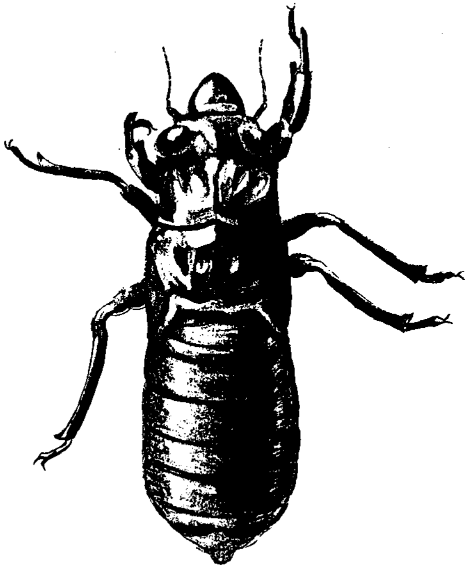

THE FULL-GROWN YOUNG CICADA, THE MATURE PUPA, AS IT EMERGES FROM THE GROUND.

(Twice natural size.)

THE SEVENTEEN-YEAR LOCUST.

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Office of Deciduous Fruit Insect Investigations, Bureau of Entomology.

[With 5 plates.]

UNDERGROUND LIFE.

Most of our familiar insects are regulated in their changes by the seasons of a single year. Hence we marvel at the 17-year life of the periodical cicada, the insect generally known as the 17-year locust. Yet there are common insects that normally take two or three years to reach maturity, and certain beetles have been known to live for 20 years or more in the larval stage, though under conditions adverse for transforming to the adult form.

Still there is something about the cicada that stirs our imagination as no other insect does. For nearly 17 years it silently toils in dreary tunnels underground. Then a springtime comes when countless thousands of the creatures issue from the earth, undergo their startling transformations and swarm into the trees. Now the very air seems swayed with the monotonous rhythm of their song, while the business of mating and egg laying goes rapidly on till the twigs of trees and shrubs are everywhere scarred with slits and punctures where the eggs are placed. In a few weeks the swarm is gone, and we may not live to see their progeny return.

Different insects undergo various degrees of change as they progress from youth to maturity. Some, like the grasshoppers, change comparatively little; others, such as the moths and butterflies, go through three utterly dissimilar forms. The cicada is intermediate between these extremes. Its young is a tough-skinned creature (pl. 1) having the front feet specially formed for digging, but otherwise, aside from lacking wings and external organs for reproduction and egg laying, it is not radically different from its parents. It feeds, by means of a piercing and sucking beak, on the sap of the roots amongst which it burrows, in the same manner as the adult feeds on the sap in the twigs and branches of the trees amongst which it spends its life.

Of the underground life of the young cicada we still know very little. The fullest account of its history is that given by Dr. C. L.

Marlatt in his report, "The Periodical Cicada," Bulletin 71, United States Bureau of Entomology, published in 1907. Doctor Marlatt describes six immature stages between the egg and the adult, the first four of which are distinguished as larval stages and the last two as pupal. But this does not mean that the "pupa" of the cicada is a resting stage like that of the moth or butterfly. The cicada pupa (pl. 1) is an active creature like the larva (fig. 9), differing principally in having short wing pads. The first pupal stage begins in about the twelfth year of the insect's life.

In the spring of their seventeenth year the cicadas burrow upward through the soil till they come to within a few inches of the surface. Recorded observations indicate that this migration takes place during the month of April. We know that the insects leave the earth during the latter part of May, so it seems that they must gather just below the surface and there await for several weeks the proper time for their emergence. Then, all of a sudden, as if at a given signal, the mass of them issues in swarms every evening for several days, and the ground is perforated with their exit holes.

It is with a feeling akin to awe that we witness for the first time vast numbers of these insects issuing from the earth. Then we realize that they have all been quietly living beneath our feet these many years where we gave no thought to them. Each exit hole now becomes a dividing point for us between knowledge and ignorance—the history of the insects after reaching the surface is so easy to read, that before so difficult. What secrets have they left behind in those narrow tunnels?

The original notes on which this paper is based were made during the season of 1919 at Somerset, Maryland, where, through the courtesy of Dr. E. F. Phillips, the writer had use of a room in the house of the Office of Apiculture, United States Bureau of Entomology. Dr. Phillips also entered into a part of the work, especially that of studying the burrows, and the emergence and transformation.

One evening it occurred to us that something might be learned simply by pouring a water solution of plaster of Paris into the burrows. Accordingly, we filled a few at first, but many swallowed up so much of the liquid that we became hopeful of a real discovery and eventually filled a score or so and allowed the plaster to set over night. The drawings on figure 1 show a part of the results revealed on the next and several subsequent days as we unearthed the hardened casts. Each represents the outline of a subterranean chamber in which the pupa had been concealed, waiting the proper time for its emergence. The longest chamber reached to a depth of 6 inches, the shortest are mere cups. All have a more or less distinct enlargement at the bottom, and most of them a swelling at the top just beneath the narrow neck, which represents the emergence hole. In all

