.
Eggs deposited in May hatched in 24 to 33 days.
Eggs deposited in June hatched in 20 to 22 days.
Eggs deposited in July hatched in 19 to 22 days.
Eggs deposited in August hatched in 19 to 21 days.
Eggs deposited in September hatched in 23 to 154 days.
Eggs deposited October 1–7 hatched in 135 to 139 days.
Eggs deposited October 15 and later have not hatched to date (February 20, 1907).

In the second series of experiments relating to incubation conducted in 1906 a special effort was made to provide conditions that would give approximately the same period that must occur under normal conditions. (See Table II.) To do so some eggs were placed on soil in open-bottom glass tubes in the open air (see Pl. II, fig. 2) and shaded for a portion of the day. Others placed under the same conditions were exposed to the sun at all times. In the third series the eggs were located in an outdoor thermometer shelter where they were protected from sun and rain. The separate lots consisted of several hundred eggs. They were deposited by different females in the laboratory and placed together for the observations under consideration. In this way a large number of eggs deposited within the same 24-hour period was obtained. It is supposed that these conditions approximate closely to those which surround the great majority of eggs in pastures. The following is a summary of the data contained in the table:

Eggs deposited in April hatched in from 39 to 54 days.
Eggs deposited in May hatched in from 27 to 33 days.
Eggs deposited in June hatched in from 21 to 28 days.
Eggs deposited in July hatched in from 22 to 26 days.
Eggs deposited in August hatched in from 23 to 32 days.

In September eggs deposited prior to the 18th hatched in from 23 to 76 days. Eggs deposited after September 18 have not hatched up to February 20, with but two exceptions. These were eggs deposited October 3 and October 7, which began to hatch on February 18. These eggs were placed in such a way that they were more exposed to the sun than other lots that have not hatched, deposited before and since the dates mentioned.

TABLE II.—*Period of incubation of Margaropus annulatus at Dallas, Tex., 1906, under various conditions.*

Eggs deposited.	Hatching.	Minimum incubation period.	Eggs deposited.	Hatching.	Minimum incubation period.
		Days.			*Days.*
Apr. 13	June 5	[a] 54	Aug. 12	Sept. 8	[a] 28
Apr. 14	May 30	[a] 47	Aug. 14	Sept. 6	[b] 24
Apr. 15	May 31	[a] 47	Aug. 18	Sept. 9	[b] 23
Apr. 27	June 4	[a] 39	Aug. 18	Sept. 18	[a] 32
May 13	June 14	[a] 33	Aug. 19	Sept. 10	[b] 23
May 15	June 12	[a] 29	Aug. 19	Sept. 11	[c] 24
May 28	June 23	[a] 27	Aug. 22	Sept. 13	[a] 23
May 30	June 26	[a] 28	Aug. 22	Sept. 14	[c] 24
May 31	June 27	[a] 28	Aug. 24	Sept. 16	[b] 24
June 9	July 5	[a] 27	Aug. 28	Sept. 20	[b] 24
June 10	July 5	[a] 26	Aug. 28	Sept. 21	[c] 25
June 11	July 7	[a] 27	Aug. 28	Sept. 23	[a] 27
June 21	July 18	[a] 28	Sept. 1	Sept. 23	[c] 23
June 22	July 14	[b] 23	Sept. 1	Sept. 24	[b] 24
June 24	July 16	[a] 23	Sept. 1	Sept. 27	[a] 27
June 24	July 16	[b] 23	Sept. 2	Sept. 26	[c] 25
June 30	July 20	[b] 21	Sept. 9	Oct. 7	[c] 29
July 1	July 22	[a] 22	Sept. 9	Oct. 10	[b] 32
July 20	Aug. 10	[b] 22	Sept. 9	Oct. 15	[a] 37
July 20	Aug. 14	[a] 26	Sept. 14	Oct. 24	[c] 41
July 22	Aug. 14	[c] 24	Sept. 14	Oct. 26	[b] 43
July 31	Aug. 22	[b] 23	Sept. 14	Nov. 5	[a] 53
July 31	Aug. 22	[c] 23	Sept. 18	Dec. 2	[b] 76
July 31	Aug. 23	[a] 24	Sept. 18	Dec. 2	[a] 76
Aug. 11	Sept. 4	[b] 25	Sept. 26	Feb. 20	[b] 148
Aug. 12	Sept. 3	[c] 23			

[a] The eggs were placed in open-bottom test tubes in sand in the open air. They were protected from the direct rays of the sun at all times by a cheese-cloth screen. Up to 11 a. m. they were within the shade of the house.
[b] In open-bottom test tubes in soil exposed to sun at all times.
[c] In open pill boxes outdoors protected from sun and rain at all times.

RELATION OF TEMPERATURE TO INCUBATION.

In the series of experiments just referred to accurate data on temperature were obtained. Standard maximum and minimum thermometers kept in an instrument shelter were used. In Table III the records of temperatures are given together with the average incubation periods for the various lots of eggs under observation during different months. The data show that there is an intimate relation between temperature and the period of incubation. The shortest average minimum incubation period (23.4 days) occurred when the average temperature was highest (80.2° F.). The longest average minimum incubation period (137 days) occurred with the lowest average mean temperature (53.2° F.). Between these extremes there is a graduated correspondence between temperature and incubation.

TABLE III.—*Relation of temperature to period of incubation in Margaropus annulatus at Dallas, Tex., 1905–1906.*

Month deposited.	No. of lots.	Incubation period.			Incubation temperature.					
					Mean.			Total effective.		
		Maximum.	Minimum.	Average.[a]	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
1905.		*Days.*	*Days.*	*Days.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
Sept	2	56	43	49.5	62.6	62.3	62.4	1,083	840.5	961.8
1906.										
Apr	4	54	39	46.7	72.6	69.7	70.8	1,475.8	1,139.1	1,286.4
May	5	33	27	29	79.7	73.5	77.6	1,103.2	981.6	1,023
June	8	28	21	24.8	80.5	79.8	80.2	1,046.6	782.7	920.7
July	7	26	22	23.4	80.5	79.8	80.2	962.1	824.3	866.5
Aug	14	32	23	24.9	79.7	78.9	77.8	1,169.3	826.7	904.4
Sept	13	154	23	46.2	79.4	54.6	70.7	1,907.9	837.6	1,127
Oct	2	139	135	137	53.4	53	53.2	1,600.6	1,510.8	1,555.7

[a] Weighted.

It will be noted that the total effective temperature necessary to cause eggs to hatch varies from 866.5° to 1,555.7°. It would be of the greatest practical importance to formulate a rule which, on the basis of effective temperatures, would show the time when eggs will hatch at different seasons of the year. It is probable that the present data are insufficient for this purpose, and special efforts will be made to add to them. However, with the data at present available the following tentative law may be proposed:[a]

When the average daily mean temperature ranges less than 53.2°, at least 1,510.8 degrees of effective temperature must accumulate before hatching will take place. When the mean daily temperature averages from 61.4° to 77.8°, from 840.5 to 1,139.1 degrees of effective temperature will be required for hatching. When the mean daily temperature averages higher than 80°, between 782.7 and 824.3 degrees of effective temperature must be accumulated before hatching will take place.

It is not our purpose to advise an attempt at the practical application of this rule at the present time, but it is supposed that such practical application can be ultimately made. To do so it would only be necessary for the stockman to have a set of self-recording maximum and minimum thermometers, such as can be purchased for $3. Or the data might be obtained from the nearest Weather Bureau station. By either of these means the average daily temperature could be easily obtained. By summing up the daily effective temperatures—that is, the number of degrees above 43—the stockman, by reference to the minimum amount of accumulated effective temperature necessary for hatching with various average daily temperatures, could determine at least within certain limits what time

[a] This rule, of course, may not apply in rare cases in which eggs are deposited where they will be subject to artificial heat rather than to weather temperature, as in manure piles. It will apply, however, to the great majority of pasture conditions throughout the infested area.

it would be necessary to remove cattle from pastures in which tick eggs might be to avoid danger of infestation by seed ticks. Possibly a more feasible application would be the collection of the necessary data from many localities by the State entomologists and the publication of predictions based upon them from time to time.

A seasonal arrangement of our data for 1905 and 1906 shows the following:

Eggs deposited in June, July, August, and up to September 15 require from 824.3 to 840.5 degrees of accumulated effective temperature for hatching.

Eggs deposited from September 16–30, in October, and in later fall and winter months, require an accumulated effective temperature of from 837.6 to 1,510.8 degrees.

Eggs deposited in April and May require from 981.6 to 1,139.1 degrees.

Naturally an arrangement by months as above must be defective, since no two seasons are exactly alike. The only accurate method must be based upon a knowledge of the temperatures that are accumulating in any particular season.

EFFECT OF HEAT AND COLD ON EGGS.

In experiments to determine the effects of heat upon eggs a continuous temperature of 100° was maintained by means of an incubator. The period of application of heat was 15 days. In one series no moisture was provided, and in this case no hatching took place. In another series in which abundant moisture was furnished, hatching took place and the incubation period was reduced to 15 days. It will thus be seen that a moist atmosphere is essential to the hatching of eggs under a constant high temperature.

In experiments relating to the effects of low temperatures on eggs, by means of a refrigerator a mean temperature of about 45° was maintained, with a minimum of 32° and a maximum of 65°. The eggs were kept in pill boxes with gauze tops to allow free circulation, except during the period of refrigeration, when the ordinary covered pill boxes were used. The eggs from about 20 engorged ticks, collected on July 26, were placed in the refrigerator on August 4 and remained for 30 days. Hatching began on September 23, and about 60 per cent of the eggs were viable.

In the case just referred to, the normal period of incubation was increased, as the result of refrigeration, by 8 days. In a long series of similar experiments, however, in which the period of refrigeration ranged from 1 to 21 days, the period of incubation was not appreciably lengthened and the normal percentage of hatching took place.

In a series of experiments with alternate cold and normal temperatures the eggs were kept in a refrigerator exposed to a mean temperature of about 45° F. from 8.30 p. m. to 8.30 a. m. During the day the eggs were removed from the refrigerator and remained at the temperature of the air. After six consecutive nights of exposure in this way from 5 to 10 per cent of the eggs hatched. It is probable that the necessary manipulation in these experiments interfered with the viability of the eggs and that normally a considerably greater percentage would hatch under the same conditions.

SUBMERGENCE OF EGGS IN WATER.

Sixteen different lots of eggs were used to determine the effect of submergence in water. One-half were submerged for from 10 to 24 days, and most of the eggs hatched. In another lot submerged for 25 days 33 per cent hatched. The experiments were performed from June to September and the incubation period under water was not appreciably different from the normal at the different periods at which submergence took place. In all these experiments complete submergence was secured by means of a screen obstruction below the surface of the water. Our results agree with those recently published by Messrs. Newell and Dougherty and with unpublished data obtained by Prof. H. A. Morgan, who suggested our experiments.

The practical importance of these experiments is to show that the flooding of pastures would have no effect whatever on the viability of tick eggs on the ground. Not only would the great majority hatch, but the time of hatching would not be materially different from that in case no water whatever were present. As a matter of fact the flooding under some conditions, as, for instance, during a drought, might hasten incubation.

These data, taken in connection with data mentioned elsewhere, showing the remarkable resistance of seed ticks to water, indicate clearly the reason why pastures overflowed for considerable periods have repeatedly been found to furnish tick infestation.

A series of eggs varying from those recently deposited to others about to hatch were submerged in tube-form vials. To keep the eggs submerged absorbent cotton was pressed down into the water. None of the eggs hatched, and we suppose this was due to insufficient aeration.

Several lots of eggs that were kept in pill boxes until they had become thoroughly dried were placed on water in Stenter dishes to determine if hatching would follow. After submergence for a short period the eggs in large part filled out and appeared viable, but did not hatch.

PERCENTAGE OF EGGS HATCHING.

To determine the exact percentage of eggs hatching is a rather difficult matter for the reason that manipulation in counting interferes greatly with their viability. In June, July, and August, 1906, a number of observations were made showing the percentage of viable eggs in different lots from 30 to 90. In these cases the eggs were counted, and it is likely that the percentage hatching under natural conditions is considerably higher than that indicated. The examination of masses of eggshells where hatching has taken place normally reveals few unhatched eggs.

Messrs. Newell and Dougherty[a] have recorded a percentage of hatching during the months of April, May, June, July, August, and September of from 61.6 to 92. These experiments were performed at Baton Rouge, La., under conditions which approached the natural ones very closely, although the eggs were counted as in our experiments.

LARVAL OR SEED-TICK STAGE.

The larval tick is a minute 6-legged creature without distinct genital opening, and with indistinct stigmata between the second and third pairs of coxæ. As Salmon and Stiles state, larval ticks frequently show indications, at least, of stigmata between the first and second pairs of coxæ, and behind the posterior coxæ in addition to those between the second and third pairs. Only the pair first mentioned seem to be functional. The color of the larva at first is whitish but soon becomes dark brownish.

NONPARASITIC PERIOD.

For a few hours the larva remains about the shell from which it has just emerged, but later makes its way upward on the first blade of grass, stick, post, or other support that presents itself. Professor Morgan informs us that he has seen seed ticks on the tips of sugar cane about 8 feet from the ground. By placing a pole in the vicinity of millions of seed ticks we have observed them to reach a height of about 6 feet in a surprisingly short time; but the tendency is strongly to remain not more than about 4 feet from the ground. In the absence of some vertical object the seed ticks do not seem to scatter to any great extent, but collect on the highest immediate point, even if it is only a small clod or stone.

On whatever support the young ticks happen to be, they collect in masses often nearly an inch in diameter. (See Pl. I, fig. 2.) Here they remain for weeks or months awaiting a host. The front legs, which combine the functions of antennæ and legs in the insects

[a] La. Crop Pest Comm., circ. 10, p. 24.

proper, are waved through the air more or less constantly, and violently when a moving object approaches. The ticks attach themselves to any animate or inanimate object which touches them. Only those that happen to attach themselves to cattle (and rarely a few other animals) ever develop; the others either die or, dropping off, become widely scattered.

Heavy rains wash the seed ticks to the ground, and it is possible that violent winds may also serve to disseminate them. In our experiments they have thus been spread to a distance of 5 or 6 feet.

It is noticeable that the seed ticks shun direct sunlight. We have repeatedly seen bunches move halfway around the support with the shade. In the morning they would be on the west and at night on the east side.

EFFECT OF WATER ON SEED TICKS.

Interesting data having a bearing on the dissemination of the cattle tick through the agency of water courses have been obtained. It has been noted that heavy rains wash seed ticks from their supports to the ground. In a considerable number of experiments seed ticks were found to endure submergence varying in different lots from 10 days to 157 days. The latter record was obtained in an experiment in which seed ticks were first placed in water in a Petri dish and a few days later removed to a tube with earth on the bottom. The details of these experiments are given in Table IV.

It is doubtless true that dissemination by water courses is not quite as important as these results would indicate. Of course it is possible that seed ticks may be carried many miles and deposited on grass or bushes, from which they may reach cattle. The enormous scattering of ticks so submerged in water, as would be the case in floods, would undoubtedly greatly reduce the chances of infestation in pastures.

TABLE IV.—*Effect of water on seed ticks.*

Eggs hatched.	Seed ticks submerged.	Longevity, submerged.	Remarks.
		Days.	
Sept. 2	Sept. 4	47	Eight inches of water in tub.
	Sept. 30	157	In Petri dish; Oct. 9 removed to tube with dirt on bottom.
Oct. 4–11	Nov. 11	14	Alive on Nov. 25, and may have lived longer.
Sept. 1	Sept. 1	12	In tub with sand and vegetable matter.
	Aug. 4	41	In Petri dish on porch, with algæ in water.
Aug. 16–17	Aug. 17	32	In Petri dish on laboratory desk.
Aug. 21–25	Aug. 21	17	Submerged as eggs.
Aug. 4–11	Sept. 4	10–17	Submerged as eggs. Culicid larva may have interfered.

Some years ago Professor Morgan obtained interesting results on the effect of low temperature on seed ticks. In brief, he found a temperature of 15° or 16° F. for a short period did not kill many seed ticks, but that such a temperature continued for 24 hours resulted in the death of practically all. Our experiments have been of two classes—(1) in water and (2) without water. In both cases the seed ticks were subjected to a temperature somewhat less than 32° F. In the case where water was supplied solid ice was obtained. Both in and out of water the seed ticks survived a freezing temperature of one hour's duration, although there was perceptible mortality among them.

LONGEVITY OF SEED TICKS.

The time that seed ticks may survive without a host is a most important matter in plans for control. Our experiments on this point have been of two kinds—(1) with seed ticks from eggs deposited by females placed on the ground in favorable circumstances, thus giving absolutely natural conditions, and (2) with seed ticks in glass tubes, where they could be observed more closely.

In the first series, which was instituted at the suggestion of Professor Morgan, several hundred engorged ticks were placed on the ground at regular intervals. The only inclosure was a cylinder of 2-inch-mesh wire screen about 4 feet in diameter to prevent disturbance. The seed ticks from females placed under these conditions accumulated in enormous numbers on the blades of grass or stakes provided for the purpose (see Pl. I, fig. 2). Table V gives the number of days the seed ticks survived in these experiments, together with other data. It will be seen that the shortest period was 49 days and the longest 159+ days. However, the important period is from the time of dropping of the adults to the death of the resulting seed ticks, since the farmer must always suppose in rotating his cattle that adults were dropped on the day of removal from the pasture which it is desired to clean. This period ranged from 91 to 175+ days. It will be noted that there is considerable variation in the period of survival, even at the same season of the year. This seems to depend upon two factors, namely, the number of seed ticks in the bunches and the amount of rainfall. The larger masses survive longer, perhaps because the moisture is better retained, and heavy rains scatter and reduce the masses. It is probable, on account of the very large numbers of seed ticks in our experiments, that the periods given in the tables are somewhat longer than normally occur in the field. However, such excessive numbers do sometimes occur in nature. For instance, when an animal dies of gross infestation thousands of ticks deposit in a very restricted area. Mr. J. D. Mitchell has seen cases of this kind in which the bunches of seed ticks were fully as numerous as in our experiments.

TABLE V.—*Longevity of seed ticks of Margaropus annulatus Say, at Dallas, Tex., 1906.*

When dropped.	Period from dropping to completion of oviposition.		When hatched.	Seed ticks all dead.	Maximum period from dropping to death of all seed ticks.	Period of life of seed ticks.
	Minimum.	Maximum.				
	Days.	*Days.*			*Days.*	*Days.*
June 20	12	18	Aug. 12	Oct. 8	110	57
June 23	12	18	Aug. 15	Oct. 21	120	[a] 67
May 19	14	21	July 5	Oct. 20	154	107
July 21	12	19	Aug. 14	Oct. 15	86	62
Do	8	16	Sept. 1	Oct. 20	91	49
Aug. 6	8	16	Sept. 14	(*b*)	175+	159+

[a] In this experiment the seed ticks were accidentally disturbed. They would have lived some days beyond the period indicated.
[b] Some alive Feb. 20, 1907.

In the second series of experiments to determine the longevity of seed ticks the eggs were placed in glass tubes with open bottoms. As will be seen from the footnotes to Table VI certain seed ticks in tubes were shaded at all times, others in tubes were exposed constantly to the sun, while the remainder were placed in pill boxes protected from sun and rain. It is supposed that these diverse conditions give an average length of survival that approaches closely to that occurring under natural conditions. The detailed results follow:

TABLE VI.—*Longevity of seed ticks of Margaropus annulatus Say, Dallas, Tex., 1906.*

Eggs deposited.	Hatching.[a]	Seed ticks dead.	Period from hatching to death.	Period from deposition to death.	Conditions.
			Days.	*Days.*	
Apr. 13	June 5	Aug. 28	84	138	(*b*)
Apr. 14	May 30	Aug. 15	77	124	(*b*)
Apr. 15	May 31	Aug. 22	83	130	(*b*)
Apr. 27	June 4	Aug. 28	85	124	(*b*)
May 13	June 14	Sept. 20	98	131	(*b*)
May 15	June 12	Oct. 5	115	144	(*b*)
May 28	June 23	do	104	131	(*b*)
May 30	June 26				(*b*)
May 31	June 27	Aug. 9	43	71	(*b*)
June 9	July 5	Sept. 26	83	110	(*b*)
June 10	do				(*b*)
June 11	July 7	Sept. 22	77	104	(*b*)
June 21	July 18	Aug. 15	28	56	(*b*)
June 22	July 14	Aug. 28	45	68	(*c*)
June 24	July 16	Aug. 6	21	44	(*b*)
Do	do	Oct. 6	82	105	(*c*)
June 30	July 20	Sept. 26	68	89	(*c*)
July 1	July 22	do	66	88	(*b*)
July 20	Aug. 10	Oct. 20	71	93	(*c*)
Do	Aug. 14	Aug. 28 (escaped)			(*b*)
July 22	do				(*d*)
July 31	Aug. 22	Feb. 18	180	203	(*c*)
Do	do				(*d*)
Do	Aug. 23	Jan. 23	153	177	(*b*)

[a] For details regarding oviposition of these ticks see Tables I and II.
[b] The seed ticks were in open-bottom test tubes in sand in the open air. They were protected from the direct rays of the sun at all times by a cheese-cloth screen. Up to 11 o'clock a. m. they were also shaded by the house.
[c] In open-bottom test tubes in soil exposed to sun at all times.
[d] In open paper pill boxes outdoors, protected from sun and rain at all times.

Considerable numbers of seed ticks in all lots hatching after August 23, 1906, are still alive (February 20, 1907).

PARASITIC PERIOD.

The data already given regarding the periods of preoviposition, incubation, and survival of seed ticks have an important bearing on the time required to free pastures or other inclosures from ticks *provided the cattle are removed.* The data given under the present heading, on the other hand, show the time required *at different seasons to free cattle of ticks by placing them in inclosures from which the ticks have been eliminated either by systematic starvation or by the use of naturally tick-free areas, as, for instance, fields that have been in cultivation for one crop season.*

In this work we have utilized a grade Durham steer, 17 months old at the beginning of the experiments. (See Pl. II, fig. 1.) By means of kerosene emulsion he was carefully cleaned of the thousands of ticks infesting him when obtained. Thereafter he was thoroughly washed to remove traces of the insecticide and hundreds of seed ticks were applied. Under proper precautions to avoid the steer's accidental infestation, these ticks were allowed to reach maturity. After the ticks of each infestation became adult the steer was thoroughly cleaned and placed in another inclosure, which in each case had been carefully disinfected by means of sprays. This process has now been repeated until ten infestations have been reared covering the period between August, 1905, and March, 1907. The details are given in Table VII. In rotation systems the minimum developmental period is the most important, because the cattle must be removed before the earliest developed ticks have had offspring to reinfest them. Therefore special reference is made in the table to the shortest periods found, although the longest and the average are both given.

The following deductions may be made from this table:

1. The period from attachment to dropping ranges from 21 to 58 days. It should be noted that in the longest periods the limit was reached by only one or two belated ticks, the majority approaching the average.

2. The average period ranges from 26.5 to 43 days.

3. The average parasitic period is normally some days longer in winter than in summer. But warm winter weather, as happened in infestation No. 9, may reduce the period even below the average for the summer.

4. The slowest developing ticks of one infestation may occupy from 10 days (in the summer) to 32 days (in the winter) longer than the most rapidly developing ones. The rapidity of development of the ticks of the same infestation depends somewhat upon their location. Those on the portions of the body where the blood supply is most abundant develop most quickly. In general it seems that heavy infestations develop a little more quickly than light ones. This may be

due to the fact that, in light infestations with widely scattered ticks, fertilization is less likely to take place than in other cases where the males may find the females more readily. We have been unable to determine that unfertilized females occupy longer in development than those that are fertilized, but our impression is that they do.

The table also shows that the principal variation in the time of development of the ticks of the same infestation takes place not in the larval or nymphal but in the adult stage.

TABLE VII.—*Development of Margaropus annulatus on steer at Dallas, Tex.*

Application No.	When applied.	First molt.	Minimum larval stage.	Second molt.	Minimum nymphal stage.	Adults dropped. First.	Adults dropped. Last.	Minimum period adult stage.	Number removed or dropped.	Period from attachment to dropping. Maximum.	Period from attachment to dropping. Minimum.	Period from attachment to dropping. Average.
	1905.		*Days.*		*Days.*			*Days.*		*Days.*	*Days.*	*Days.*
1	Aug. 16	Aug. 28	12	Sept. 2	5	Sept. 15	Sept. 27[a]	13	20	42	30	36
2	Sept. 27	Oct. 4	7	Oct. 12	8	Oct. 21	Nov. 8	9	10	42	24	33
3	Nov. 11	Nov. 22	11	Nov. 28	6	Dec. 8	Jan. 9	10	13	59	27	43
	1906.											
4	Jan. 16	Jan. 25	9	Feb. 3	9	Feb. 17	Mar. 8	14	11	51	32	41.5
5	May 22	May 31	9	June 6	6	June 14	June 30	8	9	39	23	31
6	June 29	....	....	July 16	....	July 24	Aug. 5	8	5	37	25	31
7	Aug. 2	Aug. 10–11	8–9	Aug. 18	7–8	Aug. 25	Sept. 11	7	14	40	23	31.5
8	Sept. 5	Sept. 12	7	Sept. 22	10	Sept. 26	Oct. 6	4	236	31	21	26.5
9	Oct. 6	Oct. 14	8	Oct. 21	7	Oct. 30	Nov. 12	9	200	37	24	30.5
10	Nov. 29	Dec. 8	9	Dec. 14	6	Dec. 22	Jan. 1	8	55	33	23	28
	1907.											
11	Jan. 1	Jan. 8	7	Jan. 14	6	Jan. 24	Feb. 3	10	35	33	23	27.5

[a] Removed.

DEVELOPMENT ON HOST.

When the larval ticks find themselves on the host they rapidly disappear in the hair and attach themselves to the skin. They are principally found on such parts as the legs, belly, and dewlap that come in contact with the bunches on the grass, but may be found on any part of the host. In cases of severe infestation they practically cover the entire surface of the body, even the eyelids being infested.

In from 7 to 12 days the larval ticks molt and enter the nymphal stage, in which they have eight instead of six legs. The nymphal stage is further distinguished from the larval stage by the presence of a pair of large stigmata quite in contrast to the rudimentary organs of respiration of the larva.

The second molt (from the nymphal to the adult stage) occurs in from five to ten days after the first. The nymph can be distinguished from the adult, which it resembles very closely, by the absence of any genital opening. The process of both molts is undergone by the females while the hypostome is firmly inserted in the skin of the host. The shed skin splits open along either side and drops off in two scale-like pieces. A portion of skin from the capitulum is also shed at the same time. In the case of males, while during and after the first molt the tick remains fixed to the host, after the second molt it detaches itself and travels in search of a female. As a rule the males molt two or three days ahead of females and frequently two are found attached to the skin of the host directly beneath nymphal females, awaiting the molting of the latter.

When the adult stage is reached the development is very rapid. In from as few as 4 to 14 days the females become fully engorged and fall to the ground to deposit their eggs. They die when the operation is completed.

Although female ticks are somewhat more easily removed at the time of molting than at other times, repeated careful observations show that they do not actually detach themselves at either molt. However, Mr. B. H. Ransom has shown that, when detached artificially just before or after the second molt, females will reattach if placed upon another animal.[a] Likewise he found that ticks removed just after the first molt would reattach after 24 hours. Specimens detached just before the second molt transformed and lived without host for two weeks. Several experiments have led us to the conclusion that only in the rarest accidental cases can reattachment normally take place. In many cases we have attempted to cause detached ticks to reattach, but in only two cases did we succeed. The following are some of the particulars:

February 23, 1906, eight ticks, ranging in size from nymphs to one-half engorged adults, were placed on the shoulder of a steer. The next day all but one of these ticks had disappeared. One, however, which was about one-half engorged, had fastened to the skin about 6 inches from the point where it was placed. This tick was found detached on March 1 and trying to crawl out from the hairs which had been glued together to hold it in place. At this time it was not fully engorged. It began depositing eggs on March 18, and continued oviposition until April 26, reaching a total of 523 eggs. An attempt was made to cause these eggs to hatch, but without success. It is not likely, however, that the failure to hatch was due to the experience of the tick. It is probable that the state of engorgement may have had something to do with the matter, and, moreover, at the time of the year when the eggs were under observation it is exceedingly difficult to cause them to hatch. After the experiment that has been mentioned repeated attempts were made to obtain other cases of reattachment. Ticks at various stages were placed on

[a] Lahille (Contr. l'Étude Ixodidés Argentine, p. 112) had previously detailed a number of experiments in the reattachment of *Margaropus* (*Boophilus*) *microplus*. It was found that immediately after molting the ticks would more or less frequently reattach after being removed artificially. Nothing, however, was found to indicate that the parasites naturally detach and reattach on the host.

the steer and confined to limited area by means of vaccination shields. In no case under this manipulation did reattachment take place. Recently, however, a tick removed just before the second molt became adult in a pill box and reattached after 25 hours.

ADULT STAGE.

Adult females are the ticks that are generally seen, and their appearance is familiar to most persons. The males (which do not become engorged) are generally overlooked, although they may be easily found attached to the skin of the host directly beneath the females. This gives rise to a rather prevalent popular idea that females carry young with them.

The following descriptions are taken from the work of Salmon and Stiles:[a]

Male.—Body oval, narrowed on front, broadest (1.3 mm.) at stigmal plane, 2.15 to 2.35 mm. long. Scutum reddish brown, covering entire dorsal surface, prolonged in front by two pairs of projections—one pair of more prominent dorso-lateral projections, dorsal of anterior projection of coxæ I, and one pair somewhat less prominent and more median, ventro-median of first pair and nearer the neck. Two cervical furrows shallow, extending more or less distinctly to the posterior border; may be somewhat interrupted in the middle; a median furrow present in posterior half, may be very indistinct; posterior margin of body divided into festoons, which may be only slightly marked. Relatively large circular pores, with extruding short bristly hairs, scattered over entire surface. Eyes small and pale, often problematic, at I intercoxal space. Ventral surface lighter than dorsal, all portions provided with short stout hairs; genital pore, broad, transverse, between coxæ II; anus slightly posterior of stigmal plane; two pairs of anal plates (clypei): one pair elongate, rectangular to triangular, close to anus, in some cases extending cephalad to middle of coxæ IV, and caudad to near or beyond posterior margin, the anus being about at the middle of the length, in other cases extending from height of middle of stigmal area to beyond posterior margin of body; the median border longer than lateral border, the former prolonged into a point posteriorly, the postero-lateral margin may be nearly straight, or somewhat curved, or irregular in outline, thus presenting broad tooth-like projections; lateral and contiguous to each of these shields is found another shield somewhat similar in form, but smaller in size. Median caudal appendage absent. Capitulum 450 to 500μ long, base similar to that of the female, but a little straighter, longer, more salient in front of dorsal shield, into which it penetrates by a sort of rectangular neck, lateral projections not very prominent. Mandibles 600μ long, digit about 90μ; internal apophysis with straight base and broad bifide point; external apophysis bidentate, the terminal subventral tooth may be very small while the proximal tooth is strong and large, or both may be large. Hypostome similar to that of female, four distinct rows of teeth on each half. Palpi about 190μ long, similar to those of female. Legs strong; coxæ large, those on each side contiguous, as broad as long; coxæ I triangular, apex may be prolonged anteriorly beyond the corresponding anterior point of dorsal shield, reaching anterior angle of base of capitulum, or may be very short, base posterior and more or less distinctly bidentate, the teeth short, often slightly pronounced, or quite prominent, the lateral tooth in some cases prolonged into a well-marked spine. Tarsi like those of female.

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[a] "The cattle ticks (Ixodoidea) of the United States:" 17th Ann. Rept. Bur. Animal Industry, U. S. Dept. Agric., pp. 420–424, 1901.

Female.—Body elliptical, as broad in front as in back, usually somewhat constricted in middle, near IV pair of legs; may attain 13 mm. long, 7.5 mm. broad. Color exceedingly variable; live specimens vary from a tawny yellow (younger forms) to an olive green (very old specimens), alcohol specimens from yellow to red or black; the excretory system often shows through the cuticle as tortuous whitish canals. Dorsal shield (scutum) very small, visible as a dark brownish spot in a depression at anterior end of median line; usually about 1.1 mm. long by 0.8 to 0.9 mm. broad, decidedly emarginate anteriorly to receive capitulum; lateral borders nearly straight and parallel in anterior portion, from antero-lateral points to eyes, then convergent from eyes caudad, forming a more or less bluntly rounded posterior angle in median line; cervical grooves divide the anterior half of scutum into three more or less equal longitudinal fields, and diverge posteriorly; surface of scutum provided with short bristles which are more numerous near anterior border and near the eyes than elsewhere. Eyes rather small near anterior third of margin of scutum. On nearly the entire length of dorsal surface of body are two antero-posterior grooves, interrupted or nearly effaced near plane of IV pair of legs, and ending a short distance from the shield and from posterior margins of body; also, an unpaired median groove in posterior half of body; all three vary with the muscular contractions and may more or less completely disappear when body is replete. Ventral surface shows four pairs of more or less distinct marginal constrictions corresponding to the four pairs of legs, the IV constriction being most marked, antero-median region also depressed at insertion of capitulum; vulva small, median, at plane of coxæ I; sexual grooves corresponding to the paired dorsal grooves; but showing some variation in different specimens; median groove extending from anus to posterior margin. Anus about on border of second and last thirds of body. Stigmata short oval; stigmal pore slightly crescentic, convexity lateral; stigmal field with numerous larger and smaller wart-like structures, forming a zone near the margin. Cuticle of entire body finely wrinkled, bearing short hairs. Capitulum very short, about 800μ from posterior dorsal margin to anterior end of hypostome; base of capitulum hexagonal, enlarged on its dorsal surface; inserted in emargination of scutum; lateral projections not very prominent. Mandibles 860μ long, digit 120μ. Internal apophysis conical (Neumann), bidentate (Fuller), with its base near the terminal extremity; external apophysis with three successive teeth, one terminal, subventral, small; the second stronger; third large. Hypostome rather spatulate, broad, a little longer than the palpi, provided on each half with four rows of nine to ten nearly regular denticles, which do not extend to the base. Palpi very short (310μ), subconical, articles at least as broad as long; first article partially hidden under the antero-dorsal border of the base of the capitulum; second article pedunculate, dilated in a salient crest in its middle portion, thus forming a prominence inward (toward median line) and outward, and provided with strong hairs, especially on the inner prominence; third article smaller, subtriangular on its dorsal surface, where it forms a projection in and out; fourth article small, cylindrico-conical, infero-terminal. Legs rather thin, short (pair I, 2 mm.; pair II, 2.5 mm), yellowish brown, first articles darker than the others. Coxæ: pair I subtriangular, posterior border bidentate or biundulate, the division in many cases indistinct. Tarsi I unicalcarate, II to IV bicalcarate. Pulvillum about half as long as claws. Stiff bristle-like hairs on all articles.

EFFECT OF CONTINUOUS COLD AND HEAT ON ENGORGED FEMALES.

Twenty-five ticks were used in the experiments with cold, which were conducted during the month of August, 1906. A mean temperature of about 48° F. was maintained, with extremes ranging from 34° to 53°. With exposure up to 300 hours practically all ticks recovered and in most cases deposited viable eggs. In cases of more than 300 hours' exposure practically all ticks survived, but none deposited viable eggs, although in many instances oviposition took place.

In a number of experiments with heat a mean temperature of from 98° to 102° was maintained. Up to 103 hours of exposure to this temperature practically all ticks deposited eggs that were viable. With exposure at the same mean temperature of from 144 to 218 hours' duration, eggs were deposited, but were found not to be viable. They were dry and shriveled when deposited.

Some of the females survived heating for the longest period, namely, 218.5 hours. With an exposure of 103.5 hours or more, however, at least one-half succumbed.

EFFECT OF DIRECT SUNLIGHT ON ADULTS.

Eleven unengorged females placed in a box exposed to the direct rays of the sun in September died in three days. Seven unmatured females in direct sunlight from morning until noon seemed dead at noon. They did not survive until the next day, although they were removed from the direct sunlight at 2 o'clock. Similar experiments showed that death resulted in the case of engorged females after a few hours' exposure to the sun. In experiments with eggs, tubes were subjected to direct sunlight for one day. When moistened while kept in these tubes, hatching seems to take place normally, and hatching followed in similar experiments in which the eggs were kept dry.

EFFECT OF SUBMERGENCE IN WATER ON ENGORGED ADULT TICKS.

Adult ticks have remarkable resistance to the effect of submergence, as has been pointed out to be the case with eggs and seed ticks. The immediate effect of submergence is to cause a cessation in the activity of the ticks, while they become somewhat distended apparently from the absorption of water. In August and September, 1905, a considerable number of experiments were conducted in which the adult ticks were submerged in water from the city mains at Dallas, Tex. Judging by the experiments with seed ticks and eggs mentioned elsewhere it is not likely that water impregnated with foreign matter would have changed the results. During the months mentioned a period of submergence of 24 hours did not result in the death of any appreciable number of ticks used in repeated experiments. After one or two hours the specimens recovered from the immediate effect of submergence and proceeded to deposit eggs which were found to be viable. With between 24 and 48 hours' submergence the number of ticks that recovered diminished rapidly. Occasionally specimens recovered after a period of submergence of over 48 hours. For instance, the specimen collected on July 12 and submerged for 50 hours survived and deposited viable eggs. Later in the season (that is, in October) somewhat different results were obtained in experiments in the submergence of adults. In this month many ticks recovered after from 50 to 90 hours of submergence. In fact, fully 50 per cent of the ticks submerged between these extremes regained their full activity. In one experiment two out of five ticks submerged in October for 91¼ hours recovered and deposited viable eggs. Nevertheless a number of ticks submerged for 115¼ hours did not recover.

The results that have been mentioned above indicate that where engorged ticks fall from cattle that are standing in permanent pools of water none will survive to deposit eggs. At the same time the results show that temporary flooding of from 24 to 100 hours' duration would not in all cases prevent ticks from depositing eggs. It must be noted in this connection, however, that the vitality of eggs deposited by ticks just prior to temporary flooding would not be interfered with by the water, although, of course, they might be washed away.

DROPPING FROM HOST.

It is a more or less prevalent popular idea that ticks have some sense which enables them to drop from a host in places favorable for oviposition. A few observations have shown, as was supposed in the beginning would be the case, that there is probably no such power of perception present in the cattle tick. The popular impression probably had its origin in the fact that bunches of seed ticks are found most numerously in the places where the cattle collect for the benefit of shade or water. This phenomenon obviously is due merely to the collecting and standing of the cattle.

Many observations seem to show clearly that there is no preference as to the time of dropping. In our experiments many ticks have been known to drop from host during the night and many others to drop during the day.

LOCOMOTION.

Some attention has been paid to obtaining data on the distance engorged ticks may travel after dropping from the host, since this has a practical bearing on double fencing in eradication work. In some experiments specimens were placed on the floor in the laboratory and allowed to move at will. The total movement varied from 24 inches to 123 inches, the latter distance being covered in 52 minutes.

The effect of antiheliotropism was always in evidence in these experiments. The light was admitted from different quarters at different times and the ticks always changed their course so as to travel away from it. These results are very similar to those published by Lahille from experiments with *Margaropus* (*Boophilus*) *microplus* in Argentina. The distance engorged females will travel depends upon how soon they can reach shelter. If they obtain protection under débris of any kind they seem to be disinclined to go farther. The greatest distance traveled on the ground out of doors was only 24 inches.

It is popularly supposed that engorged female ticks often burrow into the ground. In a number of experiments with light barnyard trash in tubes it was found that females will work their way down from one-half to $1\frac{3}{4}$ inches. In such cases the masses of eggs assume various shapes on account of the surrounding débris. (See Pl. I, fig. 1.) It was found that seed ticks from eggs so deposited had no difficulty in reaching the surface.

HOST RELATIONS OF THE CATTLE TICK.

Margaropus annulatus was described in 1829 by Say "from specimens taken on a Virginia deer in Florida." Since that time we have been unable to find records of the occurrence of the species on deer. However, a number of instances have come to light recently in which undoubted specimens of *Margaropus annulatus* have been found on deer. The first of these cases was the result of an examination made by Mr. R. C. Howell on a herd of tame deer in a park at Mount Pleasant, Tex., in October, 1905. Since that time Mr. J. D. Mitchell has found specimens on a deer at Oakville, Tex. Mr. T. R. Coker has sent specimens from the same locality and host. In both of these instances the ticks were found on wild deer that had just been shot. In February of the present year Mr. F. C. Pratt collected a few specimens of *Margaropus annulatus* from a dry deer hide at Kerrville, Tex., and in December he examined a fresh hide on which considerable numbers were found.

The matter of the possible development of *Margaropus annulatus* on various animals, among them guinea pigs, rabbits, dogs, and cats, has been studied by various investigators. Dr. J. W. Connaway's experiments in Missouri in 1897 showed that the ticks would not attach to rabbits or guinea pigs. They did attach to dogs in considerable numbers, but only one of them ever matured. Recently Mr. B. H. Ransom has repeated the experiments with rabbits, dogs, and cats. On rabbits and dogs the ticks attached, but remained so only a short time. On a cat a female tick remained attached from July 25 to August 30 and molted on the host. Nevertheless, it did not reach engorgement.

In our experiments with ticks we have kept several dogs primarily for experiments with species other than *Margaropus annulatus*. At the same time we have repeatedly sprinkled thousands of seed ticks of *Margaropus annulatus* on these dogs, but in no case have we noticed that attachment took place. This, with the work of Connaway, Schroeder, and Ransom, seems to indicate that dogs can play but a very unimportant part as hosts for the cattle tick. Ransom mentions the fact that the collection of the Bureau of Animal Industry contains specimens of *Margaropus annulatus* collected from a dog, from which host Francis (1894) seems to have been the first to report it.

One of the writers has had one case of an attachment of *Margaropus annulatus* to his person. This was a male specimen that attached between the fingers of the hand. It was removed after about half an hour. Mr. Ransom mentions a similar case in which, however, the specimen was a female and remained attached to his hand for twenty-four hours before it was removed. Attachment to human beings must be very rare. The junior author had worked with thousands of specimens of ticks before and after the single case of attachment that has been mentioned.

In addition to the abnormal and unusual host relations mentioned above, there are not infrequent instances in which *Margaropus annulatus* has been found to occur on horses, mules, and asses.

All this work shows clearly the remarkable host restriction of the cattle tick that is most important from the viewpoint of its attempted eradication.

The early records of Packard, showing the occurrence of the cattle tick on a porcupine and a similar record of its occurrence on the rabbit in Idaho, must have been due to a misidentification of the species.

The strict instinct for the proper host in the cattle tick is shown in the extreme infrequency of attachments of ticks to each other. Thousands of ticks have been sent to the laboratory alive inclosed together in tin or wooden boxes. In only one case was it found that a tick had inserted its rostrum in another. This happened in a lot collected in southwest Texas by Mr. J. D. Mitchell on April 19. A female had inserted its beak firmly on the lateral dorsal portion behind the posterior coxæ. The two specimens were placed in alcohol and still remained connected.[a]

RELATION BETWEEN RATION AND TICK INFESTATION.

For several months after experiments were started at Dallas in placing seed ticks on the steer used for experimental purposes it was found that a surprisingly small proportion ever became adult. In

[a] Since the above was written important discoveries regarding the occurrence of *Margaropus annulatus* on sheep have been made by the Bureau of Entomology. See Circular 91, Bureau of Entomology, U. S. Department of Agriculture, issued July 3, 1907.

many cases from 5,000 to 10,000 seed ticks were placed on the animal, but only from 1 to 20 adults ever developed. Prof. H. A. Morgan made the suggestion, based upon the observations made by him in Louisiana, that the ration the steer was receiving was responsible for this remarkably small proportion developing. At his suggestion we changed the ration. The steer had been receiving daily 4.76 pounds of corn chops and 5 pounds of prairie hay. The inspection tag on the chops guaranteed not less than 9 per cent protein crude and not less than 4 per cent fat crude. At Professor Morgan's suggestion the corn chops were eliminated. Immediately a much larger percentage of seed ticks developed to adults on the animal, although his general condition did not seem to have been changed materially. While before a dozen adults from many thousand seed ticks was the maximum, after the change in the ration hundreds developed from no larger numbers of seed ticks applied.

ENEMIES OF TICKS.

At one time it was supposed that sowbugs may sometimes be important factors in the destruction of tick eggs. A number of observations have shown that the greatly preferred food of these isopods is vegetation either live or decayed. In laboratory experiments *Armadillidium vulgare* was found to feed on dead ticks and also to devour the eggs whenever no other food was provided. Thirty-eight sowbugs, furnished with 897 tick eggs, consumed 366 at the rate of 3 eggs per day each. In another case two sowbugs devoured 159 tick eggs at the rate of 15 each per day. These results hardly seem to substantiate the impression that sowbugs may be of considerable economic importance. It should be emphasized that the experiments referred to were conducted in the laboratory, and the sowbugs were deprived of other food. Under natural conditions the results might have been quite different.

The little "fire-ant" (*Solenopsis geminata* Fab.), which has recently been found to be acquiring a special taste for the boll weevil, undoubtedly destroys many engorged ticks that have dropped to the ground. Experiments performed by placing ticks in the immediate vicinity of nests of this ant show that under such circumstances they must invariably be killed. The nests of this ant are found throughout the pastures in the South, and the total of the work done by them must be considerable.

A number of dipterous larvæ have been found feeding upon tick eggs and an undetermined species of Phoridæ has been bred.

At one time we were inclined to believe that a chalcidoid parasite of the cattle tick had been reared. Early in 1906 such a parasite was found in a pill box with the remains of an engorged tick placed there the fall before. Upon sending the specimen to Dr. L. O. Howard it was learned that it belongs to a new species and genus. Chalcidoids of the subfamily to which it undoubtedly belongs are known to be parasitic on various dipterous larvæ. Upon reexamination of the remains of the tick a portion of a dipterous cocoon was found. Consequently the hymenopteron was probably not a parasite of the tick, although the interest remains, since the dipteron was probably parasitic on the tick.

A number of observations have been made showing that domestic fowls frequently learn to remove ticks from cattle in barn lots. Mr. F. C. Pratt observed a case in which the fowls regularly visited hides hanging up to dry for the purpose of picking up the ticks which dropped from them. Mr. J. D. Mitchell has witnessed "jackdaws" (*Quiscalus major macrourus*) picking ticks from cattle near Victoria, Tex., and the farmer informed him that he believed these birds kept the cattle practically free of engorged or nearly engorged specimens. Mr. S. E. McClendon, of the Louisiana Experiment Station, informs us that he has repeatedly seen kingbirds (*Tyrannus tyrannus*) engaged in the same work.

In connection with the enemies of ticks it may be stated that it seems likely that mice are of some importance. In the laboratory it was found that the best bait for mouse traps that could be used was engorged cattle ticks. It seems likely that in the pastures field mice may frequently devour ticks. Dutton and Todd (Human Tick fever, p. 17) write as follows: "Ticks are not without natural enemies. Rats eat adults with avidity, and ants carry off young ones and eggs. We have lost ticks in both ways. One occasion over two hundred young ticks were carried off in a single night by small ants." These remarks apply to *Ornithodoros moubata* in West Africa.

THE PRACTICAL APPLICATION OF THE INFORMATION RECORDED IN THIS BULLETIN.

In the preceding pages at different places the special practical importance of the data discussed has been mentioned. As a matter of fact the work upon which this bulletin is based has been planned to accumulate additional information for use in the practical work of tick eradication. Some methods of control are satisfactory in certain districts, but much less so in others. Plans that would be feasible along the northern border, for instance, where the tick is on a rather delicate equilibrium and is never found on the cattle for months during the winter, would not be applicable to the moist regions along the Gulf where the cattle are infested throughout the year. Of the various methods of eradication undoubtedly those of the widest utility are the ones which prevent the development of the ticks by breaking up the relation between them and the cattle. Of these, the more important are the feed-lot or soiling system for relieving the cattle of ticks and the pasture-rotation system (to be used in conjunction with the former) for freeing the pastures.

In the feed-lot or soiling system the basis is the time occupied for development on the host in connection with the time from the dropping of engorged females to the hatching of seed ticks from eggs deposited by them. In a tick-free inclosure, as a feed lot, cattle may be left to drop their ticks until it is time for the eggs from the first-dropped individuals to hatch. Information as to exactly when it will be necessary to move the cattle to avoid reinfestation is given in Tables I and II, which show the numbers of days at different seasons before ticks begin to oviposit after dropping and the time before the first eggs deposited will hatch. In July, 1906, for instance, this was from 25 to 27 days. The time required for all ticks to drop from cattle, which indicates how long they must remain in one or more tick-free areas, is shown in Table VII. The period is from 31 to 59 days.

The data necessary for an intelligent plan of freeing pastures, by removing the cattle until the death of the ticks, are given in Tables V and VI, showing the period from dropping to the death of all the resulting seed ticks. The former table shows that if cattle were removed from a pasture on June 20, 110 days later it would be perfectly safe to consider it tick-free.

The data referred to above, together with the results of other experiments, have been arranged to cover maximum preoviposition and maximum oviposition periods, for convenience, in Table VIII.

TABLE VIII.—*Periods in the life history of the cattle tick upon which means of control are based.*

When ticks dropped.	Period from dropping to oviposition.		Minimum incubation period.	Minimum period from dropping of ticks to hatching of eggs.	Seed ticks all dead.	Maximum period from dropping of adult to death of seed ticks.
	Minimum.	Maximum.				
1905.	*Days.*	*Days.*	*Days.*	*Days.*		*Days.*
Sept. 2	3	5	43	46	June 22	293
Do	3	5	56	59	May 31	271
Dec. 23	21	41	54	75	Aug. 28	248
Dec. 24	21	41	47	68	Aug. 15	234
Dec. 25	21	41	47	68	Aug. 22	240
1906.						
Mar. 20	9	10	39	48	Aug. 28	161
Apr. 19	5	6	33	38	Sept. 20	154
Apr. 21	5	6	29	34	Oct. 5	167
May 1	6	10	27	33	....do...	157
May 4	6	10	28	34	Aug. 9	97
May 19	4	6	27	31	Sept. 26	130
May 21	4	6	27	31	Sept. 22	124
June 3	3	5	28	31	Aug. 15	73
June 4	3	5	23	26	Aug. 26	[a] 83
June 6	3	5	23	26	Aug. 6	[a] 61
Do	3	5	23	26	Oct. 6	122
June 12	3	4	21	24	Sept. 26	106
June 13	3	4	22	25	....do...	105
July 1	3	5	22	25	Oct. 20	[a] 111
July 13	3	4	23	26	Feb. 18	[a] 220
Do	3	4	24	27	Jan. 23	194

[a] These ticks were kept in open-bottom test tubes exposed to sun at all times.

In the above experiments (Table VIII) the eggs and seed ticks, except those marked (^{a}), were kept in cylindrical tubes of ½-inch diameter inserted for about 1½ inches into sand or soil in receptacles on or below the surface. These were kept in a cage on the west side of the laboratory so that they were protected from the sun until 11 a.m. As soon as the eggs commenced to hatch, there was placed in the tube a stopper of absorbent cotton which remained unremoved until the death of the ticks. In cases marked (^{a}) the conditions were the same, except that the tubes were exposed to the sun at all times.

The conditions furnished included a humid atmosphere and a minimum temperature as compared with the normal. The enforced bunching and protection from wind and rain furnished additional favorable conditions. It would seem that the periods are maxima and hardly to be met with in the work of extermination. One unfavorable factor met with, which could not be prevented, was the growth of algæ on the inside of some of the tubes. This accounts for some of the variation in the longevity.

In addition to the main practical data given the following are of importance:

All experiments and observations show the close host restriction of the cattle tick. Though the occurrence of the cattle tick on deer, horses, mules, asses, and some other animals is comparatively rare, it must be taken into consideration in the practical work of tick eradication.

Eggs are but little affected by water. When submerged, they hatch in about the normal time. Seed ticks are also resistant to water. In one case seed ticks survived submergence of 157 days. Adults are less resistant, but in the summer they frequently survived submergence of 48 hours. Later in the season the resistance seemed to be greater, some females surviving after more than 90 hours. It is evident that water courses must play a very important part in tick dissemination.

The adult cattle tick has only the most limited means of locomotion. After it drops from the host it crawls but a few feet at the most. On the ground in our experiments the greatest distance traversed was only 24 inches.

On the whole, no very important enemies of ticks have been found. Domestic fowls frequently devour considerable numbers of them, and some wild birds also render valuable assistance in picking them off animals or from the ground.

NOTES ON VARIOUS SPECIES OF TICKS FOUND IN THE UNITED STATES.

The rôle that *Margaropus annulatus* Say was found by Smith and Kilborne to play in the transmission of splenetic or Texas fever in cattle impressed upon investigators the importance of ticks as carriers of disease. Since that time the study of these creatures has progressed rapidly. Smith and Kilborne, Lounsbury, Theiler, Marchaux, Salimbeni, Dutton and Todd, Motas, Kossel, Ricketts, and King are among those who have demonstrated that ticks are the agents through which various diseases of man and other animals are transmitted. What is greatly needed in this country at the present time is a convenient means of identifying the various species. This the writers have attempted, in a measure, to supply in the following pages, in which will also be found notes on the life history and habits of such species as they have encountered.

CLASSIFICATION AND HABITS OF TICKS.

The following key will enable one to determine the genera of the various ticks found in this country:

KEY TO FAMILIES, SUBFAMILIES, AND NORTH AMERICAN GENERA OF TICKS, (IXODOIDEA).[a]

Scutum absent...Family Argasidæ.
Scutum present...Family Ixodidæ.

Family ARGASIDÆ.

Capitulum at least its length from the anterior margin............Genus *Argas* (p. 42).
Capitulum under a beak-like projection, close to anterior margin.
Genus *Ornithodoros* (p. 45).

Family IXODIDÆ.

1. Palpi short, not or only slightly longer than broad; capitulum short.
Subfamily Rhipicephalinæ, 2
Palpi plainly longer than broad; capitulum longer ....Subfamily Ixodinæ, 5

Subfamily Rhipicephalinæ.

2. Dorsal surface of capitulum hexagonal, the sides projecting in angles; male with anal plates...3

[a] This table is based upon those of Salmon and Stiles (1901) and Banks (1904). The genus Ceratixodes is not included (see p. 54).

Dorsal surface of capitulum rectangular, sides straight; male without anal plates..4

3. Second and third palpal segments extend laterally into sharp points; stigmata nearly circular.................................... Genus *Margaropus* (p. 49).

Second and third palpal segments even; stigmata comma-shaped. Genus *Rhipicephalus* (p. 47).

4. Eyes present; external border of palpi straight; coxæ I bidentate. Genus *Dermacentor* (p. 49).

Eyes absent; external border of palpi uneven; coxæ I not bidentate. Genus *Hæmaphysalis* (p. 52).

Subfamily IXODINÆ.

5. Anal groove surrounds anus anteriorly and opens posteriorly; eyes absent; stigmal plate nearly circular.................................... Genus *Ixodes* (p. 54).

Anal groove surrounds anus posteriorly and opens anteriorly; eyes present; stigmal plate reniform.................................... Genus *Amblyomma* (p. 58).

Lahille has recently[a] published an ingenious graphic table for the separation of the families and genera of Ixodoidea. It is reproduced

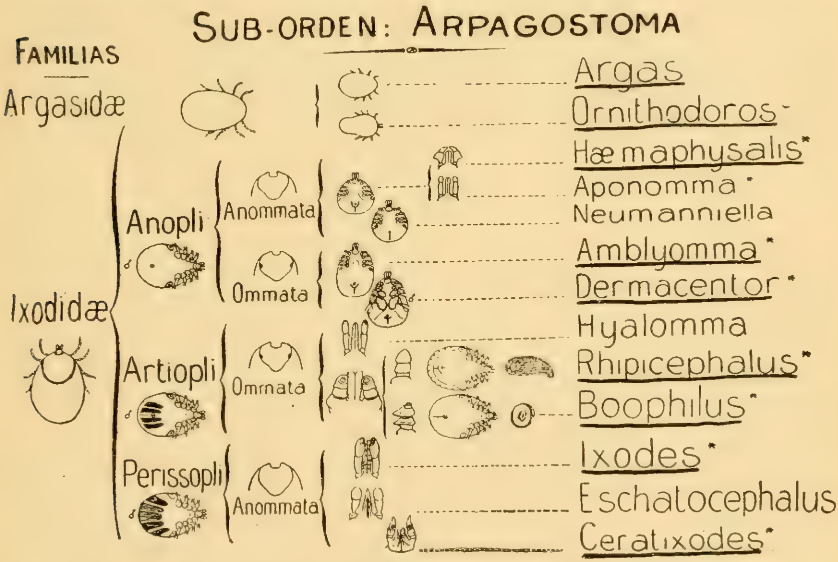


FIG. 2.—Graphic table for the separation of the families and genera of ticks. (From Lahille.) The underscored genera are represented in the United States.

here as figure 2. The genera underscored are known to be represented in the United States. The suborder Arpagostoma of Lahille is the same as the superfamily Ixodoidea of Banks, used by us.

Family ARGASIDÆ.

The family Argasidæ is represented by two genera, Argas and Ornithodoros. They are readily distinguished by the characters given in the table. The species are parasitic on mammals and birds.

[a] Ixodides Argent., 1905, p. 21.

Genus ARGAS.

The species belonging to the genus Argas are nocturnal parasites of chickens, pigeons, and other birds, and occasionally attack mammals, man included. Two species are represented in this country—*A. miniatus* Koch and *A. sanchezi* Dugès. The former has been found by Marchaux and Salimbeni to transmit spirillosis of fowls in Brazil. There is some evidence of the occurrence of this disease in the United States.

ADOBE TICK.

(*Argas sanchezi* Dugès.)

This species was described in 1891 by Dugès from larvæ collected at Guanajuato, Mexico, on a dove (*Zenaidura macroura*). In structure it is very similar to *A. miniatus*. Neumann's description is based upon a number of specimens collected at Mariposa, Cal., upon a quail, and at Santa Agueda, Lower California, upon a wild turtle dove. Mr. Nathan Banks has specimens from Deming, N. Mex., and from Arizona, and it is quite probable that it will be found in Texas, and possibly farther north. Mr. Banks states that in New Mexico it is found in houses and is there known by the common name used above.

FOWL TICK.

(*Argas miniatus* Koch.)[a]

This species was described in 1844 by Koch from Demerara. The name *Argas americanus*, applied by Packard in 1873 and used largely by writers in this country, is a synonym of *A. miniatus*. For excellent illustrations of this species see Salmon and Stiles, Ixodoidea of the United States, Plate LXXII and text figures.

The species is well distributed over the world. The records include Persia, Algeria, Russia, India, Australia, South Africa, Central and South America, and, in the United States, Florida, Texas, New Mexico, Arizona, and California. In southwestern Texas it is found in large numbers in and about chicken houses and out-door roosts, hiding away in crevices by day and coming out at night to engorge on the fowls. This species seems occasionally to attack mammals, as Mr. J. D. Mitchell has taken it once in Texas from the rabbit.

As pointed out by Lounsbury, the sexes are so much alike that, except by the size, the only safe way of separating them is through the form of the genital orifice. To quote from him, "This orifice [genital] is situated just behind the mouth parts on the under side of the front of the body; that of the male is relatively inconspicuous

[a] The name of this tick is in great confusion. The one used by the writers is that recently adopted by Banks.

and is surrounded by an oval ring, and that of the female appears as a transverse slit in the leathery surface. Both sexes are of the same dimensions when they become adult. The male, however, does not perceptibly increase in length and width by feeding, whilst the female does, and hence amongst specimens collected about a fowl house the females are generally larger than the males."

Its life history has been worked out by Lounsbury at Cape Town. As brought out by him, the life cycle and habits are strikingly dissimilar in some important respects from those of the true ticks, the general habits being found much more like those of the bedbug (*Cimex lectularius* L.) As might be expected, we have found the stages in the life cycle to vary somewhat from those he found. Unlike the ticks of the family Ixodidæ, this species feeds for but a few hours at a time, and then always at night, excepting in the larval stage, when we have found it to remain attached for five to eight days before dropping. There is also an extra nymphal molt. Unlike the ixodid ticks again, these do not die following engorgement, but live on, ovipositing repeatedly. Within a week or ten days from one feeding in warm weather they again find a fowl and engorge. As many as five different feedings as adults have been recorded by Lounsbury, each followed by the deposition of eggs.

In our experiments seed ticks were placed upon a fowl and observations made to determine the period of larval attachment. In about three days from attachment they became rounded and black from the engorgement of blood. A few hours before dropping they commenced to flatten and assume the typical Argas shape. Attachment continues for from five to eight days. In September and October fourteen days were found to pass after dropping before molting took place. The attachment for second and third engorgements Lounsbury found to last but a few hours, about two weeks to pass after the second, and a like period following the third engorgement before molting.

TABLE IX.—*Oviposition of Argas miniatus at Dallas, Tex.*

When collected.	First engorgement recorded.	First oviposition.			Number of eggs.
		From—	To—	Number of days.	
1906.					
May 12	When collected	June 23	July 4	12	113
Do	do	May 17	May 30	14	274
Do	do	May 16	May 23	8	158
Do	do	May 17	May 29	13	169
Do	do	May 18	June 3	17	194
Do	do	May 18	May 24	7	50
Do	do	May 16	May 22	7	32
Mar. 24	Apr. 17-18	May 2	May 20	19	130
Do	do	Aug. 1	Aug. 10	10	83

TABLE IX.—*Oviposition of Argas miniatus at Dallas, Tex.*—Continued.

When collected.	Second engorgement.	Second oviposition. From—	Second oviposition. To—	Second oviposition. Number of days.	Number of eggs.	Third engorgement.	Total number of eggs.
1906.							
May 12				0			113
Do	Aug. 8–9	Aug. 14	Aug. 24	11	180	Oct. 22–23	454
Do	Aug. 9–10	Aug. 15	Aug. 21	7	199	Sept. 3[a]	357
Do	Aug. 10–11	Aug. 16	Aug. 25	10	193		362
Do	Aug. 15–16	Aug. 21	Sept. 4	15	148	Oct. 17–18	342
Do	Aug. 17–18	0	0	0	0		50
Do	Aug. 23–24[b]						32
Mar. 24	Aug. 7–8	Aug. 17	Aug. 24	8	55	Sept. 28–29	185
Do	Aug. 18–19	Aug. 24	Sept. 2	10	154	Oct. 16–17	237

[a] Dead. [b] Last engorgement.

Adult ticks weighed before and after engorgement were found to increase in weight more than 300 per cent.

In order to determine the incubation period, 35 daily lots of eggs, deposited between May 16 and September 1, were recorded. Of these, four lots commenced hatching in 14 days, 26 in 15 days, and 5 in 16 days. In the incubator eggs deposited August 21 and subjected to a mean temperature of 99.8° hatched on August 29, the maximum temperature being 108°. From experiments carried out by placing eggs and seed ticks in an ice box and exposing them continuously, these were found to be exceedingly resistant to cold. Eggs deposited August 27 were exposed from September 8 to October 1 to a mean temperature of 48.9°, a maximum of 67° and a minimum of 37°. These commenced hatching October 6. Two lots of larvæ, one of 13, that hatched September 2, and a second of 30, that hatched September 8, were exposed in the ice box from September 8 to October 22 to a mean temperature of 45.9°, the maximum being 67° and the minimum 36°. These were all alive when removed and were as active as ever October 25.

At Dallas larvæ kept submerged in water to a depth of about an inch lived for 11 days.

The length of life of this tick and its capacity to exist in the absence of a host are surprising. At Dallas larvæ kept confined in summer in pill boxes immediately after hatching lived about two months, some surviving somewhat longer. Larvæ of *Margaropus annulatus* kept under similar conditions live for but *two or three days* at the most. In Australia Robertson found the nymphs to live in pill boxes for about the same period as we have found the larvæ to survive.

The longevity of the adult, however, is most remarkable. Riley reports an adult specimen as remaining alive in a corked vial without food for five years.[a] Robertson has found them to remain alive for two years and three months and Dr. Cooper Curtice informs us that he has kept them alive without food for more than two years. In our experiments adults collected in March, 1906, and kept in corked

[a] Proc. Ent. Soc. Wash., III, p. 121.

vials are still alive, March 1, 1907, although a number have succumbed. Not less surprising than the longevity of the adult is its resistance to insecticides. Lounsbury has kept adults confined for three months in a box nearly filled with flowers of sulphur with no apparent effect on them. He has also exposed them for two hours to hydrocyanic-acid gas at the strength of 1 ounce of potassium cyanid to 150 cubic feet of space and found that this scarcely served to decrease their activity. Further, many individuals survived for some days after treatment with paraffin and various oils.

Genus ORNITHODOROS.

Ornithodoros, the second genus belonging to the Argasidæ, is represented in the United States by two species, *O. megnini* Dug., and *O. turicata* Dug., both known to attack man.

A species widely distributed through Central and South Africa, *O. moubata*, was reported by Dr. Cuthbert Christy (1903), of the Liverpool School of Tropical Medicine, as the probable transmitter of tick-fever in man. In 1905 Dutton and Todd,[a] not knowing of the work of the other investigators, demonstrated that "tick-fever" in the oriental province of Kongo Free State is a relapsing fever produced by a spirillum, probably *Spirillum* (*Spirachæte*) *obermeieri*, and that this organism can be transmitted by the bite of the tick.

The life cycle of members of this genus has yet to be followed. Lounsbury states that *O. savignyi* begins to engorge at once when applied to a host, and that generally it is off again in an hour. After an engorgement, he states, it rests for many weeks or months and, generally, at least, sloughs its skin if immature or lays eggs if a mature female before again seeking an animal.

It is suspected by Mr. Nathan Banks that a species of the genus transmits a disease of cattle in California.

SPINOSE EAR TICK.

(*Ornithodoros megnini* Dugès.)

This tick was first described in 1883 by Dugès, from Guanajuato, Mexico, as a species of Argas. It has been reported in the United States from New Mexico, California, Kansas, and Nebraska, and is an important tick in Texas. The writers are informed by a rancher in the western part of the State that considerable injury is due to the irritation produced by it in the ears of cattle and that its presence can often be told by the rough appearance of the hair. A prominent stockman in Dewitt County states that, in his opinion, it is second to the fever tick in importance. In addition to cattle it is found upon horses, asses, dogs, and sheep, and has been reported several times from man. Mr. J. D. Mitchell, of the Bureau of Entomology, reports two cases at Victoria, Tex., in which specimens were taken from human ears by a physician, following prolonged severe pain. Mr.

[a] Memoir XVII of the Liverpool School of Tropical Medicine.

Mitchell informs the writers that he has known this tick to climb 3 feet from the ground and deposit its eggs in a crevice on the corner of a house and in other cases in cracks in the bark of trees at about the same height. From the action of specimens confined in nearly vertical vials he supposes that the species normally climbs some distance upward for the purpose of depositing the eggs.

The nymph and adult are quite different in appearance, so much so that Neumann states that he would hesitate to consider the two forms as belonging to the same species had he not found a cast skin about a female. Marx figured the nymph as a new genus and species, *Rhynchoprium spinosum.*

Stiles and Hassall have described and figured a pupa-like stage of this tick. This, however, does not seem to be a true resting stage, as specimens run very actively when removed and placed in boxes. The present writers, from live material in hand, are inclined to consider the so-called pupa-like stage as merely the engorged larva.

The longevity of *O. megnini* seems to be much like that of Argas. A specimen collected by the writers in July, 1905, lived to beyond January 12, 1907, having been kept in a pill box for a year and a half.

TURICATA TICK.

(*Ornithodoros turicata* Dugès.)

This tick was originally described from Mexico. It attacks man, the punctures causing large swellings that remain for several days and are followed by severe pain. It has been reported from South America on the llama; from the United States, in Florida, on a land turtle (*Gopherus polyphemus*) and in a snake's burrow, in Texas on hogs, and in California. We have a specimen taken at Burnet, Tex.

In the Canadian Entomologist for 1900, page 20, Lounsbury mentions the possibility of the African species *O. savignyi* being introduced and identical with *O. turicata*. He states, "Neumann in his monograph does not give extensive ground for separating *O. savignyi* and *O. turicata*. In this country [South Africa], natives are known to carry the tick unintentionally with their belongings from place to place. It might easily have been introduced into America with slaves in the last century or earlier, just as negroes returning to Africa are said to have introduced here the jigger flea (*Sarcopsylla penetrans* L.). This latter insect continues to spread and is now found as far south as Durban, Natal."

Family IXODIDÆ.

The members of the family Ixodidæ from their structure naturally fall into two subfamilies as suggested by Salmon and Stiles. The *first*, Rhipicephalinæ, comprises the forms with short, more or less conical palpi, represented in this country by the genera Rhipicephalus, Margaropus, Hæmaphysalis, and Dermacentor; the *second*, subfamily Ixodinæ, includes forms with long palpi and is represented in the United States by the genera Ixodes, Amblyomma, and Ceratixodes.

Subfamily RHIPICEPHALINÆ.

Genus RHIPICEPHALUS.

The genera Rhipicephalus and Margaropus (formerly Boophilus) are structurally so similar that Neumann and Fuller consider our *M. annulatus* as belonging to the genus Rhipicephalus. All species of Rhipicephalus, so far as studied, including five South African forms investigated by Lounsbury and one taken by us, drop from the host for the purpose of undergoing at least one of the molts. The three species placed under Margaropus that have been studied pass both molts upon the host. This would seem to supplement the structural differences in indicating the generic validity of Margaropus.

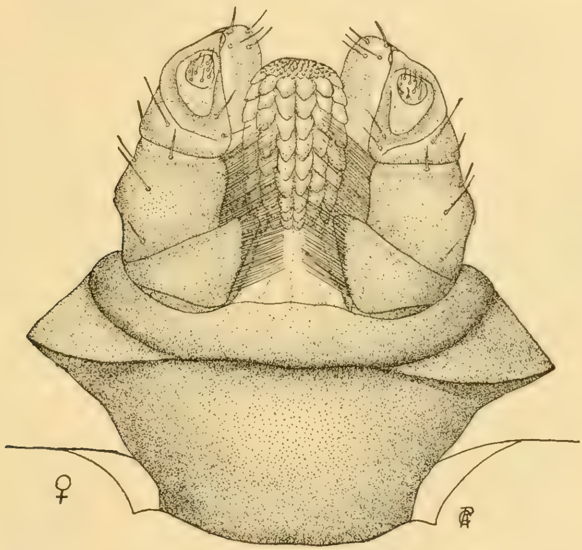


FIG. 3.—*Rhipicephalus* sp.: Capitulum of female, ventral view. Greatly enlarged (original).

BROWN DOG TICK.

(*Rhipicephalus* sp.)

Salmon and Stiles in 1901 stated that they were not acquainted with any North American species, although they called attention to the fact that *R. sanguineus* had been reported by Neumann from Panama, *R. bursa americanus* from Jamaica, and an undetermined species from Porto Rico. Banks [a] records an undetermined species from Colorado. What appears to be a new species has been taken quite generally from dogs in the southern part of Texas and also at Tlahualilo, Durango, Mexico (see figs. 3 and 4 and Pl. III, fig. 5).

[a] The Arachnida of Colorado. Ann. N. Y. Acad. Sci., Vol. VIII, 1905.

It may be called the brown dog tick. Our specimens are from nine different localities and were all taken on dogs. Unlike *Dermacentor variabilis*, Mr. Mitchell informs us, this species occurs on all parts of the body of dogs. Nathan Banks informs us that this form is closely allied to *R. sanguineus*. It is probably the same as was referred to as *R. sanguineus* in the annual report of the Bureau of Animal Industry for 1905, page 35.

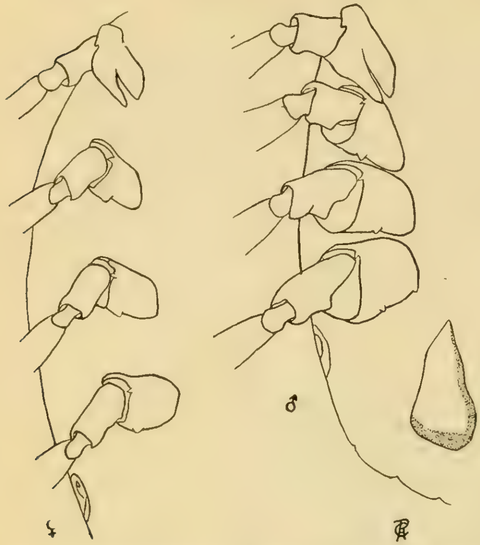


FIG. 4.—*Rhipicephalus* sp.: Coxæ of male and female. Greatly enlarged (original).

Lounsbury has found five species belonging to the genus Rhipicephalus that transmit African coast fever in cattle. The possibility of the transmission of disease by the species we have found remains to be investigated. The following are notes we have made on the life history of this form:

TABLE X.—*Oviposition of Rhipicephalus sp., from dog.*

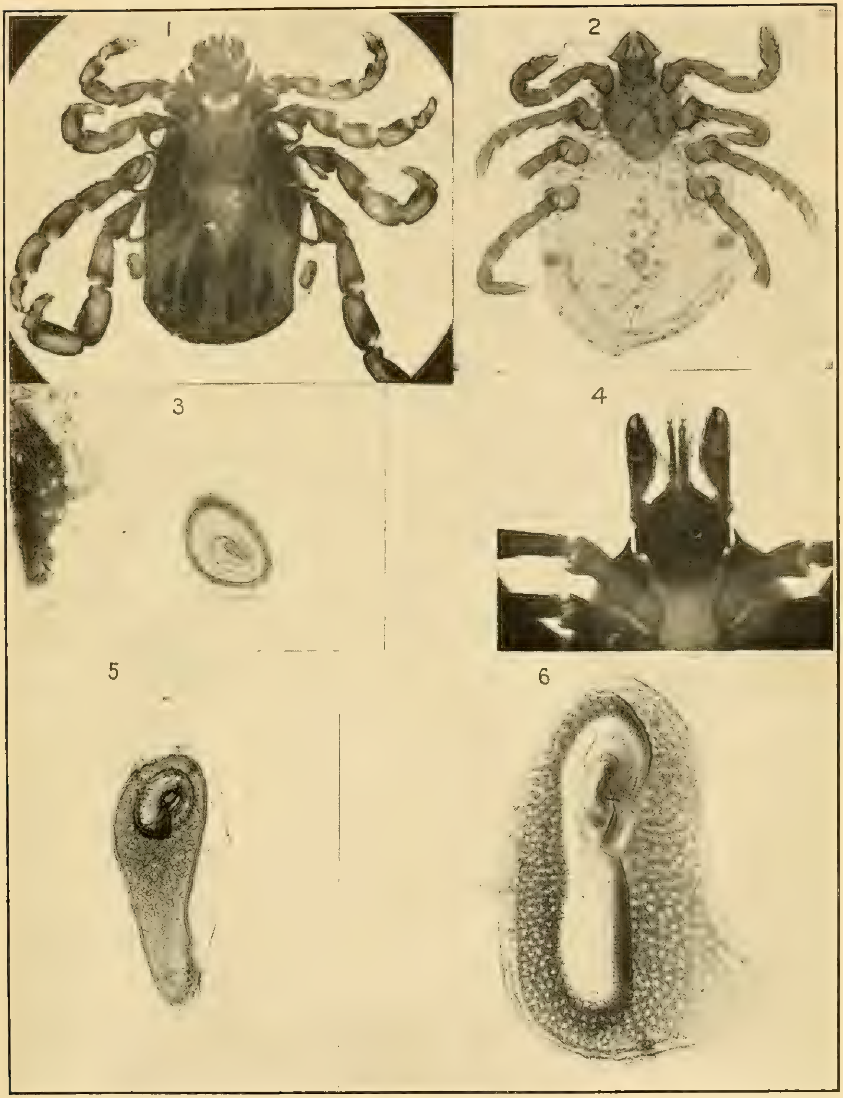
First eggs deposited.	Oviposition completed.	Period of oviposition.	Period from dropping.
		Days.	*Days.*
Apr. 2	May 5	34	37
Apr. 5	May 5	31	37
Apr. 7	May 1	25	33
Apr. 8	Apr. 27	20	29
Apr. 18	May 7	20	39
Average		26	35

In the above lot of five ticks collected March 29, as will be seen, the maximum period of oviposition was 34 days, the minimum 20, with an average of 26. The maximum number of eggs deposited in a lot of seven ticks collected July 22 was 1,270, the minimum 91, with an average of 636. An engorged tick collected April 30 commenced oviposition May 11, continuing for 12 days, as follows:

TABLE XI.—*Rate of oviposition in Rhipicephalus sp., from dog.*

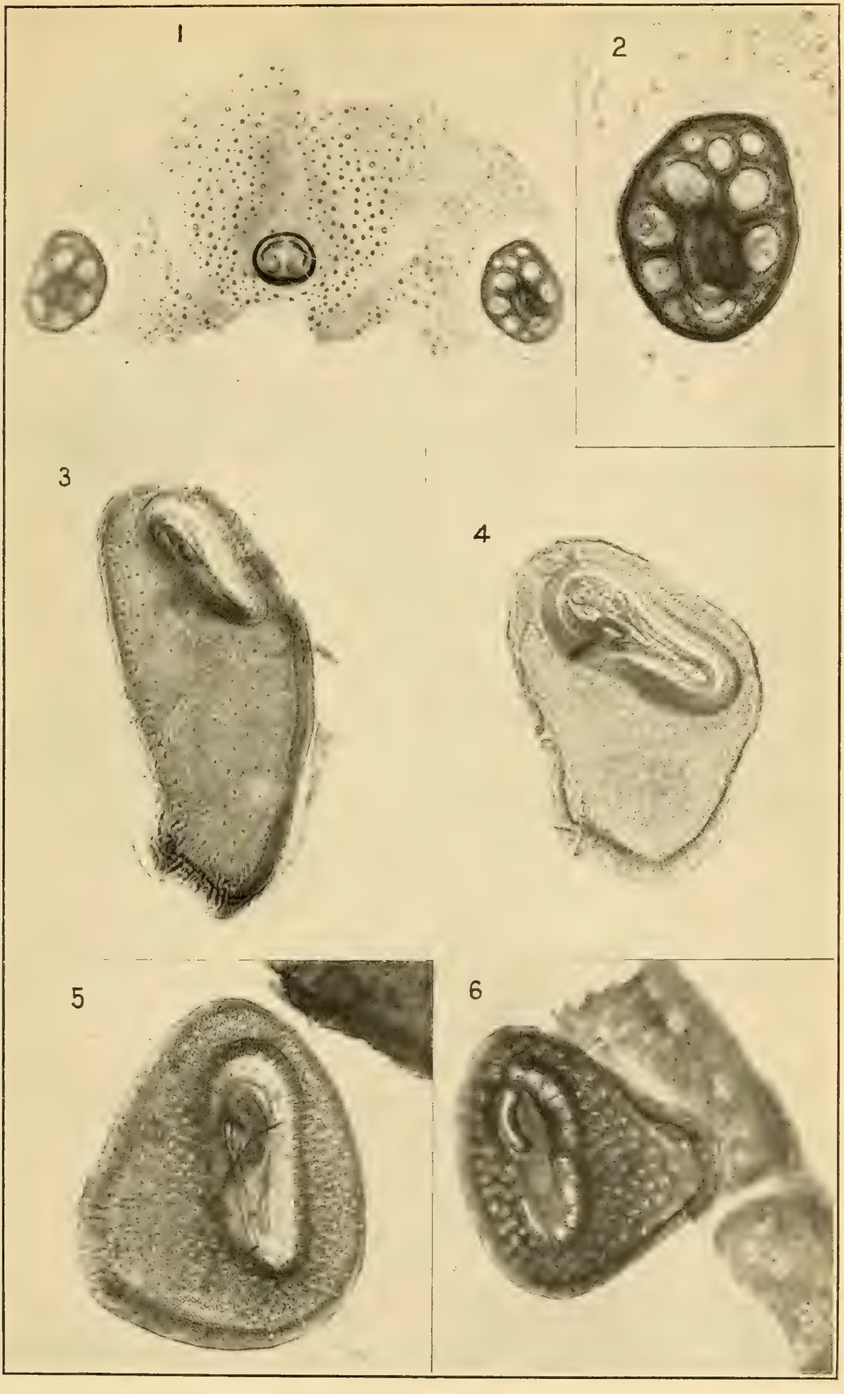
Number of eggs deposited—																Total.
May 10.	May 11.	May 12.	May 13.	May 14.	May 15.	May 16.	May 17.	May 18.	May 19.	May 20.	May 21.	May 22.	May 23.	May 24.	May 25.	
0	73	179	235	181	107	88	108	110	70	27	20	9	0	0	(*a*)	1,209

a Dead.



THE NORTH AMERICAN FEVER TICK AND OTHER SPECIES.

Fig. 1.—*Margaropus annulatus*, male. Fig. 2.—*Hæmaphysalis leporis-palustris*, female. Fig. 3.—Stigmal plate of *Margaropus annulatus*, male. Fig. 4.—Mouth parts of *Ixodes cookei*. Fig. 5.—Stigmal plate of *Rhipicephalus* sp., male. Fig. 6.—Stigmal plate of *Amblyomma maculatum*, female. Figs. 1, 2, much enlarged; fig. 4, more enlarged; figs. 3, 5, 6, highly magnified. (Original.)



STIGMAL PLATES OF TICKS.

Fig. 1.—Stigmal plates and anus of *Dermacentor nitens*, male. Fig. 2.—Stigmal plate of same. Fig. 3.—Stigmal plate of *Amblyomma cajennense*, male. Fig. 4.—Same, female. Fig. 5.—Stigmal plate of *Dermacentor variabilis*, female. Fig. 6.—Stigmal plate of *Dermacentor occidentalis*. Highly magnified. (Original.)

The incubation period of eggs deposited during the middle of April was 6 weeks and of those deposited at the end of that month, 33 days; seed ticks that emerged the first of June lived for 10 weeks, when kept in test tubes on sand.

Attempts were made to rear this species by placing seed ticks on dogs, but with poor success, as few seemed to attach. A dog was infested with seed ticks on May 29, but none could be found attached. On July 13, however, three adult ticks, two partially and one nearly fully engorged, were found between the toes on a front foot. One of the small ticks dropped July 14 and the engorged one on July 15. In the middle of October several males of this species appeared upon the dog, and these must have come from the above lot of seed ticks. They were found to change the location of their attachment from day to day. Our conclusion is that this species drops to the ground for both molts.

Genus MARGAROPUS.

Neumann stands alone in suppressing Margaropus (Boophilus) under Rhipicephalus. Although the two groups are closely related, it seems evident, not only from their structure but from their habits, that they form two distinct genera.

Neumann's latest arrangement of the forms is as follows:

R. (*M.*) *annulatus* (Say). Southern United States.

R. (*M.*) *annulatus* var. *australis* (Fuller). Australia, the Antilles, and South America.

R. (*M.*) *annulatus* var. *calcarata* (Birula). North Africa.

R. (*M.*) *annulatus* var. *decoloratus* (Koch). South Africa.

R. (*M.*) *annulatus* var. *caudata* Neumann. Japan.

R. (*M.*) *annulatus* var. *argentina* Neumann. Province of Buenos Ayres.

Neumann considers that *R.* (*M.*) *microplus* (Canest.) is very probably identical with *R.* (*M.*) *annulatus* var. *australis.*

The first portion of this bulletin deals with the sole North American representative of this genus, *M. annulatus* (see Pl. III, figs. 1, 3).

Genus DERMACENTOR.

This genus is characterized by the presence of cleft front coxæ in both sexes, the fourth pair of an immense size in the male but normal in the female. The structure of the stigmal plate furnishes valuable characters in specific determination in this genus as do the porose areas.

Salmon and Stiles in 1901 had but three species before them from the United States, which they identified as *D. electus* Koch (*variabilis* Say), *D. reticulatus* Neumann, and *D. variegatus* Neumann.

The species which they then listed as *D. reticulatus* Neumann is now considered by Doctor Stiles and Mr. Banks as Neumann's *D. occidentalis*, described from specimens collected in Sonoma County, California, and labeled *D. occidentalis* by Marx. The *D. reticulatus* of Salmon and Stiles is now considered by Banks as *albipictus* Packard. While *D. reticulatus* Fabricius is widely distributed, being found in Europe and Asia, so far as known it has not been taken in this country. *D. parumapertus*, described by Neumann in 1901 from 4 female specimens taken at Lakeside, Cal., labeled as taken on a man and in a chicken house; and *D. bifurcatus* Neumann, from a wild cat in Texas, described as Ixodes and later referred to the genus Dermacentor, seem to come close together, although they may be distinct species. According to Mr. Banks, *Ixodes nigrolineatus* Packard is a Dermacentor. To those referred to can now be added *Dermacentor nitens* Neumann, which has been collected by Mr. J. D. Mitchell, of this Bureau, making a total of 7 described species so far known to occur in the United States.

AMERICAN DOG OR WOOD TICK.

(*Dermacentor variabilis* Say.)

Synonymy (on the authority of Mr. Nathan Banks): *D. americanus* authors (not L.); *D. electus* Koch, 1844; *Ixodes albipictus* Pack. (1st Peabody Acad. Rept., p. 66, not Guide and Am. Nat.); *I. quinquestriatus* Fitch, 1871; *I. robertsoni* Fitch, 1871; *I. punctulatus* Say, 1821(?).

This species is distinguished by the finely punctate stigmal plate (see Pl. IV, fig. 5). It is widely distributed over the country, and has been taken commonly in northern and southern Texas and in Florida on the dog. In some sections of Texas *Amblyomma maculatum* and *Rhipicephalus* sp. are the common ticks on the dog, which is also the case with *I. scapularis* in Florida. Neumann records a male taken on a rabbit, *Lepus callotis*, by Dugès, at Guanajuato, Mexico. Cattle also serve as hosts.

Prof. H. A. Morgan records 7,378 eggs as deposited by a single tick between May 8 and 26. These eggs commenced hatching on August 20, an incubation period of 27 days. Our records include data on the deposition of eggs by a tick collected April 30, oviposition commencing May 8. The details follow:

TABLE XII.—*Oviposition of Dermacentor variabilis.*

Number of eggs deposited—																					
May 8.	May 9.	May 10.	May 11.	May 12.	May 13.	May 14.	May 15.	May 16.	May 17.	May 18.	May 19.	May 20.	May 21.	May 22.	May 23.	May 24.	May 25.	May 26.	May 27.	May 28.	Total.
32	72	124	232	251	320	237	246	217	257	235	253	153	35	104	34	6	0	0	0	(a)	2802

a Dead.

In five lots of eggs deposited in April the incubation period varied from 37 to 43 days. Four lots deposited during May prior to the 10th hatched in 33 or 34 days. Seed ticks that hatched from eggs deposited May 10 lived until November 8 or 10, being alive November 6, but all were dead on November 10. The period of survival was thus six months from deposition.

Under summer temperature Prof. H. A. Morgan found engorgement of the adult to take place in from 5 to 8 days. He concludes that the larvæ and nymphs attach to mammals other than cattle, as the species has only been found on cattle in the adult stage, and attempts to cause seed ticks to attach failed.

NET TICK.

(*Dermacentor occidentalis* Neumann.)

This species (see Pl. IV, fig. 6) was received by Marx from Occidental, Cal. He determined it as a new species, labeling it *D. occidentalis*. Several writers have made use of this name, but it remained for Neumann to describe it for the first time in 1904, placing it as a variety of *D. reticulatus* Fab. Curtice in 1892 referred to it briefly as *D. americanum* (*variabilis*). It is now considered by Banks to be a distinct species and is the one referred to by Salmon and Stiles as *reticulatus*. The true *D. reticulatus* Fab. is not represented in our collections, although it may possibly be found to occur here when a thorough tick survey is made.

The species seems to be a western one, being found in the region of the Rocky Mountains especially. The Bureau of Entomology and Marx collections contain specimens from California, Washington, British Columbia, Colorado, New Mexico, and Texas. Salmon and Stiles also record specimens from Oklahoma and Tennessee. In a specimen taken from a deer skin at Kerrville, Tex., we have what is apparently this species, there being some doubt because of the poor condition of the individual. The recorded hosts include cattle, horse, sheep, deer, and man.

ELK TICK.

(*Dermacentor albipictus* Packard.)

Dermacentor albipictus Packard, Am. Nat., II, p. 559; Guide to the Study of Insects, 9th ed., p. 662. Not 1st Rept. Peabody Acad., p. 66. (See Banks, A Catalogue of the Acarina or Mites, <Proc. U. S. Nat. Mus., Vol. XXXII, 1907, p. 608.)

This species is found commonly on the wapiti or "elk" (*Cariacus canadensis*) in the States of Washington, Montana, Nebraska, Nevada, and New York. Salmon and Stiles report that game keepers on the reserve of the Blue Mountain Forest Association complain of its being very common on the wapiti and that it kills numbers of them.

They suggest the possibility of disease being transmitted by it. The specimens in the Bureau of Entomology collection from Nebraska were taken on the beaver.

TROPICAL HORSE TICK.

(*Dermacentor nitens* Neumann.)

This species is readily distinguished by the characteristic structure of the stigmal plate. (See Pl. IV, figs. 1, 2, and text figs. 5 and 6.) By collections by Mr. J. D. Mitchell from the ears of horses at Brownsville and at Harlingen, Tex., this species has been added to the list of ticks found in this country. The species was described by Neumann in 1897 from specimens in the Marx collection, locality unknown, and from specimens from San Domingo and Jamaica on the horse. In 1901 Neumann listed it from Guatemala, Venezuela, and Porto Rico.

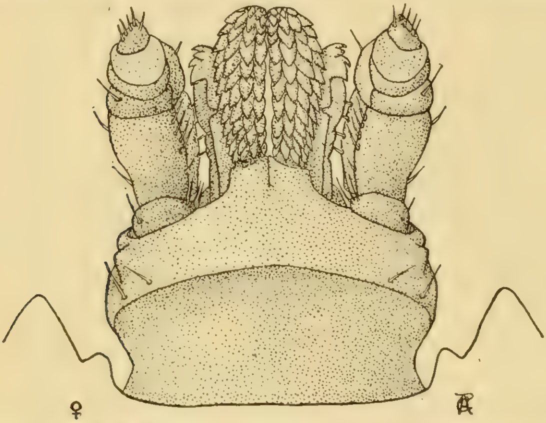


FIG. 5.—*Dermacentor nitens:* Capitulum of female. Greatly enlarged (original).

A single specimen, apparently of this species in the nymphal stage, was taken at Kerrville, Tex., by Mr. F. C. Pratt from a deer skin that had been removed in January.

Genus HÆMAPHYSALIS.

The ticks belonging to this genus may be readily recognized by the presence of conspicuous lateral prolongations on the second palpal segments. The eyes are absent; the coxæ of the male are all provided with spines, those of the female with small tubercular processes. Neumann mentions two species from North America, *H. leporis-palustris*

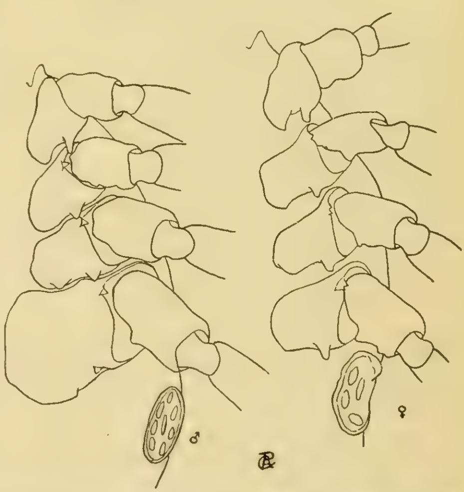


FIG. 6.—*Dermacentor nitens:* Coxæ of male and female. Greatly enlarged (original).

and *H. concinna*, but Banks informs us that he has not found the latter in this country. He recognizes *H. chordeilis* Packard as the form occurring in the eastern United States.

A South African species, *H. leachi*, has been determined by Lounsbury to transmit malignant jaundice of dogs. The larva and nymph both drop from the host to molt. Both engorge quickly, sometimes in less than 48 hours from the time they attach; usually, however, remaining from 65 to 75 hours.

RABBIT TICK.

(*Hæmaphysalis leporis-palustris* Packard).

Synonym: *Gonixodes rostralis* Dugès.

Packard described this species (see figs. 7, 8, and Pl. III, fig. 2) in 1869 from a female specimen collected at Fort Macon, N. C., on a

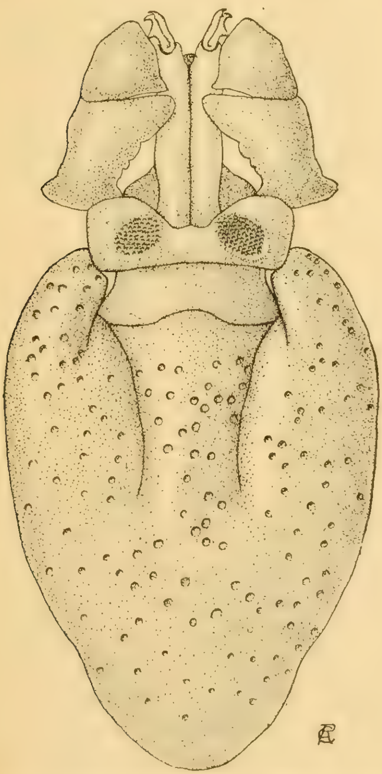


FIG. 7.—*Hæmaphysalis leporis-palustris:* Capitulum and scutum of female, dorsal view. Greatly enlarged (original).

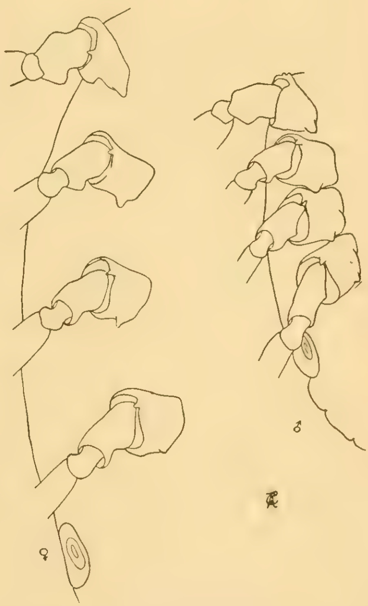


FIG. 8.—*Hæmaphysalis leporis-palustris:* Coxæ of male and female. Greatly enlarged (original).

rabbit, *Lepus palustris*. Marx reported the species as quite common in Kansas, Texas, and California. Dr. Cooper Curtice has taken an engorged female from a horse in Texas, and it has been collected in Mexico, the host not being given. Neumann mentions an engorged female in the museum of Paris labeled "from Brazil" and a molting nymph taken on a Paradoxurus by Forbes in the Malaysian archipelago. Lahille reports it from Argentine Republic. During the past two years it has been collected in Texas by agents of the Bureau at eight different times from rabbits and hares. The species seems to be generally restricted to the genus Lepus, but two instances of other hosts having been recorded and these probably accidental. On the rabbit the ear seems a favorite place for attachment. As a more extensive collection of the tick is made it will undoubtedly be found to occur in a much greater territory than is now known. A few notes on the life history of this species have been made by us.

Table XIII.—*Oviposition of Hæmaphysalis leporis-palustris.*

Number of eggs deposited—														Total.
May 20.	May 21.	May 22.	May 23.	May 24.	May 25.	May 26.	May 27.	May 28.	May 29.	May 30.	May 31.	June 1.	June 2–3.	
260	110	228	146	131	98	72	63	4	0	0	0	0	(a)	1,112
0	0	2	39	8	7	3	0	0	(a)	......	......	......	......	57
0	47	70	48	43	29	22	14	12	14	7	13	7	(a)	326
0	0	0	0	7	17	22	21	13	4	9	5	1	(a)	99

a Dead.

Table XIV.—*Period of incubation and longevity of Hæmaphysalis leporis-palustris.*

Eggs deposited.	Hatching commenced.	Minimum incubation period.	Remarks.
May 20–23	June 20	31	March 5, dead.
May 24–29	June 23	30	March 5, dead.
September 2–5	September 26	24	May 11, dead.

Subfamiiy IXODINÆ.

Three genera of this subfamily, Ceratixodes, Ixodes, and Amblyomma, are represented in the fauna of the United States. They may be readily distinguished. The Ixodes have long club-shaped palpi, the form of the third segment being typical of the genus (see Pl. III, fig. 4). The male and female have only the first coxæ provided with a spine of varying size; the anal groove surrounds the anus anteriorly, opening posteriorly; eyes are present. In Amblyomma the palpi are long but cylindrical; the male has a long spine on the first and fourth coxæ, while in the female only the first coxæ have spines, the others possessing tubercles; the anal groove surrounds the anus posteriorly and opens anteriorly. Ceratixodes, with pointed palpi, occurs on sea birds.

Genus IXODES.

(The Castor Bean Ticks.)

Previous to 1796 all ticks were placed under the Linnæan genus Acarus. In that year Latreille erected the genus Ixodes, giving *I. ricinus* as the type species. For many years following all ticks were described as belonging to this genus, as is the case with the species of Say, Fitch, and Packard.

Of the genera represented in the United States this has the largest number of species. Fourteen are recognized, as follows:[a]

I. ricinus L., *I. frontalis* Panzer, *I. scapularis* Say, *I. fuscus* Say, *I. brunneus* Koch, *I. uriæ* White, *I. cookei* Packard (Synonyms: *I. cruciarius* Fitch, and *I. hexagonus* of S. & S., on the authority of Nathan Banks), *I. arcticus* Osb., *I. diversifossus* Neum., *I. dentatus* Neum., *I. angustus* Neum., *I. inchoatus* Neum., *I. sculptus* Neum., and *I. californicus* Banks.

Of these, four have been taken in Texas by agents of this Bureau—*ricinus*, *cookei*, *scapularis*, and *sculptus*.

Comparatively little is known of the life cycle of the species of Ixodes. The work of E. G. Wheler on "Louping Ill and the Grass Tick" (*I. ricinus*) is about all that has been done. It seems probable that all species drop to molt.

As Mally ascertained to be the case with *I. pilosus* in South Africa, we have found engorged females of *I. scapularis* to dry up in captivity before ovipositing. From Wheler's studies and our experience moisture seems to be a necessity in order that molting may take place.

The longevity of the larvæ of ticks of this genus must be exceptional, even when some of the long-lived species of other genera are considered. Wheler mentions larvæ (*I. plumbeus?*) which hatched on October 9, 1898, from eggs laid in August, that lived until the beginning of August, 1899, or about 10 months. They were kept in a bottle with a sprig of moss and some damp sand.

AMERICAN CASTOR BEAN TICK.

(*Ixodes cookei* Packard.)

Synonymy (on the authority of Nathan Banks): *Ixodes cruciarius* Fitch; *I. hexagonus* S. & S. (not *hexagonus* Leach, 1815); *I. hexagonus* var. *longispinosa* Neum.

This species (Pl. III, fig. 4) was described by Packard from specimens on a woodchuck, *Arctomys monax*, at Salem, Mass. Neumann, in 1899, placed the American form with the European *I. hexagonus*, but in 1901 he separated the two as varieties. Salmon and Stiles, in 1901, followed Neumann, who at that time had all their specimens. Banks has examined the National Museum material and considers *longispinosa* the same as *I. cookei* of Packard, but states that there may be a true *hexagonus* in this country, though he has not seen it.

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[a] According to Nathan Banks, *I. nigrolineatus* Packard is a Dermacentor.

We have taken this species in Texas from a goat, a raccoon, and a skunk. Neumann records it as taken in the United States from the otter, mink (*Putorius vison*), sheep (Texas), spermophile, domestic cat (Maine), fox (Colorado), weasel, porcupine, and marmot.

EUROPEAN CASTOR BEAN TICK.

(*Ixodes ricinus* Linnæus.)

From its general distribution throughout Europe this species has been called the European castor bean tick.

Mr. Banks informs us that in this species the front tarsi are longer than in any other species of the genus found in the United States; that in structure it is very similar to *I. scapularis*, but the porose areas are larger and closer together and the scutum is more angulate on the sides than in that species. Neumann, in his list of hosts of the adult stage, includes sheep, goat, cattle, horse, stag, roebuck, dog, cat, fox, ferret, hedgehog, and man; the nymphs and larvæ having occasionally been found on lizards, birds, hares, rabbits, squirrels, polecats, ferrets, hedgehogs, mules, bats, and mice. In the United States he lists it from Maryland, "Carolina," Florida, California, Kansas, and Texas, on *Lepus sylvaticus*, *Felis pardalis*, cattle, opossum, gray fox, panther, and wild cat. While we have expected to find it frequently in Texas, in but a single instance has it been taken. This was by Mr. F. C. Pratt, at Mountain Home, from a dog. In Louisiana Prof. H. A. Morgan reports it as found on mink in all its stages, but on cattle only in the adult stage.

Although this is an old and widely distributed species, but little study has been made of its life history, that of E. G. Wheler, of England, in 1899, standing practically alone. His most valuable studies were made to determine the relation of the tick to "louping ill" of sheep, with which, in the light of present knowledge, it seems to have only an accidental connection.[a] The following is the substance of Wheler's observations made in England and published in 1899:

The adult females are readily recognized before they become distended by their deep-red bodies, dark-brown legs, shield, and other points. The males are of a uniform dark brown. A record of 2,050 eggs from a single female is given, and a very interesting account of the remarkable process of oviposition. Larvæ, upon finding a host, attach, and remain for about 2 days, by which time they are distended, black, and globular. Fully distended larvæ received February 7 and kept in a bottle became hard, dry, and torpid, but on April 29, after 11 weeks, were found to have changed into nymphs and resumed active habits. After molting the nymph takes up its position on the herbage, just as the larvæ had done, for a chance of attachment to a host.

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[a] Journal of the Royal Agricultural Society of England, Vol. X, pt. 4.

Whereas adults seem to confine themselves mostly to sheep, cattle, and deer, the larvæ and nymphs attach themselves very readily to various hosts, such as horses, dogs, and human beings. About a dozen distended nymphs taken from sheep May 29, though kept moist, had the same dry appearance as the larvæ, as before described. These molted about July 19, about 11 weeks after removal from the host. For some time previous they had appeared dead, no motion of the extended legs being perceptible. Of these about half proved to be males. About 10 days passed before the sexes attained their proper color and strength. On reaching the adult stage both males and females again wait on herbage for a passing host. At this time, as well as after distention of the female on the host, an action which appears to be sexual intercourse freely takes place even in confinement. The rostrum and other mouth parts of the male are inserted in the genital opening of the female, which is situated between the bases of the posterior pair of legs. On the host the females gradually distend, and in the course of so doing vary much in color and appearance, so much so in this case that it is difficult to believe that they are of the same species. Of the exact periods of engorgement we are not informed. Under unfavorable conditions larvæ have been kept alive for 4 months. Nymphs were kept alive for 6 months and adult males and females for 4 months, being still alive at the time of writing (1899). Without moisture, when kept in a dry empty bottle, neither larvæ, nymphs, nor adults survived more than 2 or 3 days. Females exposed to 25° F. for a night were found to be but little affected.

This species, according to recent investigations of Kossel and others in Germany, transmits European piroplasmosis of cattle. The fact that the organism *Piroplasma bigeminum* is the same as is found in this country lends great interest to investigations to determine whether *I. ricinus* may not transmit Texas fever in the United States.

BLACK-LEGGED TICK.

(*Ixodes scapularis* Say.)

Say states that this species is rather common in forests, and is frequently found attached to different animals. Neumann has not recognized the species, but Banks has identified it with a form common in some parts of the South. In Texas we have collected it from deer and dogs, and in Florida from dogs. In the latter State it seems to be very common, and was taken at Hawthorn, Orlando, and Fort Myers.

This species is remarkable for the size that the engorged seed tick reaches. These are as large or larger than the engorged nymph of *Margaropus annulatus*, although the adult is not as large as the adult Margaropus. Large numbers of seed ticks and adults have been taken on dogs, though as yet not a single nymph. This suggests the remote possibility that the species may pass from the larval to the adult stage at a single molt.

SCULPTURED TICK.

(*Ixodes sculptus* Neumann.)

This species was described in 1904 from a female specimen taken with a female *I. ricinus* in the Santa Cruz Mountains of California. So far as known it had not been taken since until Mr. F. C. Pratt collected it on prairie dogs at Sherwood, Tex., November 2, 1906. More extensive collection will undoubtedly show a wider distribution than is now known.

Genus AMBLYOMMA.

The species of the genus Amblyomma are distinguished by the palpi, which are long and cylindrical. The male has the first and fourth coxæ armed with a long spine; the female has only the first coxæ with a spine, the others with tubercles. As far as known all the species drop from the host for each molt. Lounsbury has found *Amblyomma hebræum* to be the transmitter of heartwater in cattle, sheep, and goats, and has carefully worked out its life history.

The genus is represented in the United States by four species—*americanum*, *cajennense*, *maculatum*, and *tuberculatum*. A fifth species, *A. multipunctum*, is described by Neumann from two specimens taken on a tapir and an antelope (*Dicranocerus furcatus*) in "North America." These are reported as collected by Donckier. As no species of tapir is found north of Nicaragua it seems probable that *A. multipunctum* must have been taken from that section of North America.

TABLE FOR SEPARATING THE SPECIES OF AMBLYOMMA OF THE UNITED STATES.

(Adapted from Neumann.)

MALES.

1. Marginal groove extending around the posterior border.......... 2
   Marginal groove not extending around the posterior border.......... *A. tuberculatum.*
2. Coxæ I bicuspid.......... 3
   Coxæ I armed with one long spine.......... *A. maculatum.*
3. Punctations of scutum lacking from the triangular projections, flat, radiating on posterior half.......... *A. cajennense.*
   Punctations distributed over entire surface of scutum.......... *A. americanum.*

FEMALES.

1. Coxæ I bicuspid.......... 2
   Coxæ I armed with one very long spine.......... *A. maculatum.*
2. Scutum triangular, posterior-lateral borders nearly straight.......... 3
   Scutum cordiform, oval, or pentagonal, posterior-lateral borders convex. *A. tuberculatum.*
3. Eyes in front of anterior third of scutum.......... *A. cajennense.*
   Eyes at plane of or behind anterior third of scutum.......... *A. americanum.*

LONE STAR TICK.

(*Amblyomma americanum* Linnæus.)

The lone star tick derives its name from the bright-silvery spot on the scutum of the female. It is widely distributed, having been reported from Labrador to Florida, and also from Guatemala and Brazil. After *Margaropus annulatus*, it is the most important tick in the United States. Though found more commonly on cattle we have taken it from man, horse, mule, dog, goat, hog, deer, squirrel, and wolf, and it appears to attack mammals generally. In portions of Louisiana and Texas it becomes a pest of considerable importance to moss gatherers and other persons who spend much time in the forests. It has been repeatedly taken in Texas during the summer of 1906 on the clothes or attached to the body of agents of the Bureau. Packard mentions a case in which one buried itself in the arm of a young girl, producing a raised tumor.

In May it was found on a herd of dairy cows near Dallas in large numbers, though only an occasional specimen of *Margaropus annulatus* was present. The proprietor of the dairy stated that they were very annoying through their attaching to milkers. Mr. J. D. Mitchell has found it in the vicinity of Kerrville and Llano, Tex., to be the most important species, being much more numerous than the fever tick. In that region the cattle suffer greatly from it. Its abundance seems to be due to the large numbers of sheep and goats kept in that section. These serve as hosts, spreading it broadcast, at the same time reducing the bunches of *Margaropus annulatus* seed ticks.

TABLE XV.—*Oviposition of Amblyomma americanum.*

Collected—	Oviposition.		Period of oviposition.	Dropping to end of oviposition.	Number of eggs deposited.
	From	To—			
			Days.	*Days.*	
Mar. 26	Apr. 5	Apr. 20	16	26	....
Apr. 27	May 5	May 18	14	22	2,444
May 2	May 13	May 21	9	20	984
May 15	May 25	June 5	12	22	2,508
May 19	May 27	June 7	12	20	5,040
Do	....do...	June 6	11	19	2,659
Do	....do...	June 9	14	22	1,736
Do	....do...	June 5	10	18	950
Do	....do...	June 10	15	23	1,510
Do	....do...	June 7	12	20	1,306
Total	....	....	107	....	19,137
Average	....	....	12.5	21.2	2,126

Our records regarding oviposition, as shown in the above table, are from 10 engorged ticks. It will be seen that the maximum number of eggs deposited by an individual was 5,040, deposition continuing for 12 days; the minimum, 950, with a deposition period of 10 days; an average of 2,126 eggs deposited in 12 days. Morgan records as many as 6,519 eggs.

TABLE XVI.—*Incubation and longevity of Amblyomma americanum.*

Eggs deposited.	Commenced to hatch.	Minimum incubation period.	Seed ticks all dead.	Period of— Oviposition to death.	Period of— Hatching to death.
		Days.		*Days.*	*Days.*
Apr. 15–17	June 3	50	Sept. 13	152	103
Apr. 25	June 5	42			
Apr. 28	June 8	42			
May 28 and 29	July 1	35	Nov. 8 [a]	163	129+
May 30 and 31	July 1	33	Nov. 22	177	145

[a] One or more alive.

From the above table it will be seen that the incubation period in April and May is about 7 weeks. Eggs deposited in the latter part of May hatched in 5 weeks.

Prof. H. A. Morgan has found some specimens to pass the first molt on the host, dropping in about 10 days following that molt, or just previous to the second molt. The greater number dropped in from 4 to 7 days. The molting of the nymph was found to last 6 weeks. Engorgement of the adult in March and April occupied from 7 to 11 days.

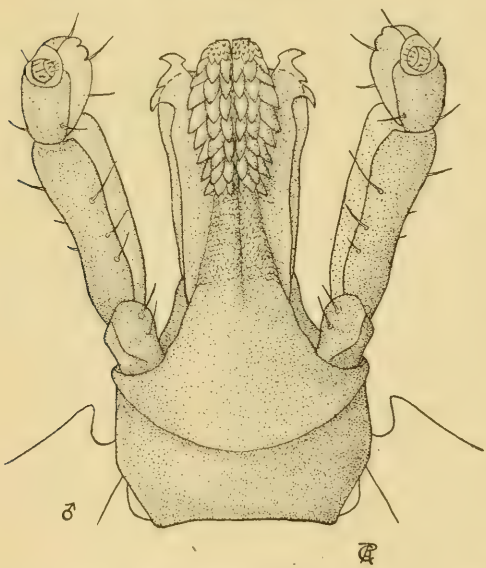

FIG. 9.—*Amblyomma cajennense:* Mouth parts of male. Greatly enlarged (original).

The resistance of the female to water seems to be similar to that of the fever tick. Seven females were submerged for 18 hours, all becoming active following removal from the water. The next day all were again submerged for 45 hours. Only one, an unengorged specimen, survived.

In the adult stage both sexes will reattach, as seems probable in the larval and nymphal stages.

Mr. Mitchell has observed adults on grass in the act of copulation.

CAYENNE TICK.

(*Amblyomma cajennense* Fab.)

Synonyms: *I. crenatum* Say (Banks), *A. mixtum* Koch (Banks), *I. herreræ* Dugès (Neum.), *A. sculptus* Berlese (Neum.).

This species was described from Cayenne in 1794, no host being given. The writers' opinion of the specific identity of specimens from Venezuela, on cattle, with Texas specimens, on horse and peccary, is confirmed by Mr. Banks. The species may be distinguished from *maculatum* readily by the characters given in the table. (See also figs. 9 and 10 and Pl. IV, figs. 3, 4.)

The species has been reported from, and seems to be generally distributed through Mexico and Central America. It has been reported from Colombia, Venezuela, Brazil, and Argentine Republic in South America. Neumann also reports it from Cuba and Jamaica. In Texas Mr. J. D. Mitchell has taken it in Live Oak County from the peccary and horse. Mr. Banks reports specimens from Louisiana, Missouri, and Florida. In addition to the hosts mentioned it has been reported from toad (*Bufo agua*), capybara (*Hydrochærus capybara*), an ant-eater, and man.

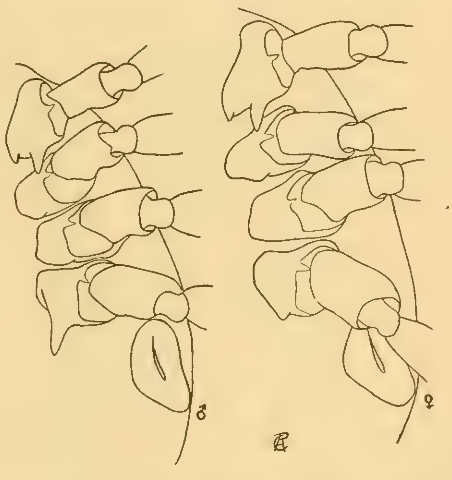

Fig. 10.—*Amblyomma cajennense:* Coxæ of male and female. Greatly enlarged (original).

Stoll, in the Biologia Centrali-Americana, states that this species is the most common of all Ixodidæ in Central America, and gives some information concerning its habits. He has never found the male in a parasitic state, but has found it free on grass and bushes in Guatemala. The female, which he states abounds in the woods and fields on grass and bushes, is occasionally brushed off by horses, cattle, or dogs, and even man. It adheres tenaciously to the skin, remaining when undisturbed for several days until filled with blood. If forcibly removed, the beak breaks off and remains in the wound, causing a disagreeable and sometimes painful inflammation. The young, which are distinguished by the inhabitants of Guatemala by the name of "mostacilla," hang to the grass in clusters of thousands, especially during the dry seasons. By their creeping on the skin and frequent biting they form one of the greatest plagues of travelers.

In a letter accompanying specimens of this species from Venezuela the writers are informed that the ticks do great damage by producing fever in cattle, which become weak and in many cases die. It hardly seems possible that the malady can be Texas fever; nevertheless this species may possibly transmit some disease.

TABLE XVII.—*Record of deposition of an engorged tick, Amblyomma cajennense, collected on peccary April 29.*

Number of eggs deposited—																							
May 9.	May 10.	May 11.	May 12.	May 13.	May 14.	May 15.	May 16.	May 17.	May 18.	May 19.	May 20.	May 21.	May 22.	May 23.	May 24.	May 25.	May 26.	May 27.	May 28.	May 29.	May 30.	May 31.	Total
67	85	212	278	44	259	289	213	336	307	206	119	60	68	33	33	23	11	3	4	0	0(a)		2,650

a Dead.

It will be seen that oviposition continued for 20 days from May 9, a total of 2,650 eggs being deposited. Eggs deposited May 14 commenced hatching June 21, an incubation period of 38 days. Two seed ticks from eggs deposited May 14–25 were alive November 6, a period of more than 5 months from deposition. The fact that this prolonged survival included summer months shows remarkable vitality in the seed ticks of this species. Seed ticks of *Margaropus annulatus* seldom survive over 3 months in the summer.

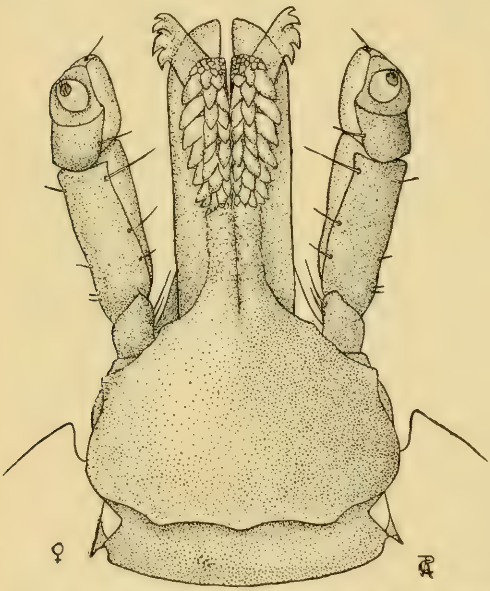

FIG. 11.—*Amblyomma maculatum:* Mouth parts of female. Greatly enlarged (original).

GULF COAST TICK.

(*Amblyomma maculatum* Koch.)

Synonyms: *A. tigrinum* Koch, *A. tenellum* Koch, *A. rubripes* Koch, *A. ovatum* Koch, *A. triste* Koch, *A. complanatum* Berlese (the preceding on the authority of Neumann), *Dermacentor occidentalis* Marx of Niles (Morgan).

This species was described by Koch in 1844 from "Carolina," no host being given. Prof. H. A. Morgan calls our attention to the fact that it was referred to as *Dermacentor occidentalis* Marx by Niles.[a]

It seems to be the common species along the Gulf coast of Louisiana and Texas. (See figs. 11, 12, 13, and Pl. III, fig. 6.) It was taken by Mr. J. D. Mitchell of this Bureau from cattle, horses, dogs, and man in Cameron Parish, La., and Calhoun, Jackson, and Victoria counties, Tex. In the Marx collection there is a male specimen

a Bul. Va. Agric. Exp. Sta., VII, No. 3, pp. 28, 29, Pl. IV.

recorded as taken from cattle at Memphis, Tenn. It seems quite probable that the animal from which the tick was collected had been bred in the Coast section. There are also several specimens in the Marx collection taken in Texas. Neumann reports it from Paraguay, Uruguay, Brazil, Mexico, and in the United States from California, Texas, and Tennessee, the latter based upon the tick before mentioned as collected at Memphis. He mentions 2 males and 1 female as being taken on a coleopteron, *Cercus campestris*, at Buenos Aires, Argentina. Lahille reports it from Argentine Republic, where the favorite host is the dog. He mentions the fact that it is used by the Indians as a leech in certain cases of inflammation.

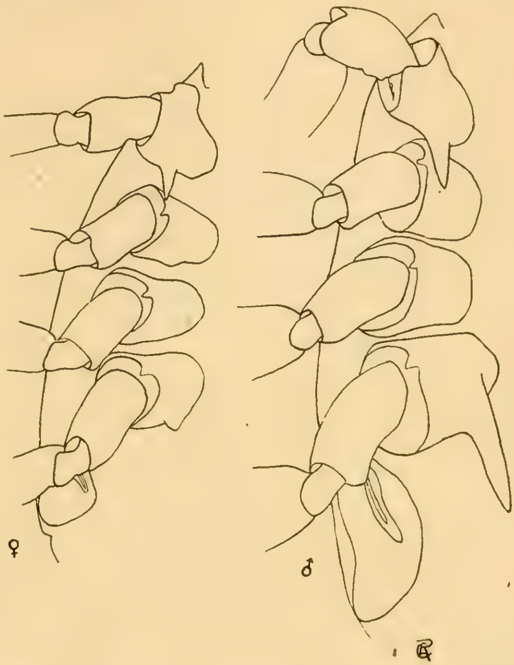

FIG. 12.—*Amblyomma maculatum:* Coxæ of male and female. Greatly enlarged (original).

The male is especially large, much more so and more elongate than either *A. cajennense* or *A. americanum*. Mr. Mitchell reports that while he has observed the sexes in close proximity on the animals he has as yet to find them *in coitu*. He has frequently noticed them to copulate after being removed from the animal. However, in Argentina, Lahille states that several males are usually found attached in the immediate vicinity of each female. Mr. Mitchell states that on one occasion he found 7 females clustered on a cow between the ear and the horn with no male near. In another case he found a cluster of 5 females on the neck of a dog with no male in the immediate vicinity. He has also seen instances where as

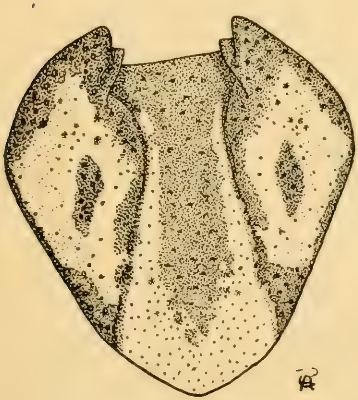

FIG. 13.—*Amblyomma maculatum:* Scutum of female. Greatly enlarged (original).

many as 5 males were located very close together without any females, and other cases on various parts in which both sexes were found together. This species is very firmly attached to the host. While *Rhipicephalus* sp. can be removed easily *A. maculatum* can not be removed without evident pain.

Attempts were made to rear the species upon dogs. On October 11 seed ticks were placed upon two small dogs. Eight were found attached on the 15th. For the first five or six days after attachment the seed ticks increase slowly in size, remaining of a light color; then in a few hours they seem suddenly to engorge with blood. The color of the body becomes purplish and afterwards still darker. On the fifth day from placing seed ticks on the dogs 8 were found still light in color and 1 dark. On the sixth day 2 were taken that had just detached themselves, leaving 2 dark and 4 light on the host. On the seventh day 3 were found to have dropped during the night; 2 dropped and the remaining 1 engorged during the day. On October 19 the eighth tick was found to have dropped during the night, making a minimum period of 5 days and a maximum period of 8 days for attachment of larval stage.

Several of the engorged larvæ were kept on moist sand to molt, but shriveled and died.

The incubation period for eggs deposited from the 1st to the 11th of September varied from 26 to 31 days. Seed ticks from these eggs were still alive on March 1, 1907.

LAND TURTLE TICK.

(*Amblyomma tuberculatum* Marx.)

This species was described by Marx in 1894 from specimens collected by Hubbard at Crescent City, Fla., from the Florida land turtle, *Gopherus* (*Xerobates*) *polyphemus*. Neumann reports a male specimen from Cuba.

We have received 3 specimens collected in February, 1907, by Dr. A. W. Morrill in Florida on a land turtle (*Gopherus* sp.), presumably the same as the host of the original specimens.

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No attempt has been made to make this bibliography complete. In Section A, relating to the cattle tick of North America and the problems caused by it, the literature is scattered through many experiment station bulletins, veterinary journals, bulletins of the Department of Agriculture, and other publications. Only the more important are included. In Section B, relating to foreign disease-transmitting ticks, the literature is found for the most part in the governmental publications of South Africa and Australia, although recently important memoirs have been issued in Germany and France. As in the preceding section, we give only the more important publications that are now available. For a very complete bibliography of this subject down to 1903, containing 221 titles, see A. Schmidt below. In Section C, relating to ticks as transmitters of human diseases, there is at present but a scanty literature. It is practically all referred to by us. In Section D, relating more particularly to the classification of ticks, practically all of the works dealing with North American species are listed, together with the more important foreign publications. For a more extended list, see Salmon and Stiles, 1901, below.

SECTION A.

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Motas.

1903.—The rôle of ticks in the development of carceag <Compt. Rend. Soc. Biol., Paris, vol. 55, no. 14, pp. 501–504.

The writers have seen only a review of this paper in Experiment Station Record.

Pound, C. J.

1899.—Notes on the cattle tick. Its development, life history, habits, and geographical distribution <P. Soc. Queensland, vol. 14, pp. 28–38.

Robertson, F. H.

1905.—Fowl tick experiments <Journ. Dept. Agr. West Australia, vol. 12, no. 6, pp. 561–563.

It was found that fowl ticks remain alive at least 2 years and 3 months without the presence of any fowls from which to derive nourishment. In these experiments the ticks were kept in small pill boxes which were practically air tight. In the nymph stage ticks may live for 2 months without food.

Schmidt, A.

1904.—The tick disease of cattle (hæmoglobinæmia ixodioplasmatica boum) in German and English East Africa and Uganda <Arch. Wiss. u. Prakt. Tierh., vol. 30, nos. 1–2, pp. 42–101.

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Stockman, Stewart.

1904.—Rhodesian redwater, vel East African coast fever, vel tropical piroplasmosis <Report of the Transvaal Dept. of Agric., 1903 to 1904, pp. 40–66.

Includes history of invasion and spread in Transvaal, permit system, dipping, immunity, preventive inoculation, prevention and eradication, and transport experiments.

THEILER, A.

1903 and 1904.—The Rhodesian tick fever <Transvaal Agr. Journ., vol. 1 (1903), no. 4, pp. 93–110, pl. 1; vol. 2 (1904), no. 7, pp. 421–438, pl. 1.

1904.—The transmission of East Coast fever by ticks <Transvaal Agr. Journ., vol. 3, no. 9, pp. 71–86, October.

1905.—Further notes on piroplasmosis of the horse, mule, and donkey <Transvaal Agr. Journ., vol. 3, no. 12, pp. 706–716.

1906.—Transmission and inoculability of spirillosis in cattle <Transvaal Dept. Agr., ann. rept. Dir. Agr. 1904–1905, pp. 123–151.

The writer shows that the natural transmission of spirillosis is by the progeny of *Rhipicephalus decoloratus*, which have developed on cattle affected by spirillosis.

WHELER, E. G.

1899.—Louping ill and the grass tick <Journ. Royal Agr. Soc. England, ser. 3, vol. 10, pt. 4, pp. 626–644.

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1902.—Parasitically inoculated diseases <Trans. Highland and Agr. Soc. Scotland, ser. 5, vol. 14, pp. 16–35, figs. 2.

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SECTION C.

RELATING TO TRANSMISSION OF HUMAN DISEASE BY TICKS.

CHRISTY, CUTHBERT.

1903.—"Tick fever" in man <The Thompson Yates and Johnson Laboratories Report, vol. 5, n. s., part I, pp. 187–189.

DUTTON, J. E., and J. L. TODD.

1905.—The nature of human tick fever in the eastern part of the Congo Free State, with notes on the distribution and bionomics of the tick <Liverpool School of Tropical Medicine, memoir 17, pp. 26.

Includes paper by Robert Newstead, "On the external anatomy of *Ornithodoros moubata* (Murray)."

KING, W. W.

1906.—Experimental transmission of Rocky Mountain spotted fever by means of the tick <U. S. T. D., Public Health and Marine-Hospital Service, Public Health Reports, vol. 21, pp. 863–864, July 27.

NEWSTEAD, R.

1905.—On the external anatomy of *Ornithodoros moubata* <Liverpool School of Tropical Medicine, memoir 17, pp. 21–26, November.

RICKETTS, H. T.

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1906.—The transmission of Rocky Mountain spotted fever by the bite of the wood tick (*Dermacentor occidentalis*) <Journ. Am. Med. Assn., vol. 47, p. 358, August 4.

STILES, CH. W.

1905.—A zoological investigation into the cause, transmission, and source of Rocky Mountain "spotted fever" <U. S. T. D., Public Health and Marine-Hospital Service, Hygienic Laboratory, bul. 20, pp. 1–121.

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Relating to the Classification and Distribution of Ticks.

Banks, Nathan.

1895.—The Arachnida of Colorado <Ann. N. Y. Acad. Sci., vol. 8, pp. 417–434.

Dermacentor americanus L. and *Rhipicephalus* sp. are listed.

1899.—Reports upon the insects, spiders, mites, and myriapods collected on the Commander Islands Expedition (The fur seals and fur-seal islands of the North Pacific Ocean, pt. 4, pp. 328–351).

Lists *Ixodes borealis,* supposes *I fimbriatus* Kramer and Neumann to be the male.

1901.—Acarina in "Some spiders and other arachnida from southern Arizona" <Proc. U. S. Nat. Museum, vol. 23, p. 590.

Mentions *Argas sanchezi* Dugès from New Mexico and Arizona; also a species of Ixodes from Arizona.

1902.—Papers from the Hopkins-Stanford Galapagos Expedition, 1898–1899, vol. 7, Entomological Results (6), The Arachnida, Proc. Wash. Acad. Sci., vol. 4, p. 70, pl. 2, fig. 9.

Argas transversa, n. sp., and mention of *Amblyomma pilosum* Neum.

1902.—Some Arachnida from New Mexico <Proc. Acad. Nat. Sci. Phila., 1901, pp. 568–596.

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1904.—The Arachnida of Florida <Proc. Acad. Nat. Sci. Phila., pp. 120–147.

Margaropus (*Boophilus*) *annulatus* Say, *Ixodes scapularis* Say, *Dermacentor variabilis* Say, *Amblyomma tuberculatum* Marx.

1904.—Some Arachnida from California <Proc. Cal. Acad. Sci., vol. 3, ser. 3, no. 13, pp. 331–369, pls. 38–41.

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Birula, A.

1895.—Ixodidæ novæ vel parum cognitæ Musei Zoologici Academiæ Cæsareæ Scientiarum Petropolitanæ <Bull. Acad. Imp. Sci. St. Petersbourg, ser. 5, vol. 2, no. 4, pp. 353–364, pls. 1–2.

Fitch, Asa.

1872.—Fourteenth report on the noxious, beneficial, and other insects of the State of New York, pp. 363–373.

Contains descriptions of the following species: *Ixodes americanus, quinquestriatus, robertsoni, cruciarius, Ixodes* (?) *odontalgiæ.*

Hassall, Albert.

1900.—Note on the chicken tick (*Argas americanus*) <U. S. D. A., Bur. A. I., 16th report, pp. 496–500, figs. 16–22, pl. 16.

Koch, C. L.

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Marx, George.

1893.—Note on the classification of the Ixodidæ <Proc. Ent. Soc. Wash., vol. 2, pp. 232–237.

Contains tables of North American genera.

1893.—On the morphology of the ticks <Proc. Ent. Soc. Wash., vol. 2, pp. 271–287.

1894.—Plate illustrating following species published in connection with obituary, Proc. Ent. Soc. Wash., vol. 3, pp. 195–201: *Rhynchoprium spinosum,* (=*Ornithodoros megnini*, nymph), *Ornithodoros americanus*, (=*O. megnini,* adult), *Argas americanus.*

MURRAY, ANDREW.

1877.—Economic entomology, Aptera, pp. 180–204.

Deals with the Ixodidæ.

NEUMANN, L. G.

1896.—Révision de la famille des Ixodidés, I <Mem. Soc. Zool. France, IX, pp. 1–44, figs. 1–36.

1897.—Révision de la famille des Ixodidés, II. Ixodinæ <Mem. Soc. Zool. France, vol. 10, pp. 324–420, figs. 1–45.

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This important monograph of the ticks of the world, unfortunately, is obtained only with considerable difficulty.

1902.—Notes sur les Ixodidés, I <Arch. Parasit., vol. 6, pp. 109–128, figs. 6.

1904.—Notes sur les Ixodidés, II <Arch. Parasit., vol. 8 (1904), no. 3, pp. 444–464, figs. 2.

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NUTTALL, G. H. F.

1899.—The rôle of insects, arachnids, and myriapods as carriers of human and animal diseases which are produced by bacteria and animal parasites <Hyg. Rundschau, vol. 9, no. 5, pp. 209–220; no. 6, pp. 275–289; no. 8, pp. 393–408; no. 10, pp. 503–520; no. 12, pp. 606–620.

OSBORN, H.

1896.—Insects affecting domestic animals <U. S. D. A., Div. Ent., bul. 5, n. s.

PACKARD, A. S., Jr.

1869.—List of hymenopterous and lepidopterous insects collected by the Smithsonian expedition to South America, under Prof. James Orton; appendix to report on Articulates, Ann. Rept. Peabody Academy of Science, pp. 1–14.

Contains descriptions of following new species of American forms: *Ixodes perpunctatus, unipunctata* (=*Amblyomma americanum*), *leporis-palustris* (*Hæmaphysalis*), *chordeilis, bovis* (=*Margaropus annulatus*), *bibronii, naponensis* (S. A.), *albipictus* (N. A.), *nigrolineatus, cookei.*

1873.—Descriptions of new insects. Arachnida <U. S. Geological Survey of Mont., Idaho, Wyo., Utah, 1872; pp. 740–741.

Includes *Ixodes bovis* Riley (= *Margaropus annulatus*) and *Argas americanus* n. sp., with figures of each.

RILEY, C. V.

1893.—Report on a small collection of insects made during the Death Valley Expedition <U. S. D. A., Biol. Surv., N. A. Fauna, no. 7, Part II, p. 252.

Lists seven species of Ixodidæ—determined by Doctor Marx.

SALMON, D. E., and CH. W. STILES.

1901.—See above.

SAY, THOMAS.

1821.—An account of the arachnides of the United States <Journ. Acad. Nat. Sci., vol. 2, pp. 59–83; Leconte edition, vol. 2, pp. 9–24.

Descriptions of the following species of Ixodes: *annulatus* (*Margaropus*), *erraticus, scapularis, orbiculatus* (=*Amblyomma americanum ?*), *variabilis* (*Dermacentor*), *fuscous* (*fuscus*), *crenatum* (=*Amblyomma cajennense*), *punctulatus* (=*Dermacentor variabilis ?*).

Stoll, Otto.

1886–1893.—Arachnida Acaridea <Biol. Cent.-Am., pp. 18–24, pls. 12–14.

Five species are discussed.

Ward, Henry B.

1899.—The ticks of Nebraska <Nebraska State Board of Agriculture, annual report for 1899, pp. 193–205. Reprint: Studies from the Zoological Laboratory, no. 38.

Wheler, E. G.

1906.—British ticks <Journ. Agr. Sci., vol. 1, pp. 400–429, pls. 5–10.

Williams, S. R.

1905.—Anatomy of *Boophilus annulatus* Say <Proc. Boston Soc. Nat. Hist., vol. 32, pp. 313–334, pls. 18–22.

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O

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 73.
L. O. HOWARD, Entomologist and Chief of Bureau.

STUDIES OF PARASITES OF THE COTTON BOLL WEEVIL.

BY

W. DWIGHT PIERCE,
Special Field Agent.

ISSUED JANUARY 21, 1908.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1908.

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MABEL COLCORD, *librarian.*

COTTON BOLL WEEVIL INVESTIGATIONS.

W. D. HUNTER, *in charge.*

F. C. BISHOPP, R. A. CUSHMAN, SPRINGER GOES, W. E. HINDS, C. E. HOOD, C. R. JONES, WILMON NEWELL, W. D. PIERCE, F. C. PRATT, C. E. SANBORN, C. S. SPOONER, W. W. YOTHERS, *special field agents.*

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., July 29, 1907.

Sir: I have the honor to transmit herewith a manuscript entitled "Studies of Parasites of the Cotton Boll Weevil," by Mr. W. Dwight Pierce, a special field agent of this Bureau engaged in cotton boll weevil investigations. Some of the preliminary results of these studies were published as Bulletin No. 63, Part II, of the Bureau of Entomology, under the title "Notes on the Biology of Certain Weevils Related to the Cotton Boll Weevil." The boll weevil in the United States is now known to be attacked by several species of parasitic insects. These have not been introduced with the boll weevil from the country from which the latter spread, but they have been here for years as parasites of other species of weevils occurring in the territory now infested by the boll weevil. The present manuscript contains a record of investigations of these parasites and deals especially with the possible practical applications which may be made of the results gained. I recommend its publication as Bulletin No. 73 of this Bureau.

Respectfully,

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

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The boll weevil has been present in the United States for fourteen years. At this time it is doing serious damage to cotton in four States, and during the present season undoubtedly will invade a fifth. In regions like Central America, where the insect has existed for many years, there are various influences that serve to hold it in check. In this country similar influences are beginning to be in evidence. Among the direct factors in the natural control of the boll weevil that are now at work are the following: Heat and dryness, the native ant *Solenopsis geminata*,[a] winter temperatures, proliferation, parasites, defoliation by the cotton leaf-worm, determinate growth, and birds. Of these, proliferation and birds have already received careful special attention, while the work of the native ant has received preliminary notice. The other factors have also been more or less discussed in the publications of the Bureau of Entomology and elsewhere, and more extensive studies of certain ones will be discussed by Dr. W. E. Hinds in Bulletin No. 74 of this Bureau.

While the work of parasites, discussed in this bulletin, is not at present one of the most important factors in the control of the boll weevil, the indications are clear that its importance will grow rapidly. Moreover, the matter has special interest for the reason that it is not unlikely that practical means may be devised to increase the work of the parasites.

In the United States fifteen species of insects which seek the weevil in its immature stages are known. These insects have not been introduced artificially from other countries, nor have they followed the boll weevil into this country. They have all been present for years, and have been actively parasitic upon other species of weevils found within the boll-weevil-infested territory. In fact, there are a great many closely related weevils of the genus Anthonomus, some of which are very common in parts of the cotton belt. These weevils are frequently held completely in control by parasites, and for the most part the parasites are not confined to the attack of a single species of weevil. In many cases the boll weevil may appear in a

[a] Not to be confused with the kelep, the introduction of which has proved unsuccessful.

region in which the parasites have reached the critical point of maximum parasitism, and in such cases the overflow of parasites must attack some other host, which naturally will be the predominant insect of the same group as their former host. It is therefore not at all surprising that when the boll weevil appears by millions in a new region these same parasites in the very first generation of the boll weevil become adapted to it as a new host.

The distribution of the other species of weevils is limited to floral or geographical regions, and consequently, to a less extent, the parasites are also limited. This condition is illustrated by the distribution of the species of parasites which have already attacked the boll weevil. It is safe to say that as the pest advances to the East and North still other insects will adopt it as their host in the same measure as it invades regions inhabited by other species of weevils. In many transitional regions there is a strong possibility that several species of weevils may be very highly parasitized and that all of them will lend parasites to the attack of the boll weevil. In such regions especially there are to be expected instances of very high percentages of parasitism. At Waco, Tex., where two regions border upon each other, a parasitism of over 40 per cent occurred at one time during the season of 1906.

There are two possible practical applications of the information obtained and recorded in this bulletin, both, however, requiring expert entomological knowledge and experience. These are: (1) The propagation and collection of parasites, and their distribution in regions where the same species are either present in but small numbers or altogether absent, and (2) the elimination of related weevils by the destruction of their food plants in or about cotton fields, thereby forcing the parasites to transfer their attention to the boll weevil.

Under the plan of artificial propagation by picking large numbers of squares in fields where the weevil is highly parasitized and placing them in cages adapted for such breeding, a large number of parasites might be obtained. The weevils should then be killed. These parasites could be released in fields with a low percentage of parasitism, and the results under favorable conditions should be apparent after one generation of the boll weevil. In this bulletin will be found an account of an apparently very successful experiment of this kind, in which, at Dallas, Tex., the percentage of parasitism was brought up 9.1 per cent by the introductions of parasites from Waco, about 100 miles away.

Under the plan of eliminating, more or less, the natural hosts of parasites that will attack the boll weevil (by the destruction of their food plants) no experiments have yet been performed. As an example of the possibilities, however, it may be mentioned that there is a common but easily controlled weed (*Croton* spp.) grown in and about cotton fields throughout the South the seed pods of which are infested by a weevil (*Anthonomus albopilosus*) closely allied to the boll weevil. This weevil has three different parasites, which also attack the boll weevil. The croton weevil does not feed upon cotton or any other cultivated plants. By merely mowing down or otherwise removing the croton plants at the proper time there could be no danger from the croton weevil, while its parasites would be forced to turn their attention to the boll weevil. It is conceivable that the encouragement of the croton plants or the actual planting and later removal might be undertaken in order to obtain the best possible results.

Other results of practical application are recorded in this bulletin. Among them may be mentioned the fact that fallen forms exposed to the sun show higher parasitism than those shaded, due undoubtedly to the light-loving character of the parasites. This gives another reason for the wide spacing of the plants and the use of varieties of cotton with the minimum tendency to form leafage and the greatest tendency to shed their leaves in the fall.

W. D. Hunter,
In Charge of Cotton Boll Weevil Investigations.

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STUDIES OF PARASITES OF THE COTTON BOLL WEEVIL.

INTRODUCTION.

Although the boll weevil (*Anthonomus grandis* Boh.) has shown adaptation to many diverse conditions, it is not free from parasites. From the work detailed in this bulletin it has become apparent that certain enemies attack it in arid regions and certain others in humid regions; that some species attack principally larvæ in dried or sun-exposed forms, while other species attack the weevil stages in moist, decaying forms; that some species work most readily in prairie country, while others prefer woodland. The weevil does not escape parasitism by dispersion, for the local parasites are capable of adaptation and attack the boll weevil in its first generation.

Being a species with an all-season food plant, *Anthonomus grandis* has made a decisive gain over most of its near relatives, which are confined to more or less limited periods because of the shorter seasons of their host plants. The most active weevil parasites in the South have become adjusted to one host after another until in most localities they have a regular seasonal rotation of hosts. From this multiplicity of parasitic relations it is but natural to evolve a new tendency and to attack the most abundant species of the locality, namely, the boll weevil.

As the native weevil hosts are more or less limited in distribution, it is found that the boll-weevil parasites are likewise geographically restricted. The combined activity of two or more species in certain favored districts has been the cause of forming three known centers of intensive parasitism in Texas, of which the most important is near Waco; the next around Goliad, Cuero, and Victoria, and the third in eastern Texas. The agencies forming these centers are in no case identical. *Catolaccus incertus* is the most active parasite at Brownsville, Tex., and Orange, La. *Bracon mellitor* (fig. 1), which is the predominant parasite for the entire infested area, is the most active in the entire western half of Texas. *Cerambycobius cyaniceps* is predominant in northeastern Texas. *Eurytoma tylodermatis* shows its greatest activity at Overton and Dallas.

HISTORY.

Prior to the year 1906 very little information concerning the parasites of the boll weevil had been accumulated. In 1895 Townsend mentioned a small hymenopterous parasite; also recorded the suspicious occurrence of several species of Scymnus in the squares, and mentioned that a fungoid parasite, a species of Cordyceps, "was found growing out of a dead pupa in its cell in a boll, November 26, in a field in San Juan Allende, Mexico." (Townsend, 1895.)[a] In 1896 Doctor Howard stated that the parasites were only abundant late in the fall and that from "15 to 20 per cent of the weevil larvæ in fallen squares in November at Beeville and Kenedy were destroyed by parasites." (Howard, 1897.)

FIG. 1.—*Bracon mellitor*, parasite of boll weevil. Much enlarged (from Hunter and Hinds).

In 1901 Professor Herrera published a preliminary note concerning *Pediculoides ventricosus* Newp. (fig. 2) (Rangel, 1901b, p. 206), and in the same year a more extensive note on the work of this mite was published by Rangel. In testing the mite's ability to propagate, 250 squares were divided into lots of 50 each and an infested larva placed with each lot for four days. One hundred check squares were used. At the time of examination the check squares were free from the mites, while the others contained 193 weevil stages, of which 61 were attacked by Pediculoides; in other words, 31.6 per cent were parasit-

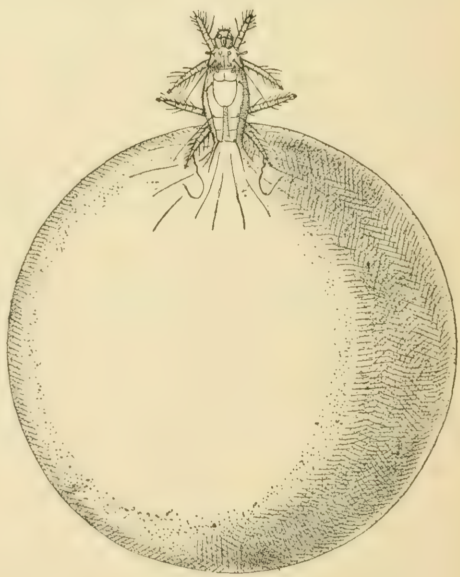

FIG. 2.—*Pediculoides ventricosus*, mite enemy of boll weevil. Much enlarged (adapted from Brucker).

[a] Bibliography, pp. 50–51.

ized. A small field test proved that the mites increased and spread (Rangel, 1901c).

In 1902 Dr. Wm. H. Ashmead described *Bruchophagus herreræ*, from Coahuila, Mexico, as a primary parasite of the boll weevil (Ashmead, 1902). In the same year Prof. F. W. Mally recorded the fact that *Bracon mellitor* Say and *Cerambycobius* (*Eupelmus*) *cyaniceps* Ashm. had, since 1899, been bred by him in considerable numbers from the weevil. He also recorded a species of Eurytoma (Mally, 1902). In 1904 Hunter and Hinds recorded additional primary parasites as follows: *Sigalphus curculionis* Fitch (fig.3), *Catolaccus incertus* Ashm., *Urosigalphus* (*robustus* Ashm.), *Bracon* (*dorsator* Say), and *Eurytoma tylodermatis* Ashm., as well as an entomogenous fungus, *Aspergillus* sp. (Hunter and Hinds, 1904, pp. 104–110). The determination of this Urosigalphus has been found incorrect. It has just been described as *Urosigalphus anthonomi* Cwfd. (Crawford, 1907a). The form known under the name of *Bracon dorsator* is merely a small, melanistic, fall form of *Bracon mellitor* Say. Finally, Banks has described a mite, *Tyroglyphus breviceps*, collected at Victoria, Tex., from boll weevil larvæ (Banks, 1906, p. 17).

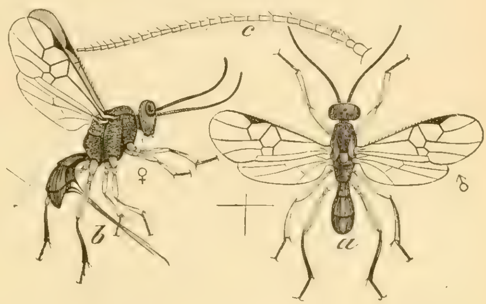

FIG. 3.—*Sigalphus curculionis*: *a*, male; *b*, female; *c*, antenna. All enlarged (after Riley).

THE WORK ON PARASITES IN 1906.

As the work of the year naturally divided itself into distinct sections, it may be thus divided for treatment in this report:

I. Examination work—ascertaining the general status of boll weevil parasitism.
II. Propagation work—attempting to increase the percentage of parasitism by release of parasites.
III. Breeding work—study of the biology of the parasites.
IV. Source work—study of the surrounding field conditions in order to ascertain the hosts which have contributed the parasites, and to learn the biology of each of these hosts.
V. Conclusions—a review of the situation as a whole.

I. EXAMINATION WORK.

In order to arrive at a proper knowledge of the status of boll weevil parasitism large collections of infested squares and bolls under various plant and field conditions were made in many parts of the weevil territory. This material was immediately shipped to the laboratory and examined by the various members of the laboratory force. Messrs. Hinds, Bishopp, Crawford, Cushman, Jones, Morgan, Pratt, and Yothers were engaged at various times in the collection of infested material and the more important work of examination. Upon their accuracy of observation the finding of the parasites was dependent, and to them belongs credit for the amount of figures herewith presented relating to the percentage of parasitism. A careful tabulated record was kept of all stages of the weevil, alive or dead, and all parasites were isolated in tubes. Each collecting lot received a number and each individual a sub-number, and its stage and the nature of its parasitism were recorded. As each parasite matured the record was placed opposite its number, and the insect was either used in experiments or laid aside for the collection. In this manner there could seldom be an error as to the nature of the parasitism, as all evidence was in the tube.

RECORDS PRIOR TO 1906.

In previous years no regular method of making the parasite records was in use, and consequently there is difficulty in the comparison of the former conditions with those now prevalent. In some cases the percentage was obtained from the breeding records only, and at other times by an examination for the total number of stages present.

In 1902 three observations were made between July 31 and August 11 at Calvert, Guadalupe, and Victoria. The figures obtained included only bred stages, omitting consideration of stages killed by heat, fungi, ants, crushing, etc.

In 1903 Dr. A. W. Morrill first pointed out in his notes that parasites occur in dry hanging forms,[a] and also in bolls. No other mention of the former condition can be found prior to 1906. Only two observations were made, both being at Victoria, in June.

In 1905 four examinations of bolls were made during March, at Calvert, Palestine, Runge, and Victoria, in order to ascertain the condition of hibernating stages. These examinations consider the total number of stages found hibernating in the bolls. The figures are important, as they prove that the parasites also hibernate in bolls.

During August of the same year nine examinations were made at Gurley, Quinlan, Victoria, and Waco. These figures were obtained from fallen forms and included the total number of stages in the forms.

In 1902 and 1903 the figures obtained must give a higher percentage of parasitism than actually occurred, as no account was taken of the stages dead from other causes. It is also very unsatisfactory to take the entire percentage of parasitism in all forms on account

[a] The term "forms" has been used to designate a mixture of squares and bolls.

of the differences which prevail between squares and bolls and between fallen and hanging squares or bolls. However, taking the figures as they are, we have the following results:

TABLE I.—*Total percentage of parasitism of the boll weevil, by years, prior to 1906.*

Year.	Months.	Weevil stages.	Parasites.	Percentage of parasitism.
1902	July 31 to August 11	601	6	0.99
1903	June 3 to 9	178	6	3.37
1905	March 1 to 23 (hibernating)	1,005	32	3.18
1905	August 12 to 31	1,702	21	1.23

In 1905 some of the records differentiated between squares and bolls, so that a comparison may be given between the percentages of parasitism in each.

TABLE II.—*Percentage of parasitism of the boll weevil in fallen forms at Gurley, Quinlan, Victoria, and Waco, Tex., in 1905.*

Form.	Weevil stages.	Parasites.	Percentage of parasitism.
Squares	852	17	1.99
Bolls	123	1	.81

BREEDING RECORDS OF 1906.

Although the work of 1906 was very incomplete in some respects, it is representative of the conditions. The facts have been ascertained one at a time, and as each one has been proved, it has been found that more complete records should have been taken earlier in the season. The material was collected at 25 representative localities in Texas, 2 in Indian Territory, and 5 in Louisiana. Seventy collections of infested forms were made, comprising about 87,000 bolls and squares. The result is that these infested forms contained 39,183 weevil stages, of which 1,689, or 4.31 per cent, were parasitized. The material collected was separated into lots, according to location and the nature of the forms.

A brief classification of the results, by months and by the four plant conditions, gives some very important information. In the first place, the percentage of parasitism is, to all intents and purposes, about equal throughout the season and not highest in the fall. It must, of course, be borne in mind that the collections were not made at regular intervals at stated places, but are from different localities each month and include different factors. During September and October a number of localities on the extreme border line were examined, but the percentage is not appreciably altered. The plant conditions were altered also, so that one month there might be more squares than bolls, and another month more bolls than squares, examined. A correct view of the monthly variation may be obtained by an examination of the complete tables of observations, which are given on succeeding pages. It will be noticed in that connection that there is no graduated seasonal wave of parasitism. Other and still unknown factors enter into the problem.

The following summary also discloses the fact that hanging forms provide conditions superior to those afforded by fallen forms, and that squares are more favorable than bolls.

Finally, it appears by comparison with the table of results for previous years that there has been a gain in the total percentage of parasitism as well as in the two classes of forms.

TABLE III.—*Percentage of parasitism of the boll weevil, by months, in 1906.*

Month.	Fallen squares.			Hanging squares.			Fallen bolls.			Hanging bolls.			Total.		
	Stages.	Parasites.	Per cent.	Stages.	Parasites.	Per cent.	Stages.	Parasites.	Per cent.	Stages.	Parasites.	Per cent.	Stages.	Parasites.	Per cent.
1906.															
June	3,831	118	3.08	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	3,831	118	3.08
July	4,621	210	4.54	247	76	30.76	169	0	0.00	22	0	0.00	5,059	286	5.65
August	10,342	174	1.68	2,973	348	11.70	2,490	20	.80	2,925	192	6.54	18,730	734	3.91
September	5,665	286	5.04	1,883	117	6.26	1,591	23	1.44	1,140	67	5.87	10,279	493	4.79
October	347	8	2.30	20	0	0.00	57	1	1.75	860	49	5.69	1,284	58	4.51
Entire season	24,806	796	3.20	5,123	541	10.56	4,307	44	1.02	4,947	308	6.22	39,183	1,689	4.31

[a] No records made.

The observations for June were made only at Victoria; those for October were made at Dallas for hanging forms and at Mineola for fallen forms.

Owing to the extensiveness of the tables the figures are considerably condensed, but still retain the value of their records. Numerous cases of high parasitism were found, of which the following may be cited as notable examples:

	Number of stages.	Per cent parasitized.
Fallen squares:		
Roosevelt, Tex.,[a] September 24	69	14.4
Brownsville, Tex.,[a] September 5	1,147	12.4
Hanging squares:		
Waco, Tex., July 25	99	52.6
Waco, Tex., September 20	109	23.8
Cuero, Tex., August 31	347	21.3
Fallen bolls:		
Corsicana, Tex., September 18	34	5.9
Junction, Tex., September 24	17	5.8
Hanging bolls:		
Marshall, Tex., August 22	52	13.5
Trinity, Tex., August 9	142	12.0
Waco, Tex., September 20	303	11.8

[a] In both of these localities fallen squares would naturally be dry.

Numerous other high percentages were found, but these will convey an impression as to the promises of success obtained.

In the table herewith presented only the totals for each locality are given, and in more specific tables the seasonal variation at given localities will be recorded separately.

MOST FAVORABLE PLANT CONDITIONS FOR PARASITISM OF THE BOLL WEEVIL.

TABLE IV.—*Most favorable plant conditions for parasitism of the boll weevil.*

Locality.	Season.	Squares fallen.			Squares hanging.			Bolls fallen.			Bolls hanging.			Totals.		
		Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.
TEXAS.	1906.															
Brownsville	July 28–September 29.	3,095	202	6.5	...	...	...	384	13	3.3	...	...	...	3,479	215	6.1
Beeville	July 12–September 3.	2,660	36	1.3	...	...	...	324	0	0.0	...	...	...	2,984	36	1.2
Corpus Christi	July 10	438	39	9.0	...	...	...	20	0	0.0	...	...	...	458	39	8.5
Goliad	August 7–September 3.	821	70	8.5	209	29	13.8	133	3	2.2	265	13	4.9	1,428	115	8.0
San Antonio	August 15	33	0	0.0	...	...	...	...	...	...	...	...	...	33	0	0.0
Kerrville	August 26–September 3.	38	4	10.5	...	...	...	295	7	2.3	...	...	...	333	11	3.3
Roosevelt	September 24	69	10	14.4	...	...	...	74	0	0.0	...	...	...	143	10	6.9
Junction	do	129	11	8.2	...	...	...	17	1	5.8	...	...	...	146	12	8.2
Mountain Home.	September 13	93	0	0.0	...	...	...	...	...	...	...	...	...	93	0	0.0
Lula	September 26	95	0	0.0	...	...	...	...	...	...	...	...	...	95	0	0.0
16 miles south of Roosevelt.	September 25	81	2	2.4	...	...	...	9	0	0.0	...	...	...	90	2	2.2
Cuero	August 9–31	1,059	11	1.0	439	87	19.9	80	0	0.0	189	2	1.0	1,767	100	5.5
Hallettsville	August 9–30	1,040	5	0.4	401	37	9.2	93	1	1.0	295	11	3.7	1,829	54	2.8
Victoria	June 16–September 1.	6,557	203	3.0	802	82	10.2	162	0	0.0	201	1	0.5	7,722	286	3.7
Taylor	August 16	153	1	0.6	160	8	5.0	63	1	1.5	40	1	2.5	416	11	2.6
Waco	July 25–September 20.	1,508	128	8.4	460	126	27.3	283	5	1.7	746	83	11.1	2,997	342	11.4
Calvert	August 22–September 13.	1,054	15	1.4	81	8	9.8	347	0	0.0	181	12	6.6	1,663	35	2.1
Corsicana	August 23–September 18.	16	0	0.0	102	12	11.7	34	2	5.9	176	6	3.4	328	20	6.0
Palestine	August 10–September 4.	1,054	14	1.3	414	48	11.5	209	1	0.4	211	7	3.3	1,888	70	3.7
Trinity	August 9–30	1,554	20	1.2	169	21	12.4	949	4	0.4	269	28	10.3	2,941	73	2.4
Dallas	August 17–October 6.	75	0	0.0	150	7	4.6	74	0	0.0	1,068	64	5.9	1,367	71	5.1
Terrell	September 19	53	0	0.0	...	...	...	46	0	0.0	...	...	...	99	0	0.0
Mineola	August 10–October 2.	445	9	2.0	...	...	...	57	1	1.8	...	...	...	502	10	2.0
Overton	August 23	197	2	1.0	45	1	2.2	37	0	0.0	89	4	4.5	368	7	1.9
Marshall	August 22	23	0	0.0	6	1	16.6	18	0	0.0	52	7	13.5	99	8	8.0
INDIAN TERRITORY.																
Fort Towson	September 12	...	...	...	521	0	0.0	...	...	...	...	...	...	521	0	0.0
Kosoma	September 14	...	...	...	64	0	0.0	...	...	...	...	...	...	64	0	0.0
LOUISIANA.																
Mansfield	August 24–September 29.	491	3	0.6	249	7	2.9	211	0	0.0	626	37	5.9	1,577	47	2.9
Many	August 23	1,315	6	0.4	633	66	10.4	321	5	1.5	539	32	5.9	2,808	109	3.8
Orange	September 23–30	435	5	1.1	...	...	...	67	0	0.0	...	...	...	502	5	0.9
Minden	September 8	...	...	...	218	1	0.5	...	...	...	...	...	...	218	1	0.5
Johnsons Bayou.	August 22	225	0	0.0	...	...	...	...	...	...	...	...	...	225	0	0.0
Total		24,806	796	3.2	5,123	541	10.5	4,307	44	1.02	4,947	308	6.2	39,183	1,689	4.3

The records from only five points extend into three months, and these may be taken as indicative of the seasonal variation at a given locality.

TABLE V.—*Parasitism of the boll weevil in fallen squares, Brownsville, Tex.*

Date.	Stages.	Parasites.	Percentage parasitized.
1906.			
July 28	1,568	50	3.2
August 3	115	2	1.7
September 5	1,147	142	12.4
September 29	265	8	3.0

TABLE VI.—*Parasitism of the boll weevil in fallen squares, Beeville, Tex.*

Date.	Stages.	Parasites.	Percentage parasitized.
1906.			
July 12	656	26	4.0
August 8	442	2	.45
August 13	884	2	.22
September 3	678	6	.9

TABLE VII.—*Parasitism of the boll weevil in fallen squares, Victoria, Tex.*

Date.	Stages.	Parasites.	Percentage parasitized.
1906.			
June 16	864	15	1.8
June 23	667	9	1.3
June 25	396	11	3.0
June 26	652	26	3.9
June 27	829	33	4.0
June 28	423	24	5.7
July 5	535	19	3.5
July 9	560	13	2.3
July 20	518	32	6.1
July 22	87	5	5.7
September 1	1,026	16	1.6

TABLE VIII.—*Parasitism of the boll weevil in all forms, Waco, Tex.*

Date.	Fallen squares.			Hanging squares.			Fallen bolls.			Hanging bolls.		
	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.
1906.												
July 25	259	26	10.0	99	52	52.6	44	0	0.0	22	0	0.0
August 17	32	2	6.2	22	3	13.6	24	0	0.0	16	0	0.0
August 28	1,217	100	8.2	230	45	19.5	215	5	2.3	405	47	11.6
September 20	......	......	......	109	26	23.8	......	......	......	303	36	11.8

TABLE IX.—*Parasitism of the boll weevil in hanging forms, Dallas, Tex.*

Date.	Hanging squares.			Hanging bolls.		
	Stages.	Parasites.	Per cent of parasitism.	Stages.	Parasites.	Per cent of parasitism.
1906.						
August 29	12	1	8.5	26	0	0.0
September 12	118	6	5.0	182	15	8.2
October 2	8	0	0.0	250	10	4.0
October 6	12	0	0.0	610	39	6.3

The only one of these tables in which there appears any definite progression is the Victoria table, in which there is a regular increase of percentage throughout the last half of June.

FIELD CONDITIONS.

In order to arrive at an explanation for the obviously irregular conditions of parasitism, the figures have also been rearranged according to field conditions. It was found that generally hanging forms in wooded or cleared country were more highly parasitized than those on prairie land. The only definite comparisons which could be found were as follows:

TABLE X.—*Percentage of parasitism of the boll weevil in forms in woodland and on prairie.*

Locality.	Date.	Woodland.		Prairie.	
		Hanging forms.	Fallen forms.	Hanging forms.	Fallen forms.
	1906.				
Goliad	September 3	11.2	8.2	6.0	6.4
Waco	September 19	14.9	....	14.6	....

Stages in fallen forms on prairie land were found to have a higher general percentage of parasitism than those in woodland, although the definite case of Goliad gives a different condition. It is only necessary to quote the highest percentages reached in each condition to give support to these statements.

The highest percentage in hanging forms on woodland was 42.6.

The highest percentage in fallen forms on woodland was 8.3.

The highest percentage in hanging forms on prairie was 14.6.

The highest percentage in fallen forms on prairie was 10.1.

Considerable contradictory matter was brought out in comparing the parasitism in fallen forms in shade and in those exposed to the sun. The weight of evidence supports the statement that those fallen and exposed to sunlight are more highly parasitized than those which fall on moist shaded soil. Only five definite comparisons can be presented to show the irregularities which exist.

TABLE XI.—*Parasitism of the boll weevil in fallen forms in sun and shade.*

Locality.	Date.	Woodland.		Prairie.	
		Shade.	Sun.	Shade.	Sun.
	1906.				
Mansfield, La	August 24	0.54	1.09	....	....
Taylor, Tex	August 16	....	....	0.69	1.3
Trinity, Tex	August 8	2.3	1.07	....	....
Victoria, Tex	July 20	....	....	....	6.5
Victoria, Tex	July 22	....	....	2.6	....
Waco, Tex	August 29	8.7	6.8	....	....

The highest percentages obtained in each class are as follows:

In shade on woodland	8.7
In sun on woodland	8.3
In shade of plants on prairie	8.2
In sun on prairie	10.1

Should further inquiry prove that sun-dried squares are the most highly parasitized, another reason is presented for wide rows.

GEOGRAPHICAL CONSIDERATIONS.

By far the most important facts established by the table of percentage of parasitism (Table IV) were elicited by using the geographical map of Texas, published in the census of 1880, as a base.

I. The alluvial prairie of the Rio Grande is represented by Brownsville with an average percentage of parasitism in all forms of 6.1.

II. The coast prairie is represented by Corpus Christi with 8.5 per cent, Goliad with 8.0 per cent, Cuero with 5.5 per cent, and Victoria with 3.7 per cent.

III. The Edwards plateau is represented by Junction with 8.2 per cent, Roosevelt with 6.9 per cent, and 16 miles south of Roosevelt with 2.2 per cent. This latter case was a farm with very rank growth of cotton, from which shaded squares were picked on the ground. The weevil had not been present long.

IV. The black prairie is represented by Kerrville with 3.3 per cent, Taylor with 2.6 per cent, Corsicana (IVb) with 6.0 per cent, and Dallas with 5.1 per cent.

V. The cross timbers are represented by Waco with 11.4 per cent.

VI. The eastern hardwoods are represented on the south by Beeville with 1.2 per cent, Hallettsville with 2.8 per cent, each at the tip of an extension of this region, and by Calvert with 2.1 per cent, Palestine 3.7 per cent, Mineola 2.0 per cent, Overton 1.9 per cent, Marshall 8.0 per cent, Mansfield, La., 2.9 per cent, Many, La., 3.8 per cent. Marshall is probably represented by a field on a red-land knoll, which would account for the discrepancy.

VII. The eastern pine country is represented by Trinity with 2.4 per cent, and Orange, La., with 0.9 per cent. Trinity is in a transitional region of pines and hardwoods, but seems to belong more typically to the hardwood region.

It will be readily observed that regions I, II, III, V, with Corsicana in IVb, which really belongs to the brown loam region in the eastern hardwoods, and Marshall in VI, which belongs to the red-land areas of the eastern hardwoods, are the most highly parasitized, while the regions IV, VI, and VII are the lowest parasitized.

The map on the opposite page (fig. 4) is presented to illustrate these statements.

While it may be merely a coincidence that the places in the same belt have about the same proportion of parasitism, it is nevertheless worthy of some attention. It is undoubtedly true that each of these floral regions is also a distinct subfaunal region. It may therefore be expected that different weevils will exist in the different belts and different parasites operate upon these weevils. Some of these parasites may be able more readily than others to adopt the boll weevil as a host, or in certain regions there may be more species of parasites capable of doing this. In the discussion of the geographical distribution of the parasites more light will be thrown upon this question.

FIG. 4.—Map of Texas, divided into geographical regions and illustrating average percentage of parasitism of the boll weevil in all cotton forms: I, alluvial prairie; II, coast prairie; III, Edwards Plateau; IV, black prairie; IV^b, brown loam prairie; V, cross timbers; VI, oak, hickory, and pine; VII, pines. (Original.)

BOLL WEEVIL STATUS.

That there should be some definite relation between the percentage of infestation and the percentage of parasitism was expected, on the ground that a condition favorable to the weevil should be favorable to the parasites. It was, of course, conceded that climate would be another agency to figure in the question. The year's work is deficient in that coordinate examinations of infestations and parasitism were not taken. In another year this will be necessary in order to show whether the parasites are reducing the infestation.

At present no relation can be found between parasitism and infestation or climatology. Beeville, Goliad, and Victoria have a mean annual temperature of 70° and a precipitation of 30 inches. At Beeville the average percentage of parasitism in fallen squares was 1.3 per cent, at Goliad 8.5 per cent, at Victoria 3 per cent. This condition occurs throughout the entire State. At Calvert the percentage of infestation of squares on August 28 was 55.6 per cent and at Goliad it was 20.9 per cent, and yet the average percentage of parasitism in fallen squares at Calvert was 1.4 per cent and Goliad 8.5 per cent. A reverse condition may be cited as follows: At Cuero the percentage of infestation of squares on August 28 was 74 per cent and at Victoria it was 32.7 per cent, and the average percentage of parasitism in hanging squares at Cuero was 19.9 per cent and at Victoria 10.2 per cent. Table XII gives in detail the irregularity displayed between these three factors.

TABLE XII.—*Boll weevil status and parasitism.*

Locality.	Mean annual temperature.	Mean annual precipitation.	First examination, July 3, 1906. Average per acre.		Weevil status, Aug. 28, 1906. Percentage infested.		Average parasitism, 1906. Squares.		Average parasitism, 1906. Bolls.	
			Plants.	Weevils.	Squares.	Bolls.	Fallen.	Hanging.	Fallen.	Hanging.
Brownsville, Tex	72	25					6.5		3.3	
Corpus Christi, Tex	70	30	9,412	212	71.0	84.0	9.0		0.0	
Beeville, Tex	70	30	8,859	300	21.8	3.1	1.3		0.0	
Goliad, Tex	70	30	10,169	305	20.9	1.6	8.5	13.8	2.2	4.9
Victoria, Tex	70	30	8,334	119	32.7	15.0	3.0	10.2	0.0	.5
San Antonio, Tex	68	25	12,186	101	38.0	.2	0.0			
Yorktown, Tex	68	30			67.2	20.5				
Cuero, Tex	68	30	7,225	135	74.0	59.0	1.0	19.9	0.0	1.0
Hallettsville, Tex	68	30	8,056	289	78.0	3.2	.4	9.2	1.0	3.7
Austin, Tex	68	30	15,580	73	19.2	.27				
Giddings, Tex	68	30	15,600	76	34.5	2.1				
Lula, Tex	66	25					0.0			
Sixteen miles south of Roosevelt, Tex	66	25					2.4			
Roosevelt, Tex	66	25					14.4		0.0	
Junction, Tex	66	25					8.2		5.8	
Mountain Home, Tex	66	25					0.0			
Kerrville, Tex	66	25					10.5		2.3	
Bryan, Tex	68	40	10,170	38	52.3	4.1				
Hempstead, Tex	68	40	12,255	84	74.7	10.5				
Eagle Lake, Tex	68	40	5,735	89	20.8	13.0				
Wharton, Tex	68	40	5,127	93	54.0	17.3				
Taylor, Tex	66	30					.6	5.0	1.5	2.5
Cameron, Tex	66	30	16,317	67	73.3	46.0				
Waco, Tex	66	30	13,800	49	68.7	6.2	8.4	27.3	1.7	11.1
Hillsboro, Tex	66	30	18,200	0	4.8	3.4				
Corsicana, Tex	66	30	20,524	0	38.0	1.4	0.0	11.7	5.9	3.4
Mexia, Tex	66	30	18,520	0	.8	0.0				
Calvert, Tex	66	40	11,377	196	55.6	8.0	1.4	9.8	0.0	6.6
Palestine, Tex	66	40	12,712	61	52.8	14.4	1.2	11.5	.4	3.3
Athens, Tex	66	40	11,568	21	21.6	1.7				
Troupe, Tex	66	40	8,126	390	92.0	67.5				
Jacksonville, Tex	66	40	10,963	160	70.0	32.0				
Henderson, Tex	66	40	7,536	564	87.6	52.8				
Dallas, Tex	64	40			22.5	0.0	0.0	4.6	0.0	5.9
Terrell, Tex	64	40	14,000	0	0.0	0.0	0.0		0.0	
Mineola, Tex	64	40	1,607	105			2.0		1.8	
Marshall, Tex	66	50	9,480	69	78.0	29.0	0.0	16.6	0.0	13.5
Trinity, Tex	68	50	9,990	182	50.8	11.0	1.2	12.4	.4	10.3
Lufkin, Tex	68	50	11,320	36	53.2	10.7				
Overton, Tex	68	50	7,780	69	78.0	29.0	1.0	2.2	0.0	4.5
Fort Towson, Ind. T	64	50		0	0.0	0.0		0.0		0.0
Kosoma, Ind. T	64	50		0	0.0	0.0		0.0		0.0
Mansfield, La	68	50					.6	2.9	0.0	5.9
Many, La	68	50					.4	10.4	1.5	5.9
Orange, La	68	50					1.1		0 0	
Minden, La	66	50		0	0.0	0.0		.5		
Johnsons Bayou, La	70	50					0.0			

BOLL WEEVIL CHRONOLOGY.

The boll weevil has been present in the United States since 1892. Year by year it has extended its ravages, although during the summer of 1896 and the winter of 1904–5 it received severe setbacks. Its territory now extends into four States, and in three of these observations as to parasitism were made. Several examinations were made immediately after the dispersion of August in newly infested fields, and at Minden, La., it was actually found that parasitization had commenced within two weeks of the weevil's arrival. The parasites do not follow the weevil; they are already present and native to the country invaded. Thus it is that in some parts of Texas where the weevil has been present ten or more years the parasites have not as great a hold as they have at Waco, which has only had it four years. There are probably more sources for parasites at Waco than at other points.

TABLE XIII.—*Weevil chronology and parasitism.*

Locality.	Chronology.	Average parasitism.			
		Squares.		Bolls.	
		Fallen.	Hanging.	Fallen.	Hanging.
Minden, La.	Weevil arrived in the August dispersion of 1906. First generation in green squares collected.		.5		
Fort Towson, Ind. T.	do		0.0		
Kosoma, Ind. T.	do		0.0		
Lula, Tex.	Weevil arrived in 1906, probably	0.0			
Sixteen miles south of Roosevelt, Tex.	Weevil arrived in 1905 or 1906	2.4			
Roosevelt, Tex.	Weevil arrived in 1905	14.4		0.0	
Junction, Tex.	do	8.2		5.8	
Mountain Home, Tex.	do	0.0			
Kerrville, Tex.	Weevil arrived in 1904 or 1905	10.5		2.3	
Dallas, Tex.	Weevil arrived in 1904; set back February, 1905; rearrived 1905.	0.0	4.6	0.0	5.9
Mineola, Tex.	do	2.0		1.8	
Terrell, Tex.	do	0.0		0.0	
Johnsons Bayou, La.	Weevil arrived in the August dispersion of 1904.	0.0			
Mansfield, La.	do	.6	2.9	0.0	5.9
Marshall, Tex.	do	0.0	16.6	0.0	13.5
Overton, Tex.	do	1.0	2.2	0.0	4.5
Many, La.	Weevil arrived in the fall of 1903	.4	10.4	1.5	5.9
Corsicana, Tex.	Weevil present in 1903	0.0	11.7	5.9	3.4
Waco, Tex.	Weevil present in 1902	8.4	27.3	1.7	11.1
Trinity, Tex.	Weevil present in 1901	1.2	12.4	.4	10.3
Palestine, Tex.	do	1.2	11.5	.4	3.3
Calvert, Tex.	do	1.4	9.8	0.0	6.6
Taylor, Tex.	do	.6	5.0	1.5	2.5
Hallettsville, Tex.	Weevil present in 1897	.4	9.2	1.0	3.7
San Antonio, Tex.	Weevil arrived in 1894; set back until 1897.	0.0			
Cuero, Tex.	Weevil arrived in 1895; set back until 1896.	1.0	19.9	0.0	1.0
Victoria, Tex.	do	3.0	10.2	0.0	.5
Goliad, Tex.	Weevil present in 1894	8.5	13.8	2.2	4.9
Corpus Christi, Tex.	Weevil present in 1893	9.0		0.0	
Beeville, Tex.	do	1.3		0.0	
Brownsville, Tex.	Weevil present in 1892	6.5		3.3	

CONCLUSIONS.

A few points of practical importance have been deduced from the foregoing general tables.

1. Inasmuch as the parasites are known to attack the weevil in its first generation in a newly infested locality, it may be expected that by releasing the proper parasites in a given locality the percentage of parasitism may be increased in a very short time. Such a case was actually obtained by the release of *Bracon mellitor* at Dallas, as described in the section on propagation.

2. Dryness and sunlight assist attack by the chalcidoid and braconid parasites of the weevil, as proved by the following considerations: (It is, of course, to be understood that this conclusion may hold only for those species and regions studied. In fact two or three of the minor species, such as the tachinids, give promise of doing most favorable work under directly opposite conditions in regions so far unstudied.)

a. Stages in hanging forms are, as a rule, parasitized to a higher degree than those in fallen forms.

b. Stages in fallen forms on prairie land are generally more highly parasitized than those in wooded country, although frequently hanging forms in wooded country are more highly parasitized than those in prairie land.

c. Fallen and hanging forms on unshaded ground are more highly parasitized than those on shaded soil.

These facts give an added importance to certain cultural methods already advocated, viz:

a. That the rows should be far apart, in order to allow the sun to dry the squares on the ground.

b. That determinate varieties should be planted in order to give additional heat and light for the parasites during the cooler autumn months.

That, as indicated by the present studies, dryness seems to be a most favorable condition for attack by hymenopterous parasites is quite natural, as these delicate little insects are very fond of sunlight and warmth.

II. Propagation Work.

1. Interior work—transfer or artificial propagation of parasites.

It has not been a difficult matter to breed the parasites of the boll weevil. There have been used in this laboratory four distinct methods of obtaining parasites, all of which served the purpose for which they were used. In all cases where definite records of percentage, length of stages, or nature of parasitism were required there has been a careful examination of each form (square or boll), and those forms containing parasites, or sometimes only the parasite and its host, were placed in individual pill bottles, numbered, recorded, and placed in trays for daily observation. A somewhat less exact method has been to place a limited number of squares in a tumbler on moist or dry soil in order to make the time of development more nearly normal. These tumblers were covered with cheese cloth and tagged.

When definite records were not requisite large quantities of squares or bolls were placed in Riley breeding cages and the parasites were obtained in larger quantities with less mortality, which is frequently caused by rough handling in the closer examinations. Closed boxes with numerous tubes on one side, after the pattern of the parasite breeding cages adopted by the California board of horticulture, were also used for small quantities of squares. These cages probably hasten development by increasing the heat and moisture.

There was, however, another problem which proved beyond solution for this season. It may be described as the effort to induce the parasites to attack the stages in forms placed in cages of various kinds. No positive results were obtained, but considerable experience was gained in the matter of breeding-cage technique.

The first work was done with various kinds of glassware, closed with cheese cloth. As fast as males and females of the same species could be bred they were isolated in pairs and placed with a limited number of infested squares. These squares were fresh, flared, or fallen, in order to test all conditions.

Glass tumblers covered with cheese cloth proved too dark. When dry earth was placed in the tumbler or when there was no earth, the squares rapidly dried and became very hard, and the parasites quickly died. When moistened earth was used the squares quickly molded and the parasites were killed by the fungus. When a water reservoir was sunk in the earth the parasites drowned.

When glass lamp chimneys were placed on clay saucers filled with moist soil there was plenty of light and the material remained in good condition. The objection to this method is that the parasites can not be easily handled.

Erlenmyer flasks gave plenty of light and were easy to handle as they have a small mouth, but they sweat profusely and the parasites were caught in the moisture on the glass. Blotters, absorbent cotton, and corks with large wire-covered openings failed to prevent the sweating.

The last attempt on this line was with mica lamp chimneys such as are used with the ordinary incandescent gas burners. These were covered at both ends with cheese cloth. They are of light weight, give plenty of sunshine and sufficient circulation. For a small breeding cage they are very handy in many ways. But the parasites did not attack the weevil even in these cages.

In all of the above types of cages the life of the parasite was hardly a day. In wire types of cages the parasites lived several days. In the following, several of each sex of the parasites were used.

The first type was a cubic cage made very easily by using strips of cork for the framework and fine meshed wire (known as 50 to the inch, but really 35 and 45 to the inch) for the sides. One side was fixed with two openings which were closed on the inside by a tin shutter. The lower opening was round, and in this a cork with a glass tube through it was placed before the shutter was raised. Thus the parasites, being attracted to light, could be quickly removed by darkening the sides and allowing the light to enter only through the tube. When the shutter was raised higher it exposed a larger opening through which material could be passed.

With this first cage as a type various modifications were contrived, all with wire fronts, shutters of various kinds, and corked holes for the admission of a tube or for passing in small objects. Cigar boxes became the bases for these cages.

Still another modification was a wire cylinder corked at one end and with a smaller cork centered in this for the removal of material. The other end was covered with cheese cloth.

It was found impossible to provide plant conditions in a small cage unless the plant were actually transplanted or grown from seed. A branch of cotton withers so quickly that experiments of this sort were of no value.

Both kinds of tubes were tested on the plants, but the mica tube caused a heavy sweat and killed the branch it was on; the wire tube was too heavy. All of the plants placed under the large parasite-tight cages with glass sides died before results could be expected.

2. FIELD WORK—RELEASE OF PARASITES.

The release of parasites in the field was not commenced until September 12 on account of the small amount of material gathered prior to that date. Notwithstanding that fact the results give an indication of success. On the laboratory farm at the top of the hill there were released 35 parasites on September 12 and 38 on September 15. These parasites were of three species. An examination of hanging forms was made in this part of the field and another down the hill at the opposite side and about 350 yards distant. At this time the check area ("B," fig. 5) showed 1.9 per cent higher parasitism than the parasite area ("A," fig. 5). Twenty days later, on October 2, like examinations were made with the result that the percentages were reversed; "A" showed an increase of 2.6 per cent and "B" showed a decrease of 6.5 per cent; that is, "A" was 7.2 per cent more highly parasitized than "B" and showed a real gain in parasitism of 9.1 per cent. On October 6 this examination was followed by another, and, although the difference was less, "A" was 3.9 per cent more highly parasitized than "B." Plat "A" was next to a fence and separated from another field of cotton by a road and a high hedge of *Ambrosia trifida* with scattered *Solanum rostratum*. As a further check on the experiment the nearest part of this field ("D," fig. 5) was examined and proved to be parasitized by 2.1 per cent less than "A." On the contrary, the farther part of the field ("E," fig. 5) showed 5.8 per cent higher parasitism than "A." The conclusion was that "E" and "D" did not influence "A."

The results are given in Table XIV for the entire experiment, and also according to species. It is believed by the writer that it was the release of *Bracon mellitor* which accomplished the change.

The evidence upon which this belief is founded is both positive and negative. *Bracon mellitor* was not found breeding upon any other species of weevil in the vicinity, and yet the examinations showed an increase of parasitization by this species in the "parasite

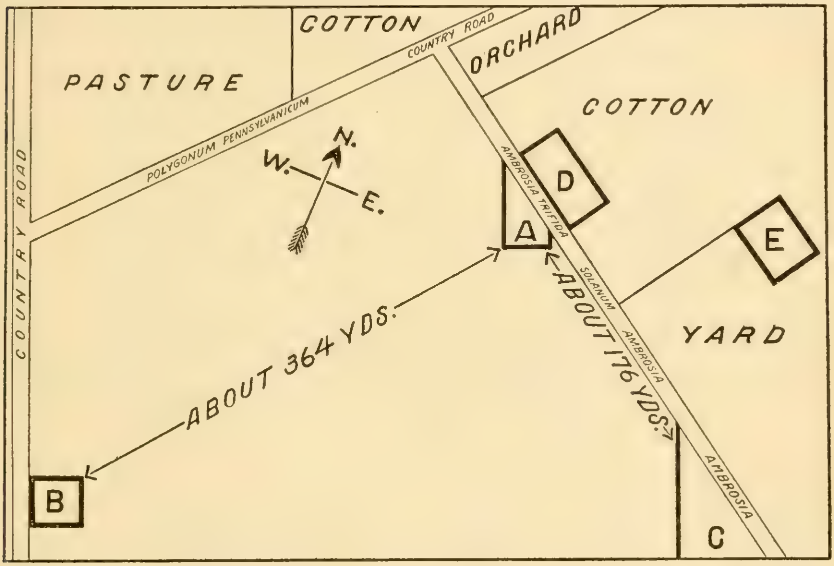

FIG. 5.—Diagram of cotton plantation of H. O. Samuel, Dallas, Tex., of 644 acres, showing location of plats where observations and experiments on boll-weevil parasitism were made. (Original.)

area" opposed to a decrease in the "check area." *Catolaccus incertus*, although released in large numbers, did not take hold at all, nor was it found breeding upon any other species of weevil in the vicinity. A few *Cerambycobius cyaniceps* were released, but the only trace of parasitization by this species was found in the original check. And yet this species was bred from *Lixus musculus* in the stems of *Polygonum pennsylvanicum* near by, and also from *Trichobaris texana* Lec., in the stems of *Solanum rostratum* adjacent to "A". No *Eurytoma tylodermatis* were released, although this species was abundant throughout the field. It is known as a parasite of *Lixus scrobicollis* Boh., which breeds in *Ambrosia trifida* stems. Immense numbers of this plant were growing along the road adjacent to "A." In order to show that plat "E," which was highly parasitized by

Bracon mellitor, did not influence the numbers of that species in "A," the fact may be cited that the higher percentage of *Eurytoma tylodermatis* in "E" evidently had no influence upon the presence of that species in "A."

TABLE XIV.—*Release of parasites of the boll weevil—Summary of all species.*

Date.	"A." Parasite area.			"B." Check area.			"C." Check area.			"D." Area across road.			"E." Area 100 yards from "D."			Total.		
	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.
Sept. 12	120	7	5.8	180	14	7.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	300	21	7.0
	Released 27 ♀, 8 ♂.																	
Sept. 15	Released 35 ♀, 3 ♂.																	
Oct. 2	95	8	8.4	163	2	1.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	258	10	3.8
Oct. 6	183	13	7.1	125	4	3.2	.....	.....	.....	218	11	5.0	96	11	12.9	622	39	6.2
Oct. 10	.....	.....	.....	.....	.....	.....	247	5	2.02	.....	.....	.....	.....	.....	.....	247	5	2.0

TABLE XV.—*Release and parasitism of Bracon mellitor.*

Date.	"A." Parasite area.			"B." Check area.			"C." Check area.			"D." Area across road.			"E." Area 100 yards from "D."			Total.		
	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.
Sept. 12	120	2	1.66	180	4	2.22	.....	.....	.....	.....	.....	.....	.....	.....	.....	300	6	2.0
	Released 14 ♀, 6 ♂.																	
Oct. 2	95	5	5.26	163	1	.61	.....	.....	.....	.....	.....	.....	.....	.....	.....	258	6	2.3
Oct. 6	183	6	3.27	125	1	.80	.....	.....	.....	218	7	3.22	96	5	5.21	622	19	3.0
Oct. 10	.....	.....	.....	.....	.....	.....	247	5	2.02	.....	.....	.....	.....	.....	.....	247	5	2.0

TABLE XVI.—*Release and parasitism of Catolaccus incertus.*

Date.	"A." Parasite area.			"B." Check area.			"C." Check area.			"D." Area across road.			"E." Area 100 yards from "D."			Total.		
	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.
Sept. 12	120	0	0.0	180	4	2.22	.....	.....	.....	.....	.....	.....	.....	.....	.....	300	4	1.3
	Released 10 ♀, 2 ♂.																	
Sept. 15	Released 30 ♀, 1 ♂.																	
Oct. 2	95	0	0.0	163	0	0.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	258	0	0.0
Oct. 6	183	1	.54	125	0	.0	.....	.....	.....	218	0	0.0	96	0	0.0	622	1	0.1
Oct. 10	.....	.....	.....	.....	.....	.....	247	0	0.0	.....	.....	.....	.....	.....	.....	247	0	0.0

TABLE XVII.—*Release and parasitism of Cerambycobius cyaniceps.*

Date.	"A." Parasite area.			"B." Check area.			"C." Check area.			"D." Area across road.			"E." Area 100 yards from "D."			Total.		
	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.
Sept. 12	120	0	0.0	180	1	0.55	....	....	....	....	....	....	....	....	....	300	1	0 3
	Released 3 ♀.																	
Sept. 15	Released 5 ♀, 1 ♂.																	
Oct. 2	95	0	.0	163	0	0.0	....	....	....	....	....	....	....	....	....	258	0	0.0
Oct. 6	183	0	.0	125	0	.0	....	....	....	218	0	0.0	96	0	0.0	622	0	0.0
Oct. 10	....	....	....	....	....	....	247	0	0.0	....	....	....	....	....	....	247	0	0.0

TABLE XVIII.—*Parasitism of Eurytoma tylodermatis.*

Date.	"A." Parasite area.			"B." Check area.			"C." Check area.			"D." Area across road.			"E." Area 100 yards from "D."			Total.		
	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.	Stages of the weevil.	Number of stages parasitized.	Percentage parasitized.
Sept. 12	120	0	0.0	180	3	1.66	....	....	....	....	....	....	....	....	....	300	3	1.0
Oct. 2	95	2	2.10	163	0	.0	....	....	....	....	....	....	....	....	....	258	2	0.7
Oct. 6	183	1	.54	125	1	.80	....	....	....	218	2	0.91	96	6	6.25	622	10	1.6
Oct. 10	....	....	....	....	....	....	247	0	0.0	....	....	....	....	....	....	247	0	0.0

III. PARASITE BREEDING WORK.

Four new primary parasites of the boll weevil have been bred this year, and several definite cases of predaceous attack have been observed. There are now known 11 primary hymenopterous parasites, 1 primary dipterous parasite, 2 acarid parasites (at least), 2 coleopterous enemies, and 2 ant enemies which attack the weevil stages in the cotton forms. They are as follows (insects which attack the adult weevils are omitted from the consideration):

PRIMARY PARASITES.

Hymenoptera.

Chalcidoidea.

Torymidæ, Monodontomerinæ.

1. *Microdontomerus anthonomi* Cwfd. (Texas).

Eurytomidæ.

2. *Eurytoma tylodermatis* Ashm. (Mexico, Texas, Louisiana).
3. *Bruchophagus herreræ* Ashm. (Mexico).

Encyrtidæ, Eupelminæ.

4. *Cerambycobius cyaniceps* Ashm. (Louisiana, Texas).

Pteromalidæ, Pteromalinæ.

5. *Catolaccus incertus* Ashm. (Texas, Louisiana).

Hymenoptera—Continued.
  Ichneumonoidea.
    Braconidæ, Sigalphinæ.
      6. *Sigalphus curculionis* Fitch (Texas).
      7. *Urosigalphus anthonomi* Cwfd. (Texas, probably Mexico).
      8. *Urosigalphus schwarzi* Cwfd. (Guatemala).
    Braconinæ.
      9. *Bracon mellitor* Say (Mexico, Texas).
      10. *Bracon dorsator* Say (Texas).
      11. Undetermined braconid (Texas).

Diptera.
  Tachinidæ.
      12. *Myiophasia ænea* Wied. (Texas, Louisiana).

Acarina.
      13. *Pediculoides ventricosus* Newp. (Mexico).
      14. *Tyroglyphus breviceps* Banks (Texas).

PREDACEOUS ENEMIES.

Coleoptera.
  Cleridæ.
      15. *Hydnocera pubescens* Lec. (Texas, Louisiana).
  Cucujidæ.
      16. *Cathartus cassiæ* Reiche (Texas).

Hymenoptera.
  Formicoidea.
    Myrmicidæ, Myrmicinæ.
      17. *Solenopsis geminata* Fab. (Guatemala, Texas, Louisiana).
    Formicidæ, Formicinæ.
      18. *Formica fusca subpolita perpilosa* (Mexico).

HYPERPARASITES.

Hymenoptera.

Microdontomerus anthonomi Cwfd.	Accidental on *Bracon mellitor* Say.
Eurytoma tylodermatis Ashm.	
Cerambycobius cyaniceps Ashm.	

POSSIBLE PRIMARY PARASITES.

Hymenoptera.
      Catolaccus anthonomi Ashm. (Texas).

Two species of entomogenous fungi, *Aspergillus* sp. and *Cordyceps* sp., have been recorded as probably parasites of boll-weevil larvæ.

OCCURRENCE OF SPECIES.

1. *Microdontomerus anthonomi* Cwfd.[a] This species was collected as follows: Goliad, Tex., September 3, 1906, 1 bred from *Bracon mellitor* cocoon; Cuero, Tex., August 31, 1906, 1 bred from *Bracon mellitor* cocoon; Hallettsville, Tex., August 30, 1906, 4 females, primary parasites upon *A. grandis;* Waco, Tex., August 28, 1906, 2 females, primary parasites upon *A. grandis;* Waco, Tex., August 29, 1906, 1 male, 3 females, primary parasites upon *A. grandis;* Waco, Tex. August 29, 1906, 1 male, bred from *Bracon mellitor* cocoon.

[a] Crawford, 1907a, b.

The range of the Microdontomerus is evidently western. Twenty-three per cent were secondary parasites.

2. *Eurytoma tylodermatis* Ashm. This species, while not very important in any part of the State, is very well distributed. It was recorded continuously after July 12, 1906. Specimens were bred from material collected at Beeville, Brownsville, Calvert, Cuero, Dallas, Goliad, Hallettsville, Overton, Palestine, Trinity, Victoria, and Waco, Tex., and at Mansfield and Many, La. No records were obtained from Corpus Christi, Corsicana, Junction, Kerrville, Lula, Marshall, Mineola, and Taylor, Tex.; nor from Orange, La. Specimens were sent in by Prof. A. L. Herrera from Allende, Coahuila, Mexico, with the note that it was abundant at that place.

3. *Bruchophagus herreræ* Ashm. This parasite has not been taken in the United States. It was described from Coahuila, Mexico.

4. *Cerambycobius cyaniceps* Ashm. This parasite has been taken at all points investigated except those in the Edwards Plateau region.

5. *Catolaccus incertus* Ashm. This parasite has not been taken at Overton or Marshall in northeastern Texas, but is common at all other points investigated.

6. *Sigalphus curculionis* Fitch has not been recorded since the first specimen was bred at Calvert, Tex.

7. *Urosigalphus anthonomi* Cwfd.[a] One female was bred from a cocoon in a weevil cell from material collected September 5 at Brownsville, Tex. As the former record was also from Brownsville, this species may be taken to be Mexican in origin.

8. *Urosigalphus schwarzi* Cwfd.[a] From 300 squares Mr. E. A. Schwarz and Mr. H. S. Barber bred 5 females and 1 male of this newly described species at Cacao, Finca Trece Aguas, Alta Vera Paz, Guatemala, during April, 1906.

9. *Bracon mellitor* Say was bred from all points, except Overton and Marshall in northeastern Texas. The form known as *Bracon xanthostigma* has only been bred from the weevil between September 16 and April 28 in the various years of this investigation. A specimen of this species is recorded on the Bureau of Entomology files (D. A. 6424 (412)) as bred from the boll weevil at Coahuila, Mexico, November 15, 1902, by Professor Herrera. Specimens were sent in by Professor Herrera from Allende, Coahuila, Mexico, during 1906, with the notes that they were quite common.

10. *Bracon dorsator* Say was not bred until October in 1906. It is only known to occur between August 2 and December 17 in Texas. It is probably another instance of seasonal dimorphism and identical with *Bracon mellitor*.

11. Braconid. One female of this species was bred September 1 from a cocoon in material collected on the ground at Victoria, Tex. The specimen was lost in transit.

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[a] Crawford, 1907a.

12. *Myiophasia ænea* Wied. Pupæ of this species within the larval skin of the weevil were taken from material collected at Many, La. (3 specimens), and Waco, Tex. (1 specimen); also one specimen in imperfect condition was found in a small boll collected at Victoria, Tex., July 12. Its puparium was within the skin of a weevil larva.

13. *Pediculoides ventricosus* Newp. is a common weevil parasite in Mexico.

14. Mites were frequently found to have destroyed the weevil stages in fallen squares, especially at Calvert, Tex.

Tyroglyphus breviceps Banks was described as a weevil enemy from Victoria, Tex.

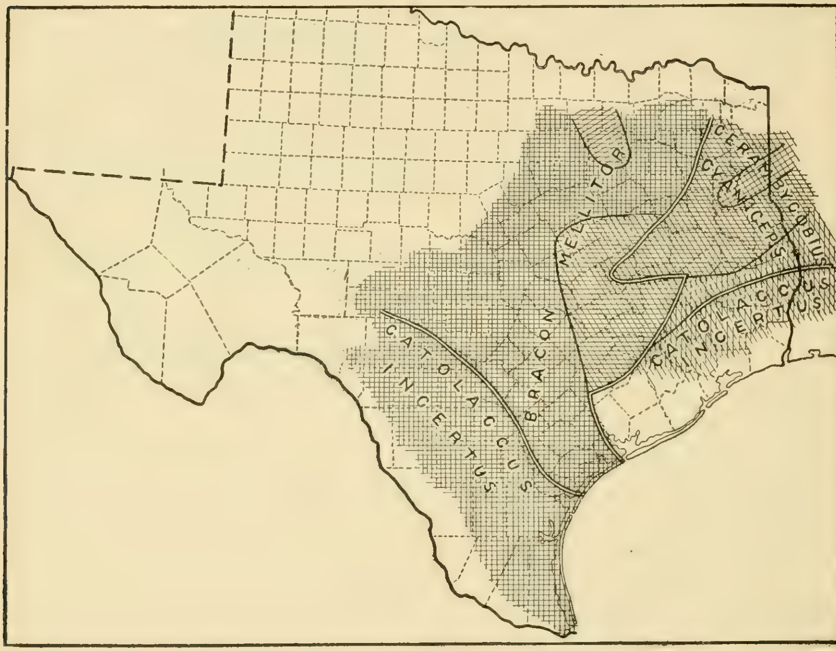


FIG. 6.—Occurrence of predominant parasites of the boll weevil in Texas and western Louisiana showing—
||| Occurrence of *Catolaccus incertus*. ≡ *Bracon mellitor*. \\\\ *Cerambycobius cyaniceps*. //// *Eurytoma tylodermatis*. // Limits of predominance of single species. / Limits of two predominant species. (Original.)

15. *Hydnocera pubescens* Lec. was found frequently to have killed weevil stages. Records of this predatory habit are from Brownsville and Waco, Tex., and Many, La. In a great many other cases evidence of its predatory nature was less reliable.

16. *Cathartus cassiæ* Reiche was found several times to be predaceous in its larval stage upon the weevil.

Catolaccus anthonomi Ashm., determined by J. C. Crawford. Four specimens practically identical in character with the type of this species were bred from cotton squares collected October 12, 1906, at

Waco, Tex. Although a large quantity of these squares were examined, no specimens of this species were obtained except from the general breeding cage. The species is known as a parasite of an æstivating weevil (*Anthonomus signatus* Say), and it is possible that in the fall the parasites may attack *Anthonomus grandis*.

GEOGRAPHICAL AND SEASONAL DISTRIBUTION OF PARASITES.

Only four of these parasites are at present of any great importance. In arranging the percentages of each species with regard to the total number of parasites the following table (Table XIX) has brought out sufficient data for the production of a map (fig. 6) which shows the area over which any two of them are predominant. Thus, over the entire western half of the area studied *Bracon mellitor* and *Catolaccus incertus* are the most active, while in the Northeast and East *Cerambycobius cyaniceps* shares the importance with the other three in more or less limited belts:

TABLE XIX.—*The seasonal distribution of the parasites.*

Locality.	Date.	Total number of parasites.	Bracon mellitor.		Catolaccus incertus.		Eurytoma tylodermatis.		Cerambycobius cyaniceps.	
			Number.	Percentage.	Number.	Percentage.	Number.	Percentage.	Number.	Percentage.
	1906.									
Beeville, Tex.	July 12	26	8	30.7	5	19.2	2	7.6	1	3.8
Do	August 8	2	2	100.0						
Do	August 13	2								
Do	September 3	6	6	100.0						
Brownsville, Tex.	July 5	43	38	88.3	5	11.7				
Do	July 28	119	39	32.7	77	64.7	3	2.6		
Do	August 3	2								
Do	September 5	155	50	32.2	85	54.8	1	0.6	2	1.2
Do	September 29	53	12	22.6	40	75.4				
Calvert, Tex.	August 28	13	3	23.0	3	23.0	1	7.6	4	30.7
Do	September 13	21	3	14.2					4	19.0
Corpus Christi, Tex.	July 10	39	9	23.0	12	30.7	1	2.5		
Corsicana, Tex.	August 23	19	9	47.3	4	21.0	1	5.2		
Do	September 18	2	1	50.0						
Cuero, Tex.	August 9	13	3	23.0	2	15.3			1	7.6
Do	August 31	87	45	51.7	25	28.7	6	6.8	4	4.5
Dallas, Tex.	August 29	1								
Do	September 12	21	6	28.5	4	19.0	3	14.2	1	4.7
Do	October 2	10	6	60.0			2	20.0		
Do	October 6	39	19	48.4	1	2.5	9	23.0		
Do	October 10	5	5	100.0						
Goliad, Tex.	August 7	7								
Do	September 3	108	73	67.5	22	20.3	3	2.7	2	1.8
Hallettsville, Tex.	August 9	15	3	20.0	3	20.0	2	13.3	1	6.6
Do	August 30	39	7	17.9	4	10.2	7	17.9	8	20.4
Junction, Tex.	September 24	12	10	83.3	2	16.7				
Kerrville, Tex.	August 26	6	3	50.0	2	33.3				
Do	September 3	5	2	40.0	1	20.0				
Mansfield, La.	August 24	47	5	10.6	2	4.2	1	2.1	36	76.5
Many, La.	August 23	109	6	5.5	12	11.0	8	7.3	45	41.2
Marshall, Tex.	August 22	8							6	75.0
Mineola, Tex.	August 10	1								
Do	October 2	9	4	44.4	4	44.4				
Orange, La.	September 30	5			4	80.0				
Overton, Tex.	August 23	7					1	14.2	2	28.4
Palestine, Tex.	August 10	70	12	17.1	10	14.2	6	8.5	7	10.0
Roosevelt, Tex.	September 24	10	5	50.0						
Sixteen miles south of Roosevelt, Tex.	September 25	2			1	50.0				
Taylor, Tex.	August 16	11	3	27.2			2	18.1		
Trinity, Tex.	August 9	69	12	17.3	9	13.0	7	10.1	12	17.3
Do	August 30	14	1	7.1	5	35.7			2	14.2

TABLE XIX.—*The seasonal distribution of the parasites*—Continued.

Locality.	Date.	Total number of parasites.	Bracon mellitor.		Catolaccus incertus.		Eurytoma tylodermatis.		Cerambycobius cyaniceps.	
			Number.	Percentage.	Number.	Percentage.	Number.	Percentage.	Number.	Percentage.
	1906.									
Victoria, Tex	June 16	15	......	......	......	......	......	......	......	......
Do	June 23	9	5	55.5	2	22.2	......	......	......	......
Do	June 25	11	2	18.0	6	54.5	......	......	......	......
Do	June 26	20	10	38.4	7	26.9	......	......	......	......
Do	June 27	33	15	45.4	8	24.2	1	3.0	......	......
Do	June 28	24	......	......	......	......	......	......	......	......
Do	July 2	24	......	......	......	......	......	......	......	......
Do	July 5	19	......	......	......	......	......	......	......	......
Do	July 9	13	3	23.0	......	......	......	......	......	......
Do	July 18	32	18	56.2	2	6.2	1	3.1	......	......
Do	July 22	5	3	60.0	......	......	......	......	......	......
Do	September 1	75	45	60.0	3	4.0	3	4.0	11	14.6
Waco, Tex	July 25	78	25	32.0	6	7.6	3	3.8	4	5.1
Do	August 17	5	1	20.0	1	20.0	1	20.0	......	......
Do	August 28	83	44	54.2	......	......	7	8.4	25	29.8
Do	August 29	114	64	56.1	11	9.6	3	2.6	12	10.5
Do	September 19	36	19	52.7	2	5.5	8	22.2	20	55.5
Do	October 12	31	......	......	......	......	......	......	......	......

These figures show very plainly the range of each species and have therefore been used to form a map of the two predominant species throughout the State. The centers of the areas predominated by Catolaccus are Brownsville, Tex., and Orange, La. The influence of Bracon radiates from Goliad and Corsicana, Tex. The center of predominance for Cerambycobius is Marshall, Tex. Eurytoma becomes an active agency at Dallas and Overton, Tex.

BIOLOGICAL NOTES ON THE PARASITES.

1. *Microdontomerus anthonomi* Cwfd. The Torymidæ have always been considered by Dr. William H. Ashmead as parasitic on Diptera. In addition to the records of parasitism upon the boll weevil, which are given on a preceding page, one other specimen was bred September 13, 1905, at Mexia, Tex., by F. C. Pratt from *Brachytarsus alternatus* Say, breeding in the stems of *Sideranthus rubiginosus*. The species is not at all abundant, and has only been collected in cotton forms between August 28 and September 3. It is perhaps a one-generation species, although it may have some other and still unknown host. There is but one individual to each host, and the host may be in the larval or pupal state when attacked. The sexes occurred in the proportion of 2 males and 11 females.

In order to ascertain the length of the developmental periods, the following scheme had to be used: The maximum period from collection to maturity is the nearest approach possible to the total developmental period, and next to this is the total period in a Bracon cocoon in case of hyperparasitism. The maximum period from the observation of the larva to maturity is the nearest approach possible to the total period passed as larva and pupa. The exact length of the pupal period may be defined as between the maximum period from observation of the pupa to maturity and the minimum period from observation of the larva to maturity. Thus it will appear from the following that the total developmental period is over twenty-three days, and the pupal stage lasts from six to nine days during August and September.

TABLE XX.—*Length of developmental periods in Microdontomerus anthonomi.*

Locality.	Date.	Collection to maturity	Larva to maturity.		Pupa to maturity	In Bracon cocoon to maturity.	Development.		
		Maximum.	Minimum.	Maximum.	Maximum.	Maximum.	Total.	Larva + pupa.	Pupa.
	1906.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
Cuero, Tex	August 31	14				9			
Goliad, Tex	September 3	23				19	23+		
Hallettsville, Tex	August 30	14	9	9	6				6
Waco, Tex	August 28, 29	10	9	9	5	6			
							23+	23	6–9

It was impossible with a lens to find any characters to distinguish the larvæ of this species from any of the other chalcidoids, as all of the chalcidoid larvæ concerned in this report are finely, transversely lineolate and clad with a few hairs regularly placed in a line around the middle of each segment. The pupa is nearest in appearance to that of Cerambycobius. The female pupa is robust, brown until almost mature, with no darker spots on the dorsal abdominal segments, but with three longitudinal white lines and a transverse white line on each segment; the ovipositor is appressed to the dorsum and proportionately longer than in Cerambycobius. The exuvium is easily recognized by the form of the ovipositor and its brown color. (See figure of pupa and of chalcidoid larva, Pl. I, figs. 4, 7.)

A most interesting point in the biology of this parasite is the fact that a number of individuals were bred from Bracon cocoons. This is one of those phenomena which are here designated as accidental secondary parasitism—that is, where a natural primary parasite finds its host consumed by another parasite and in order to retain its hold on life is compelled to attack that parasite itself.

The breeding records of the parasite are as follows:

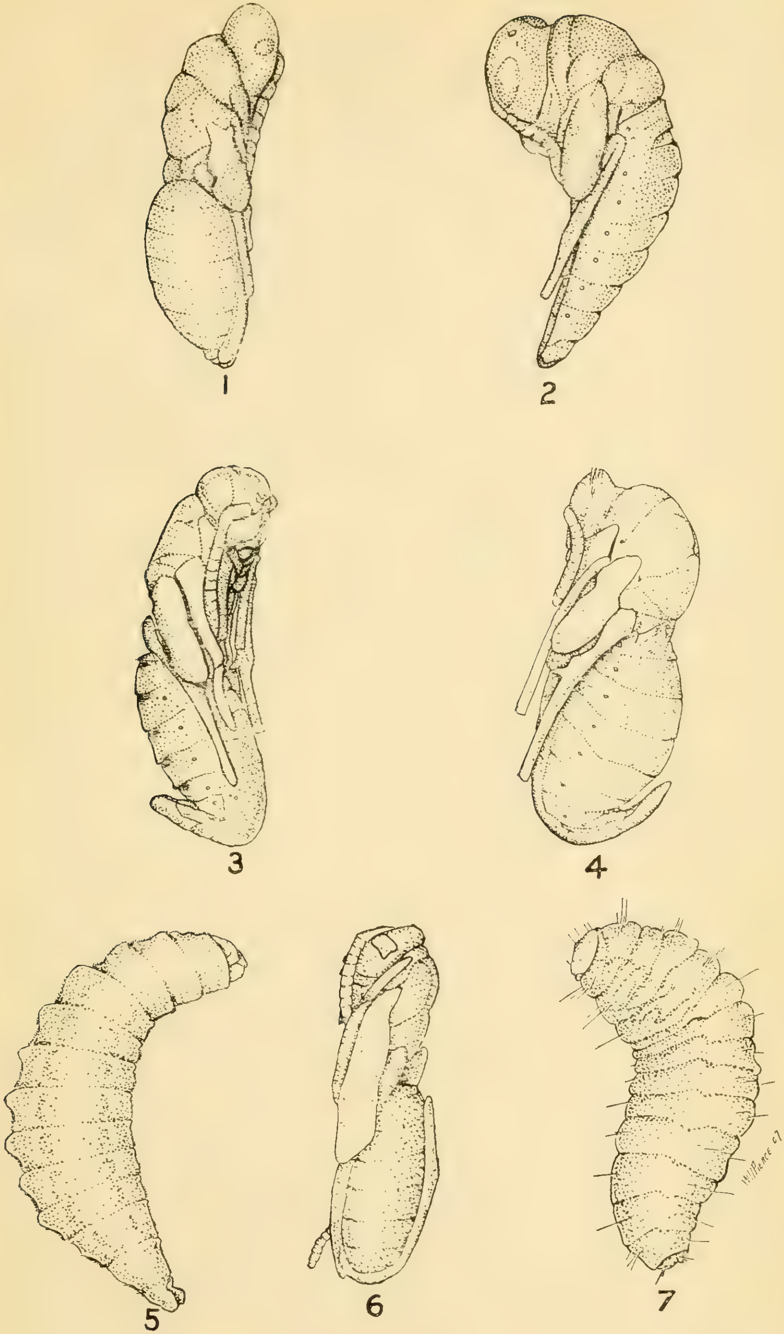
TABLE XXI.—*Breeding records of Microdontomerus anthonomi.*

Locality.	Date.	Total.		As primary parasites.		As secondary parasites.	
		Male.	Female.	Male.	Female.	Male.	Female.
	1906.						
Cuero, Tex	August 31		1				1
Goliad, Tex	September 3		1				1
Hallettsville, Tex	August 30		4		4		
Waco, Tex	August 28		2		2		
Do	August 29	2	3	1	3	1	
		2	11	1	9	1	2

Thirteen parasites were bred, of which 23 per cent were secondary. Owing to numerous expressions of incredulity concerning this dual parasitism it may be proper to state the proofs. In the first place, primary parasitism has been thoroughly established in the case of this species and also in the case of *Eurytoma tylodermatis* and *Cerambycobius cyaniceps.* Adults have been bred from larvæ which were actually observed to be feeding upon the weevil larvæ. The developmental period of those adults bred precludes any arguments that they were bred from unobserved eggs of parasites on the larvæ. In the second place, the Bracon and chalcidoid larvæ are very easily distinguished, so that the notes in most cases stated whether the larva observed was a Bracon or a chalcidoid. In no case was one of the latter bred from a Bracon except when the Bracon cocoon was already formed at the time of the observation. Finally, secondary parasitism was proved because the parasites were actually bred from isolated Bracon cocoons, which were subsequently opened and from which the known exuvia of the secondary parasites were removed.

2. *Eurytoma tylodermatis* Ashm. This species was bred by Townsend in 1895 and by Mally during several years from the boll weevil. Ashmead described it as a parasite of *Tyloderma foveolatum* Say (Ashmead, 1896), a weevil breeding in the stems of *Onagra biennis* and also in a species of Epilobium. It was reared by F. H. Chittenden from the larva of *Tyloderma foveolatum* Say in stems of *Onagra biennis,* September 23, from material collected at Rosslyn, Va.

This species was bred by the writer from *Anthonomus disjunctus* Lec. breeding in the heads of *Heterotheca subaxillaris* at Jacksonville, Tex., October 13, 1905 (1 male); from *Anthonomus squamosus* Lec., breeding in the heads of *Grindelia squarrosa nuda* at Clarendon, Tex., September 22, 1905 (6 females), and September 26, 1905 (2 males); from *Orthoris crotchii* Lec. breeding in the seed pods of *Mentzelia nuda* at Clarendon, Tex., October 2, 1905 (1 male); and from *Lixus musculus* Say, which forms galls in the stems of *Polygonum pennsylvanicum,* at Clarendon, Tex., October 2, 1905 (2 females), and October 17, 1905 (1 male). Mr. W. W. Yothers bred this Eurytoma from *Lixus*



PARASITES OF WEEVILS.

Fig. 1.—*Eurytoma tylodermatis*, pupa. Fig. 2.—*Catolaccus incertus*, pupa. Fig. 3.—*Cerambycobius cyaniceps*, pupa. Fig. 4.—*Microdontomerus anthonomi*, pupa. Fig. 5.—Larva of Bracon. Fig. 6.—*Bracon mellitor*, pupa. Fig. 7.—Larva of chalcidoid. Much enlarged. (Original.)

scrobicollis, which breeds in great abundance in the stems of the common road weeds *Ambrosia trifida* and *A. psilostachya*, at Victoria, Tex., April 5, 1905 (1 female). In a personal letter dated August 30, 1906, Dr. Wm. H. Ashmead writes of this species: "*Eurytoma tylodermatis* Ashm. is another similar case [referring to his remarks on Cerambycobius, given later]. I have had several species of Eurytoma bred by Hopkins, Marlatt, etc., from beetles, and I can only quote their records. The genus seems to be primary and secondary as well as phytophagous, unless we can find characters to still further subdivide it generically."

This parasite is quite abundant throughout the season and is a continuous breeder. The number of generations is probably little less than that of the weevil. There is but one individual to each host, and the latter may be in the larval or pupal state when attacked. The sexes are in the proportion of 29.1 per cent male and 70.9 per cent female. The females are very much larger than the males.

Proceeding in the same manner as for the preceding species it is ascertained that the total developmental period is over 12 to 15 days, that the larval plus pupal period is over 11 to 14 days, and that the pupal period alone is at the minimum 6 days and maximum 13 days. Judging from this last period, for which the figures are definite, it may be safely said that the estimates for the larval and egg periods are very low. The increase in the length of the pupal period in October is noticeable.

The data upon the biology of *Eurytoma tylodermatis* are comparatively continuous from July 18 to October 19. In studying the length of the various stages the same methods were used as outlined for Microdontomerus. The only stage which could be definitely limited as to the period of development was the pupal stage, which was found to last from 7 to 8 days in the latter half of July, 6 to 9 days during August, 7 to 9 days in September, and 11 to 13 days in October.

The larvæ of Eurytoma were described in the notes as smooth, transversely lineolate, and with wrinklings at the sutures. The pupæ are white, pink-eyed, turning black toward maturity. They may be easily distinguished, by the lateral compression of the abdomen and the straight venter, from the pupæ of Catolaccus with their dorso-ventral compression and obtusely angulated venter. The exuvium is cast in parts and is never found intact as in the case of the other chalcidoids studied; the remains are yellowish transparent. (See figure of pupa, Pl. I, fig. 1.)

Secondary parasitism: One male was bred from material collected August 9 at Trinity, Tex., and two males from material collected September 19 at Waco, Tex., as secondary parasites in the cocoons of *Bracon mellitor*. In each case the cocoon was isolated when first found, so that no doubt could be expressed as to the source of the parasites. Corroboration was obtained by examining the cocoons.

3. *Bruchophagus herreræ* Ashm. Considerable doubt has been raised by very eminent parasitologists as to the actual parasitism of the boll weevil by this species and some doubt has been raised concerning its generic location. No subsequent corroboration has been obtained to prove parasitism of the boll weevil.

4. *Cerambycobius cyaniceps* Ashm. The first published record of the parasitism of the boll weevil by this species is found in Mally's Report (Mally, 1902), in which that writer states that he had bred it since 1899 at Austin, Tex. Only four records were obtained in previous years by the boll-weevil laboratory of the Bureau of Entomology; 1 female bred July 7 at Calvert, Tex., by G. H. Harris; 1 male and 1 female bred July 25 at Victoria, Tex., by W. E. Hinds, and 1 female bred March 11 at Corsicana, Tex., by C. M. Walker.

Dr. F. H. Chittenden has reared it from the larva of *Tyloderma foveolatum* breeding in the stems of *Onagra biennis*, September 11, from material collected at Chevy Chase, Md. He has also reared it from *Bruchus exiguus* Horn (Chittenden, 1893b). In a personal letter dated August 30, 1906, Dr. Wm. H. Ashmead said of this species: "It is not rare, has been bred from cerambycids and other beetles, and I have always supposed it to be a primary parasite. All of these beetles, however, have braconid parasites, and it may yet prove to be a secondary parasite as other of the eupelmines are said to be."

One female was bred by the writer October 17, 1905, as a probable parasite of *Lixus musculus* Say, breeding in stem galls of *Polygonum pennsylvanicum* collected September 19 at Clarendon, Tex. On October 26, 1906, a female was bred from a *Lixus musculus* pupa collected in the same plant at Dallas, Tex., opposite the farm on which release experiments were conducted. On September 11 and 12, 1906, 2 females were bred from *Anthonomus albopilosus* breeding in seed of *Croton engelmanni* collected August 26, 1906, at Johnsons Bayou, La., by J. D. Mitchell. On October 30, 1906, 1 female was bred from *Trichobaris texana* found breeding in stalks of *Solanum rostratum* by R. A. Cushman and the writer, along the road close to the plat upon which parasites were released at Dallas.

This parasite is very abundant in eastern Texas, diminishing to the Southeast, and is entirely absent at Brownsville and through western Texas. It is a continuous breeder, attacking the weevil larvæ and pupæ, one individual for each host. The sexes are in the proportion 19.7 per cent males and 80.3 per cent females. The females are several times longer than the males.

The developmental periods for *Cerambycobius cyaniceps* have been worked out from data covering the period between July 12 and October 4. The pupal period in July is 10 days or less, in August is from

8 to 11 days, and in September from 9 to 12 days. During August it was ascertained that the entire developmental period exceeds 26 days.

The larvæ of Cerambycobius are described in the breeding notes as white, transversely lineolate, with a row of prominent hairs around the middle of each segment. The pupæ are elongate brown, with a short, obtuse, erect ovipositor, and with the dorsum of the abdomen marked with two dark spots on each segment. The brown exuvium is easily recognized from the ovipositor. The pupæ may be easily distinguished from those of Microdontomerus after a little practice. (See figure of pupa, Pl. I, fig. 3.)

Secondary parasitism: On September 14 a female Cerambycobius was bred from a larva which was found feeding on a Catolaccus pupa in material collected August 28 at Calvert. Although numerous cases of parasitism of *Bracon mellitor* were found, only 11.5 per cent of this species were secondary parasites. It was found as a secondary parasite on Bracon as follows:

Beeville, Tex., July 12, 1 female.
Corpus Christi, Tex., July 10, 1 female.
Cuero, Tex., August 31, 1 female.
Mansfield, La., August 24, 2 females.
Trinity, Tex., August 9, 1 male, 1 female.
Victoria, Tex., September 1, 1 female.
Waco, Tex., August 28, 3 males, 10 females.
Waco, Tex., September 19, 1 male, 2 females.

In one case the attack of the Bracon is known to have been prior to spinning.

5. *Catolaccus incertus* Ashm. This species has been one of the most important species mentioned in the literature of the boll weevil. It was described as a primary parasite of *Anthonomus signatus* (Chittenden, 1893a). It was reared by F. H. Chittenden from *Apion decoloratum* Sm. breeding in *Meibomia paniculata* at Washington, D. C., from *Apion griseum* Sm. breeding in *Phaseolus perennis* at Washington, D. C., and from *Bruchus exiguus* (Chittenden, 1893b).

Two females were bred by the writer October 16, 1905, from *Anthonomus disjunctus* breeding in the heads of *Heterotheca subaxillaris* collected at Jacksonville, Tex. From *Anthonomus eugenii* breeding in peppers at San Antonio, Tex., F. C. Pratt bred 3 females on October 18, 1905. From *Anthonomus albopilosus* breeding in the seed of *Croton engelmanni* at Johnsons Bayou, La., the writer bred 2 females on September 6, 1906, and from the same weevil breeding in *Croton capitatus* at Leesville, La., the writer bred 1 female on September 29, and subsequently 3 females and 3 males.

Catolaccus incertus is very common in all parts of the State and is well established as a boll weevil parasite. (See Plate III, *E*.) It is a continuous breeder, attacking the weevil larvæ and pupæ, one individual for each host. The developmental period seems to be considerably shorter than in either of the species preceding. The data upon which the following figures are based cover the period from June 25 to October 28. During June and July the total developmental period is known to be over 11 or 12 days, during August it is over 14 days, and during September and October over 18 days. The pupal period in June and July is only 4 to 6 days, in August 6 to 7 days, in September 5 to 9 days, but in October 13 to 15 days.

The larvæ of Catolaccus were described in the notes as having short hairs in a row on each segment. The pupæ are white to yellow, the thorax turning black first as they approach maturity. The abdomen is very flat below and bent at an obtuse angle to the thorax. The head is very broad, and the eyes are pink. The exuvium is yellowish and resembles a little pointed cap. (See figure of pupa, Pl. I, fig. 2.)

6. *Sigalphus curculionis* Fitch. No corroboration has been recorded of the parasitism of the boll weevil by this species. This parasite is very commonly bred from the plum curculio (*Conotrachelus nenuphar* Hbst.). Chittenden also records it as a primary parasite of *Trichobaris trinotata* Say, which breeds in the stems of *Solanum rostratum* (Chittenden, 1902).

7. *Urosigalphus anthonomi* Cwfd. This parasite was again bred September 20 from material collected September 5 at Brownsville. The period in the cocoon was at least 9 days. The cocoon with weevil larva's head attached was half in a cotton seed in a boll. It was very much finer meshed than that of *Bracon mellitor* and easily broken. In addition to this species and (8) *Urosigalphus schwarzi* Cwfd., both bred from *Anthonomus grandis*, *Urosigalphus armatus* Ashm. has been bred from Balaninus, and another species (*Urosigalphus bruchi* Cwfd.) from *Bruchus prosopis* Lec. taken at Harlingen, Tex., in beans of *Prosopis glandulosa*. Hence it is very probable that the species of this genus are normally weevil parasites.

9, 10. *Bracon mellitor* Say. *Bracon dorsator* Say. *Bracon xanthostigma* Cress.

These are all forms of a single very variable species, of which the entirely red form holds the name *B. mellitor*, that with black sternum and metathorax the name *B. xanthostigma*, and that with the thorax almost entirely black and the vertex of the head also black, being also smaller in size, has been known as *B. dorsator*.

A peculiar record is furnished by F. H. Chittenden who reared this species from the strawberry leaf-roller *Ancylis* (*Phoxopteris*) *comptana* Fröl., from material collected at Cabin John, Md., July 9, 1899.

In a personal letter dated August 30, 1906, Dr. Wm. H. Ashmead writes: "*Bracon mellitor* Say is undoubtedly a most important parasite, widely distributed in the United States, and must affect very many different beetles, although usually rhynchophorous beetles."

The typical form has been bred from *Anthonomus grandis* at all times and in all places between June 15 and October 4. The form *xanthostigma* has only been bred from the boll weevil between September 16 and April 28, while *dorsator* was bred August 2, 1903, at Victoria; November 20, 1895, at Goliad, and December 17, 1895, at Beeville. *B. mellitor* was bred June 19, 1905, at Dallas by W. W. Yothers from *Anthonomus fulvus* Lec., which breeds in the buds of *Callirrhoe involucrata*, and on June 14 he bred *dorsator* from the same weevil. On September 20, 1905, F. C. Pratt bred male and female *dorsator* and female *mellitor* from *Desmoris scapalis* Lec., breeding in the flower heads of *Sideranthus rubiginosus* at Mexia, Tex.; on September 23 he bred the typical form from the same weevil collected at Calvert, Tex.; on September 29 both the typical form and *dorsator* from Mexia material; and on October 27 he again bred the typical form from Mexia material. On September 30, 1905, the writer bred *mellitor* and *xanthostigma* from *Anthonomus squamosus* Lec., breeding in the heads of *Grindelia squarrosa nuda* at Clarendon, Tex.; on October 2, 4 of the typical form and 1 *xanthostigma* were bred; on October 3, 3 typical, and finally on October 16 a *xanthostigma*, were bred. On October 18 and 23 *dorsator* was bred by F. C. Pratt from *Anthonomus eugenii* Cano, breeding in peppers at San Antonio, Tex. On September 6, 1906, J. D. Mitchell bred a typical form from *Anthonomus albopilosus* Dietz, breeding in seed of *Croton capitatus* at Victoria, Tex.

The data upon the life-cycle of *Bracon mellitor* cover the period from June 25 to November 15. The entire developmental period covers at least 21 days in June and 33 in October, but probably considerably more. The period within the cocoon has been limited to between 5 and 6 days in June, to 7 days in July, 6 to 11 days in August, 3 to 7 days in September, and 15 to 27 days in October. The minimum of 3 days in September is based upon an observation of the spinning of the cocoon and the time of maturity, and the record of 5 days in June was obtained in the same manner.

The larvæ of Bracon can be immediately separated by the absence of hairs and by the body being punctate instead of lineolate. The pupæ are yellowish, loosely constructed, with the appendages very fragile and inclosed in a stout one-meshed silken cocoon, which varies from pure white to golden yellow or dark brown. In several cases where particular note was made of the brown color of the cocoon hyperparasites were bred, but this was not a constant indication. The species varied greatly in size, depending upon the amount of food available. (See figures of larva and pupa, Pl. I, figs. 5, 6.)

No dark forms of this species were bred until September 10, 1906, except a single *B. dorsator* which was bred from Cuero material collected August 31. The rest were all bred from material collected at Brownsville, September 29; Dallas, October 2, 6, 10; and Waco, October 12. The record of all Bracon bred after October 10 is as follows:

October	10,	*Bracon mellitor*,	3 males, 5 females.
	11,	Do.	1 male.
	12,	Do.	1 male.
	13,	Do.	1 female; *mellitor xanthostigma*, 2 females.
	15,	Do.	1 female.
	18,	*Bracon mellitor xanthostigma*,	3 females.
	20,	Do.	2 females.
	22,	*Bracon mellitor*,	3 females; *mellitor xanthostigma*, 2 females; *mellitor dorsator*, 2 males, 1 female.
	24,	*Bracon m. xanthostigma*,	1 female.
	25,	Do.	2 females; *m. dorsator*, 1 female.
	31,	Do.	2 females.
November	1,	Do.	3 females; *m. dorsator*, 1 male.
	5,	Do.	1 female.
	6,	*Bracon mellitor dorsator*,	1 female.
	14,	*Bracon mellitor xanthostigma*,	1 female.

11. An undetermined braconid of the size of *Bracon mellitor*, but with the base of the abdomen black and belonging to a different subfamily, was bred September 17 from a yellow cocoon in a fallen square collected at Victoria, Tex., September 1. Unfortunately this was lost in the mails.

12. *Myiophasia ænea* Wied. This species is recorded as a parasite of *Balaninus nasicus* Say, *Chalcodermus* sp., *Conotrachelus juglandis* Lec., and *Sphenophorus parvulus* Gyll. (Coquillett, 1897), and also of *Ampeloglypter sesostris* Lec. (Aldrich, 1905). One specimen was bred July 6 by the writer from a larva of *Conotrachelus affinis* Boh. found in a hickory nut collected June 8 at Logansport, La. As parasites of the boll weevil from fallen squares collected at Many, La., August 23, 1 male was bred September 5 and 1 female September 8, while 1 failed to mature. From a hanging square collected at Waco, Tex., August 29, a puparium was obtained but the fly not bred. From a small boll collected at Victoria, Tex., July 12, a deformed fly was bred.

Parasitism by this species can always be positively proved if the puparium is found, as it is inside of the stretched skin of the weevil larva. The affected larva is of a tawny parchment color and shows the projections of the appendages of the fly puparium.

The developmental period is undoubtedly in excess of 28 days, as shown by the first record above.

13. Several attempts have been made to introduce *Pediculoides ventricosus* Newp. into Texas as a parasite of the boll weevil, but

with no success. Much has been written upon this mite by Professor Herrera and his staff.

14. There are, however, native mites, including *Tyroglyphus breviceps* Banks (Banks, 1906, p. 17), which in some cases are a considerable factor in the destruction of the immature weevils. At Calvert, Tex., in moist fallen squares collected September 13, 11 out of 18 cases of parasitism were mites. *T. breviceps* was described from Victoria.

15. *Hydnocera pubescens* Lec. This clerid was found to be predaceous in its larval stage upon the boll weevil and all of its parasites. The egg is probably inserted into the cell of the weevil, and the young predator immediately starts its attack, consuming whatever it finds in the way of insects, and finally spins a loosely meshed, single-layer, silken cocoon, and pupates therein. From data of material collected at Waco, Tex., August 28, an approximation of the developmental periods was obtained. The longest period from collection to spinning was 34 days, the period in the cocoon was 12 days, the adult being formed 3 days before leaving the cocoon. In order to prove the predaceous habit live weevil pupæ were furnished individual clerid larvæ, and in most cases were completely consumed. In several cases large larvæ were found in Bracon cocoons which were punctured with holes large enough only for the very smallest of the larvæ.

16. In a number of cases, material collected at Victoria, Dallas, and Brownsville gave evidence of a predaceous attack upon weevil stages by *Cathartus cassiæ* Reiche.

IV. The Sources of the Parasites.

In the preceding sections it has been pointed out that the parasites of *Anthonomus grandis* are also common to various other species of weevils. There is a more or less clearly defined theory in parasitology that the parasites of a particular genus or tribe are confined to the insects of a particular family or order. With this idea in mind a list of the known parasites of the Rhynchophora has been compiled, in order to show the characteristic groups and the possible sources of boll-weevil parasites.

PARASITES KNOWN TO ATTACK RHYNCHOPHORA.

Parasite.	Host.
Fungi.	
Aspergillus sp	*Anthonomus grandis* Boh.
Cordyceps sp	*Anthonomus grandis* Boh.
Empusa (*Entomophthora*) *sphærosperma*	*Phytonomus punctatus* Fab.
Entomophthora phytonomi	*Phytonomus punctatus* Fab.
Sporotrichum globuliferum	*Epicærus imbricatus* Say.

Parasite.	Host.
Acarina.	
Tarsonemidæ.	
Pediculoides ventricosus Newp	*Anthonomus eugenii* Cano.
	Anthonomus grandis Boh.
Tyroglyphidæ.	
Tyroglyphus breviceps Banks	*Anthonomus grandis* Boh.
(?)	*Anthonomus eugenii* Cano.
Diptera.	
Dexiidæ.	
Metadexia basalis G. T	*Conotrachelus juglandis* Lec.
Tachinidæ.	
Myiophasia ænea Wied	*Ampeloglypter sesostris* Lec.
	Anthonomus grandis Boh.
	Balaninus nasicus Say.
	Chalcodermus æneus Boh.
	Conotrachelus affinis Boh.
	Conotrachelus juglandis Lec.
	Sphenophorus parvulus Gyll.
Myiophasia robusta Coq	*Sphenophorus robustus* Horn.
Hymenoptera.	
Proctotrypoidea.	
Platygasteridæ. Platygasterinæ.	
Trichacis rufipes Ashm	?*Balaninus nasicus* Say.
Chalcidoidea.	
Torymidæ. Monodontomerinæ.	
Microdontomerus anthonomi Cwfd	*Anthonomus grandis* Boh.
	Brachytarsus alternatus Say.
Eurytomidæ. Eurytomini.	
Eurytoma magdalidis Ashm	*Magdalis armicollis* Say.
Eurytoma tylodermatis Ashm	*Anthonomus disjunctus* Lec.
	Anthonomus grandis Boh.
	Anthonomus squamosus Lec.
	Apion segnipes.[a]
	Lixus musculus Say.
	Lixus scrobicollis Boh.
	Orthoris crotchii Lec.
	Tyloderma foveolatum Say.
Bruchophagus herreræ Ashm	*Anthonomus grandis* Boh.
Cleonymidæ. Cleonyminæ.	
Cheiropachys colon L	*Magdalis ænescens* Lec.
Encyrtidæ. Eupelminæ. Eupelmini.	
Cerambycobius cyaniceps Ashm	*Anthonomus grandis* Boh.
	Anthonomus albopilosus Dietz.
	Bruchus exiguus Horn.[a]
	Lixus musculus Say.
	Trichobaris texana Lec.
	Tyloderma foveolatum Say.[a]
Pteromalidæ. Pteromalinæ. Metaponini.	
Bruchobius laticollis Ashm	*Bruchus pisorum* L.
Pteromalidæ. Pteromalinæ. Rhaphitelini.	

[a] On the authority of F. H. Chittenden.

Parasite.	Host.
Chalcidoidea—Continued.	
Dinotus sp.	*Magdalis æenescens* Lec.
Pteromalidæ Pteromalinæ. Pteromalini.	
Catolaccus anthonomi Ashm.	*Anthonomus signatus* Say.
Catolaccus cœliodis Ashm.	*Acanthoscelis acephalus* Say.
Catolaccus incertus Ashm	*Anthonomus æneolus* Dietz.
	Anthonomus eugenii Cano.
	Anthonomus albopilosus Dietz.
	Anthonomus disjunctus Lec.
	Anthonomus fulvus Lec.
	Anthonomus grandis Boh.
	Anthonomus nigrinus Boh.
	Anthonomus signatus Say.
	Apion decoloratum Sm.[a]
	Apion griseum Sm.[a]
	Auletes tenuipes Lec.
	Bruchus exiguus Horn.[a]
	Zygobaris xanthoxyli Pierce.
Neocatolaccus tylodermæ Ashm.	*Lixus parcus* Lec.
	Lixus musculus Say.
	Tyloderma foveolatum Say.
Pteromalidæ. Spalangiinæ.	
Cerocephala pityophthori Ashm	*Pityophthorus consimilis* Lec.
Cerocephala scolytivora Ashm.	A scolytid.
Eulophidæ. Entedoninæ. Omphalini.	
Omphale livida Ashm.	*Ceutorhynchus rapæ* Gyll.
Eulophidæ. Entedoninæ. Entedonini.	
Asecodes albitarsis Ashm.	*Magdalis æenescens* Lec.
Entedon lithocolletidis Ashm	*Anthonomus nigrinus* Boh.
Eulophidæ. Tetrastichinæ. Tetrastichini.	
Tetrastichus sp	*Orthoris crotchii* Lec.
Mymaridæ. Mymarinæ. Anaphini (egg parasites).	
Anaphes conotracheli Girault	*Conotrachelus nenuphar* Hbst.
Ichneumonoidea.	
Ichneumonidæ. Ophioninæ. Porizonini.	
Porizon conotracheli Riley	*Conotrachelus nenuphar* Herbst.
Braconidæ. Blacinæ. Calyptini.	
Calyptus tibiator Cress.	*Anthonomus signatus* Say.
Braconidæ. Sigalphinæ.	
Sigalphus canadensis Prov.	*Anthonomus scutellatus* Gyll.
Sigalphus copturi Riley ms.	*Podapion gallicola* Riley.[b]
	Cylindrocopturus longulus Lec.[b]
	Conotrachelus posticatus Boh.

[a] On the authority of F. H. Chittenden. [b] Breed together.

Parasite.	Host.
Ichneumonoidea—Continued.	
Sigalphus curculionis Fitch	*Anthonomus grandis* Boh.
	Conotrachelus juglandis? in nuts.
	Conotrachelus nenuphar Hbst.
	Trichobaris trinotata Say.
Sigalphus sp	*Chalcodermus æneus* Boh.
Sigalphus zygobaridis Cwfd	*Zygobaris xanthoxyli* Pierce.
Urosigalphus anthonomi Cwfd	*Anthonomus grandis* Boh. (Texas).
Urosigalphus armatus Ashm	*Balaninus* spp., *Conotrachelus* spp.
Urosigalphus bruchi Cwfd	*Bruchus prosopis* Lec.
Urosigalphus schwarzi Cwfd	*Anthonomus grandis* Boh. (Guatemala).
Braconidæ. Cheloninæ.	
Phanerotoma tibialis Hald	*Anthonomus nigrinus* Boh.
Braconidæ. Agathidinæ. Microdini.	
Microdus simillimus Cress	*Lixus scrobicollis* Boh.
Braconidæ. Braconinæ. Braconini.	
Glyptomorpha lixi Ashm	*Lixus scrobicollis* Boh.
Glyptomorpha mavaritus Cress	*Lixus scrobicollis* Boh.
Glyptomorpha novitus Cress	*Lixus musculus* Say.
Glyptomorpha rugator Say	*Lixus concavus* Say.
	Lixus musculus Say.
Vipio belfragei Cress	*Lixus scrobicollis* Boh.
Melanobracon simplex Cress	*Dendroctonus piceæperda* Hopk.
Microbracon nuperus Cress	*Orthoris crotchii* Lec.
Bracon analcidis Ashm	*Tyloderma fragariæ* Riley.
Bracon anthonomi Ashm	*Anthonomus signatus* Say.
Bracon mellitor Say	*Anthonomus eugenii* Cano.
	Anthonomus albopilosus Dietz.
	Anthonomus fulvus Lec.
	Anthonomus grandis Boh.
	Anthonomus squamosus Lec.
	Desmoris scapalis Lec.
Bracon pissodis Ashm	*Pissodes strobi* Peck.
Bracon rhyssemati Ashm. ms	*Rhyssematus lineaticollis* Say.
Bracon smicronygis Ashm. ms	*Smicronyx tychoides* Lec.
Bracon sp	*Tomicus pini* Say.
Bracon sp	*Brachytarsus limbatus* Say.
Bracon sp	*Baris* sp.
Braconidæ. Rhogadinæ. Rhyssalini.	
Rhyssalus pityophthori Ashm	*Pityophthorus* sp.
Braconidæ. Spathiinæ. Spathiini.	
Spathius canadensis Ashm	*Dryocœtes autographus* Ratz.
	(?) *Magdalis olyra*.
	Phlœosinus graniger Chap.
	Tomicus sp.

BIOLOGIES OF THE WEEVILS CONTRIBUTING PARASITES.

It is of considerable importance in framing means of combating the boll weevil with parasites that the weevils usually found in the vicinity of cotton fields should be thoroughly known. In order that the conclusions in this regard may be more thoroughly understood, this subject must be introduced by a series of brief biologies of all the weevil species which have contributed parasites to the attack of the boll weevil.

CURCULIONIDÆ. APIONINÆ.

1. *Apion decoloratum* Sm. breeds in *Meibomia paniculata.* It is parasitized at Washington, D. C., by *Catolaccus incertus.*

2. *Apion griseum* Sm. breeds in *Phaseolus perennis,* and is parasitized by the same species as the preceding.

CURCULIONINÆ. CLEONINI.

3. *Lixus musculus* Say makes a gall in the stems of *Polygonum pennsylvanicum.* The larvæ and pupæ are found in these galls. The weevil and its host plant are typical of the fall, the plant being found in low moist ground, frequently in close proximity to cotton fields. The weevil is attacked by two of the important boll-weevil parasites.

4. *Lixus scrobicollis* Say dwells in the stems of *Ambrosia trifida* and *psilostachya,* two of the commonest roadside and waste-place weeds throughout the country in summer and fall. The entire stem is riddled by the weevil larvæ, which pupate in cells of frass at the end of their burrows. *Eurytoma tylodermatis* and other parasites not concerned in the discussion have been bred from this weevil.

ERIRHININI.

5. *Desmoris scapalis* Lec. breeds in the seed heads of *Sideranthus rubiginosus,* a summer weed, which is very abundant in some localities along roadsides and on prairies. The larvæ are expelled with the seed and enter the ground for pupation, maturing in the following spring. This species is parasitized by *Bracon mellitor,* which has a much more rapid development than its host. (See Pl. III, *B, D, F, G.*)

ANTHONOMINI.

6. *Anthonomus* (*Anthonomorphus*) *fulvus* Lec. breeds in the buds of *Callirrhoe involucrata,* an early spring mallow, which is common in May and June on moist meadows. The larvæ feed upon the floral column of the bud or the imperfectly opened flower and pupate in a cell of excreta in the capsule or fallen corolla. *Bracon mellitor* and *Catolaccus incertus* have been bred from it. (See Pl. II.)

7. *Anthonomus signatus* Say, the strawberry weevil, breeds in a number of rosaceous plants, such as strawberry, blackberry, raspberry, and wild rose, as also in red-bud. It is an early spring weevil, ovipositing in the buds, which soon drop to the ground, where the larva transforms to the pupa stage. It is parasitized by *Catolaccus incertus.*

8. *Anthonomus nigrinus* Say is an eastern weevil which breeds in the buds of *Solanum carolinense* and various other solanaceous plants, occurring principally in the spring and early summer, but not confined to one generation. It oviposits in the buds, causing them to fall. The larva makes its cell in the center of the bud through the pistil and all of the stamens and pupates in this cell. It is a host of *Catolaccus incertus*.

9. *Anthonomus albopilosus* Dietz is a fall species which breeds in the seed of *Croton capitatus* and *C. engelmanni*, weeds which are very abundant in pastures. The larvæ eat out one seed and then enter a second and form their pupal cell in this. The weevil serves as a host to *Cerambycobius cyaniceps*, *Catolaccus incertus*, and *Bracon mellitor*.

10. *Anthonomus æneolus* Dietz is a spring species which breeds in the buds of *Solanum torreyi*, *S. rostratum*, and *S. eleagnifolium*. The larvæ feed within one or two anthers, in the latter case forming a cell which cements the two together. In many cases the flower does not fall, and is able to fruit. The weevil is a host of *Catolaccus incertus*.

11. *Anthonomus eugenii* Cano (*æneotinctus* Champ.), the pepper weevil, is a recent introduction from Mexico. It is a fall species, which breeds in the interior of the cultivated peppers. (See Plate III; *A*, *C*.) It is a host to *Catolaccus incertus*, *Bracon mellitor*, and *Pediculoides ventricosus*, as determined by Professor Herrera. *Anthonomus mexicanus* Boh., another pepper weevil, is very likely identical.

12. *Anthonomus squamosus* Lec. breeds in the heads of *Grindelia squarrosa*, a fall plains plant, which is very abundant in semiarid Texas. The weevil larva makes a cell among the seed, which is formed of the hardened gum of the flower and excreta. It has probably only one generation. It is very highly parasitized and principally by *Bracon mellitor* and *Eurytoma tylodermatis*.

13. *Anthonomus disjunctus* Lec. breeds in the heads of *Heterotheca subaxillaris*, a fall plant, which is very abundant along roads, waste places, and on meadows. The weevil larva makes a small cell, formed of the hardened gum and excreta of the weevil, among the seed. There is but one generation. *Eurytoma tylodermatis* and *Catolaccus incertus* have both been bred from this weevil.

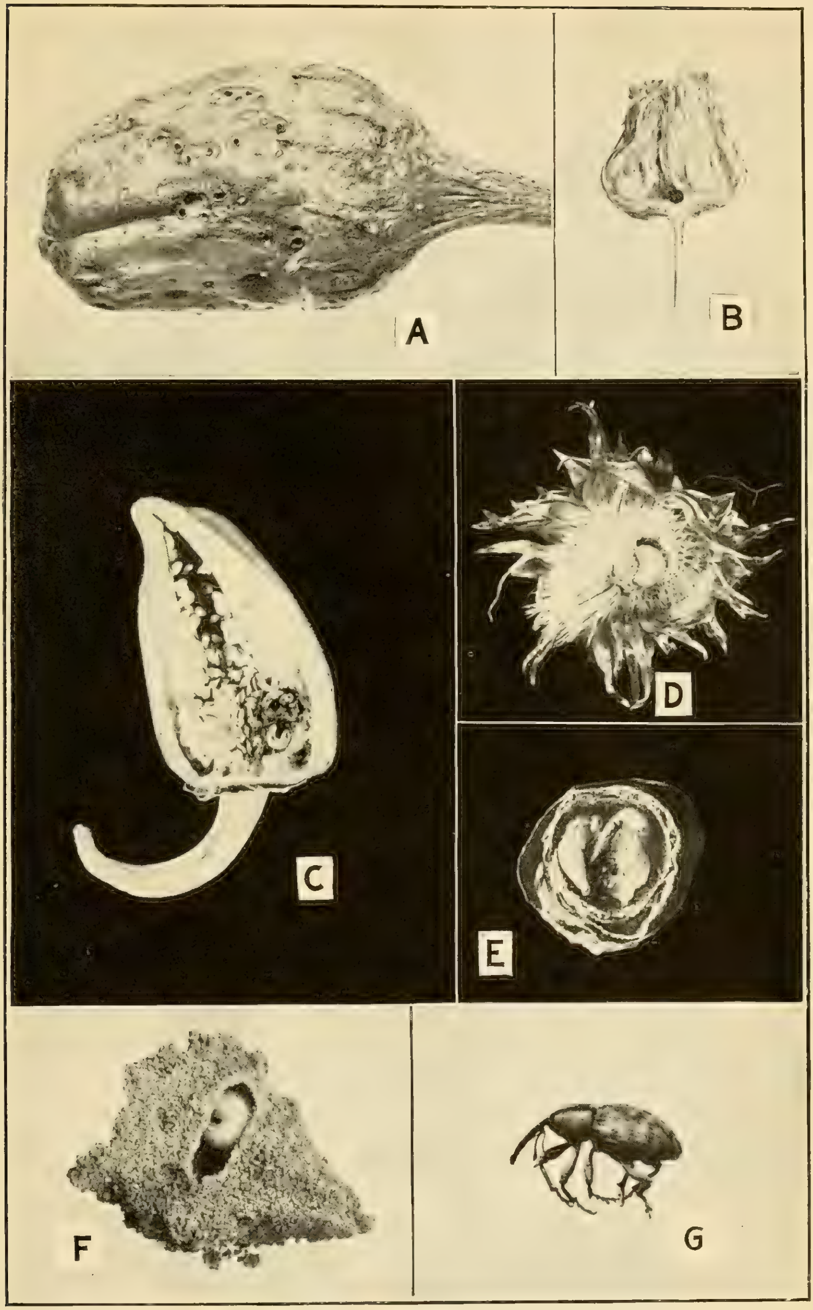
CRYPTORHYNCHINI.

14. *Conotrachelus affinis* Boh., the hickory nut weevil, has been found to be the host of *Myiophasia ænea*. It is an early summer weevil. Pupation is in the ground.

15. *Conotrachelus nenuphar* Herbst, the plum and peach curculio, breeds in the fleshy part of the fruit and pupates in the ground. It is the host of *Sigalphus curculionis*, which has once been bred from *Anthonomus grandis*.

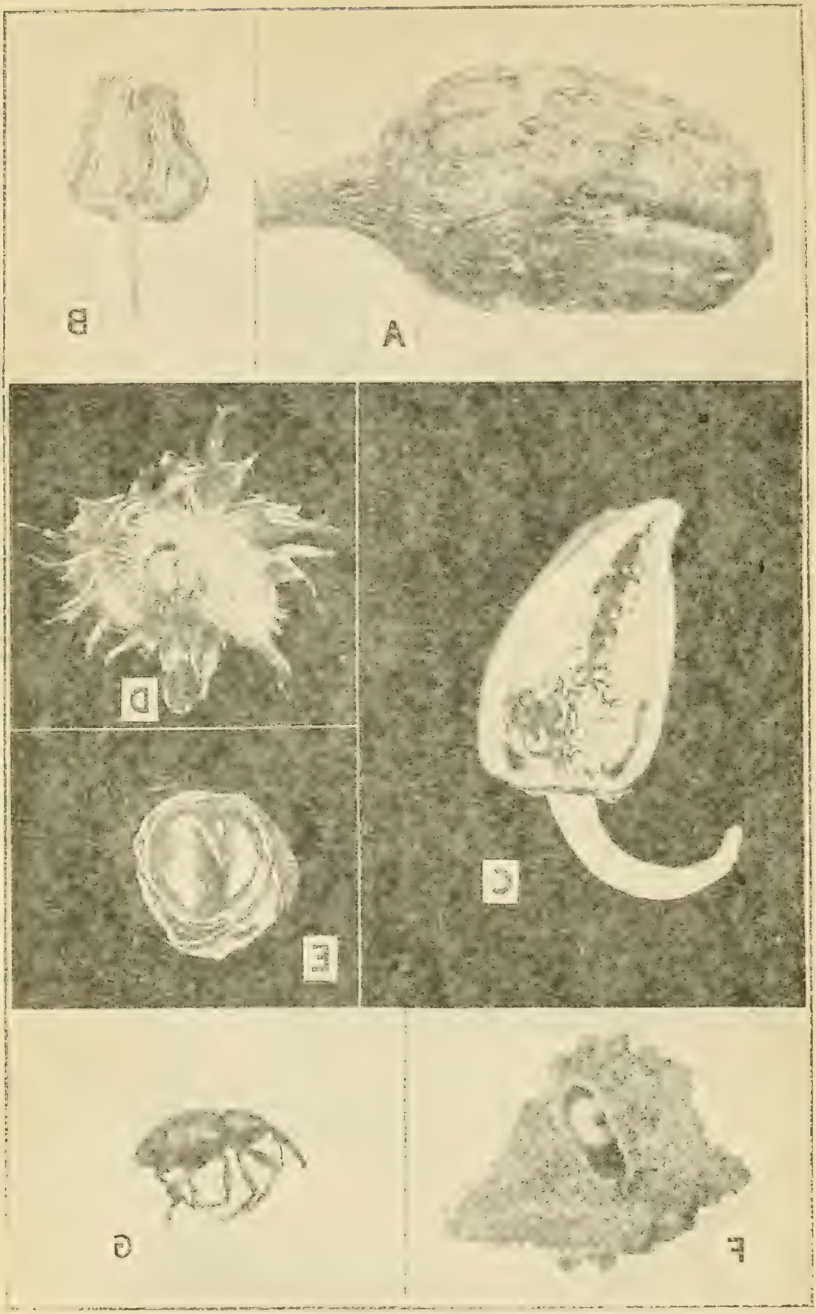
THE PURPLE MALLOW (CALLIRHOE INVOLUCRATA), A FOOD PLANT OF TWO WEEVILS RELATED TO THE BOLL WEEVIL.

Fig. A.—The buds and flowers, which are subject to attack by *Anthonomus fulvus*, and the capsule, subject to attack of *Macrorhoptus estriatus*. Fig. B.—Bud infested by *Anthonomus fulvus*. Fig. C.—Flower injured by adult weevil of *Anthonomus fulvus*. (Original.)



BIOLOGIES OF WEEVILS.

Fig. A.—Pepper, showing egg punctures of *Anthonomus eugenii*. Fig. B.—Head of *Sideranthus rubiginosus*, showing cell of *Desmoris scapalis*. Fig. C.—Pepper, showing larva of *Anthonomus eugenii* in situ. Fig. D.—Head of *Sideranthus rubiginosus*, with larva of *Desmoris scapalis* in its cell. Fig. E.—Section of cotton square, showing pupa of *Anthonomus grandis* and pupa of primary parasite *Catolaccus incertus*. Fig F.—Earthen cell of larva of *Desmoris scapalis*. Fig. G.—*Desmoris scapalis*, adult weevil. (Original.)



BIOLOGIES OF WEEVILS.

Fig. A.—Pepper, showing egg punctures of *Anthonomus eugenii*. Fig. B.—Head of *Sideranthus rubiginosus*, showing cell of *Desmoris scapalis*. Fig. C.—Pepper, showing larva of *Anthonomus eugenii* in situ. Fig. D.—Head of *Sideranthus rubiginosus* with larva of *Desmoris scapalis* in its cell. Fig. E.—Section of cotton square, showing pupa of *Anthonomus grandis* and pupa of primary parasite *Catolaccus incertus*. Fig. F.—Earthen cell of larva of *Desmoris scapalis*. Fig. G.—*Desmoris scapalis*, adult. (Original.)

16. *Chalcodermus æneus* Boh. is the cowpea-pod weevil, although it has once been bred from a cotton square. It is recorded as a host of *Myiophasia ænea.*

17. *Tyloderma foveolatum* Say breeds in the stems of *Onagra biennis,* an early summer evening primrose. Pupation takes place in the larval burrow. It is parasitized by *Eurytoma tylodermatis* and *Cerambycobius cyaniceps.*

CEUTORHYNCHINI.

18. *Auletes tenuipes* Lec. This species was found to breed in the buds of *Galpinsia hartwegi* at Dallas in the spring. The larvæ feed within a single anther in the bud, leaving it when the flower opens and entering the ground for pupation. The entire life cycle does not exceed 25 days, of which 11 days only is spent in the bud. *Catolaccus incertus* has been bred as a parasite.

BARINI.

19. *Orthoris crotchii* Lec. is a very abundant fall weevil in western Texas, breeding in the seed pods of *Mentzelia nuda,* a plains plant. Pupation is in a cell formed within several seeds. The species is highly parasitized by several species, the least of which, however, is *Eurytoma tylodermatis.*

20. *Trichobaris texana* Lec. is a stalk weevil, breeding in the stems of *Solanum rostratum,* a plant common in waste places in the summer and fall. The weevil cells are not more than an inch apart throughout the stem. *Cerambycobius cyaniceps* has been bred as a parasite.

21. *Trichobaris trinotata* Say, the potato stalk weevil, is another host of *Sigalphus curculionis.*

22. *Ampeloglypter sesostris* Lec. is a grapevine weevil, and a host of *Myiophasia ænea.* It is not recorded from Texas.

23. *Zygobaris xanthoxyli* Pierce. This new species breeds in the berries of Xanthoxylum at Runge and Beeville, Tex., in the spring. The larvæ feed in the interior of the seed until the seed is thrown to the ground. They then enter the soil and pupate in a tiny earthen cell, being in the ground about a month. *Catolaccus incertus* has been bred as a parasite.

ANTHRIBIDÆ.

24. *Brachytarsus alternatus* Say breeds in the stems of *Sideranthus rubiginosus.* It is a constant breeder, entirely riddling the stems. Microdontomerus has been bred from it.

BRUCHIDÆ.

Although not considered Rhynchophora by American writers, it is very probable that the Bruchidæ are a connecting link between the Anthribidæ and Chrysomelidæ.

25. *Bruchus exiguus* Horn breeds in the seed pods of *Amorpha fruticosa* in the fall. It is a host of *Cerambycobius cyaniceps* and *Catolaccus incertus*.

It is noticeable from the foregoing that *Bracon mellitor* attacks bud, flower, pod, and seed weevils; *Catolaccus incertus* attacks bud, pod, and seed weevils; *Cerambycobius cyaniceps* attacks bud, pod, and seed, but mainly stem weevils; *Eurytoma tylodermatis* attacks bud, flower, pod, and stem weevils; *Microdontomerus anthonomi* attacks bud, capsule, and stem weevils; *Myiophasia ænea* attacks bud, fruit, pod, nut, and stem weevils, and *Sigalphus curculionis* attacks bud, fruit, pod, and stem weevils. Such general habits indicate a generalization of habit in the species concerned and give promise of the possibility of more extensive adaptation to the boll weevil as a host.

ROTATION OF HOSTS.

The most important item in the solution of the parasite question is probably concerned with the treatment of the other hosts. It is found that the parasites which now attack the weevil are naturally parasitic on weevils of short season and few generations, and the most feasible proposition is that of forcing them to attack the boll weevil only.

Two lines of action are suggested as possible and practicable. The first is, that such plants as the Crotons, hosts of *Anthonomus albopilosus*, might be planted in abundance in the pastures because they make good feed and are easily destroyed, and that thus the weevils and their parasites would increase in great numbers and the latter might perhaps attack the boll weevil.

The counter proposal is that the timely elimination of the summer series of host plants would cut off the possibility of finding any host but the boll weevil, which would be in abundance. The cutting of the weeds around the fields could not result disadvantageously, as there are numerous pests harbored by these same weeds. At present the information as to the rotation of hosts is incomplete, and it is therefore necessary to go very fully into this question as well as to test both methods which have been suggested.

The known hosts of *Bracon mellitor* would insure it an uninterrupted rotation if they all occurred in a given locality. They do not, so there are still other unfound hosts of this species. The season of its hosts as far as known are as follows:

Anthonomus fulvus breeds from May 3 to July 12.
Desmoris scapalis breeds from July 25 to September 22.
Anthonomus squamosus breeds from August 11 to September 19.
Anthonomus albopilosus breeds from August 26 to September 29.
Anthonomus eugenii breeds from October 6 to October 31.

Important gaps exist in the host rotation of *Catolaccus incertus*. Its hosts breed as follows:

Anthonomus signatus breeds from April 11 to June 12.
Anthonomus fulvus breeds from May 3 to July 12.
Auletes tenuipes breeds from May 9 to May 25.
Zygobaris xanthoxyli breeds from May 11 to June 29.
Anthonomus æneolus breeds from May 17 to July 12.
Anthonomus nigrinus breeds from June 30 to July 18.
Anthonomus albopilosus breeds from August 26 to September 29.
Anthonomus eugenii breeds from October 6 to October 31.
Anthonomus disjunctus was found breeding October 11 to 14.

The known habits of the hosts of *Cerambycobius cyaniceps* are as follows:

Tyloderma foveolatum breeds from June 22 to September 23.
Trichobaris texana breeds from June 26 to October 11.
Lixus musculus breeds from August 11 to September 19.
Anthonomus albopilosus breeds from August 26 to September 29.

The following data comprise all that is known of the hosts of *Eurytoma tylodermatis:*

Tyloderma foveolatum breeds from June 22 to September 23.
Lixus scrobicollis breeds from July 12 to April 17 (following year).
Anthonomus squamosus breeds from August 11 to September 19.
Orthoris crotchii breeds from August 11 to September 19.
Lixus musculus breeds from August 11 to September 19.
Anthonomus disjunctus was found breeding October 11 to 14.

In the field at Dallas upon which release experiments were conducted, and in a series of five fields in various directions from Waco, it was found that the various species of parasites were exceedingly localized, indicating that the parasites were derived from the immediate vicinity.

On the Dallas field, by reference to the tables given in Section II, it will be noticed that Plat B with one small exception was the only plat in which Catolaccus was found; that Plat B was the only one from which Cerambycobius was bred; that Eurytoma was not found in Plat C, but was predominant on Plat E; and, finally, that Bracon was well distributed.

At Waco on all five fields *Bracon mellitor* was present in the proportion of 20 to 50 per cent. On the prairie land field, surrounded only by Ambrosia, Helianthus, and Xanthium, 41.6 per cent of the parasites were *Eurytoma tylodermatis*. On the other fields, which were on the bottoms, only one Eurytoma was taken to a field. *Catolaccus incertus* was present on the prairie land field and one bottom land field. Cerambycobius was present in all the bottom lands and very numerous, 58.3 per cent, in a field which had considerable *Solanum rostratum* about it; it was entirely absent on the prairie. The commonest plants on the bottoms were *Heterotheca subaxillaris*, *Croton* spp., *Solanum* spp., and Xanthium.

V. Conclusions and Prospects.

In conclusion the writer would say that there are a number of very important points obtained which indicate a possible natural control of the boll weevil. The actual combinations of conditions which bring about the instances of high parasitism can not be understood. It is very evident that the elements in the combination are relative moisture and light, plant response to weevil injury, abundance of other species of weevils in the immediate vicinity, and, finally, the ability for rapid adjustment to new host relations possessed by the local parasites.

Very high parasitism has been found, and it may therefore be expected again, perhaps locally, perhaps regionally. It may not necessarily be expected two years in succession at the same place, for a change in cultivation, an eradication of certain surrounding plants, or various other conditions might destroy the advantages previously gained. On the other hand, these same agencies in another locality might attain the opposite result.

Release of parasites in the open field on a small scale has been found to increase the rate of parasitization. This will be tried on a more extensive and better planned outline another year.

The abundance of hosts which have parasites in common with the weevil and the fact that parasitization takes place in the first generation give promise that the weevil's advance may be constantly disputed by the parasites.

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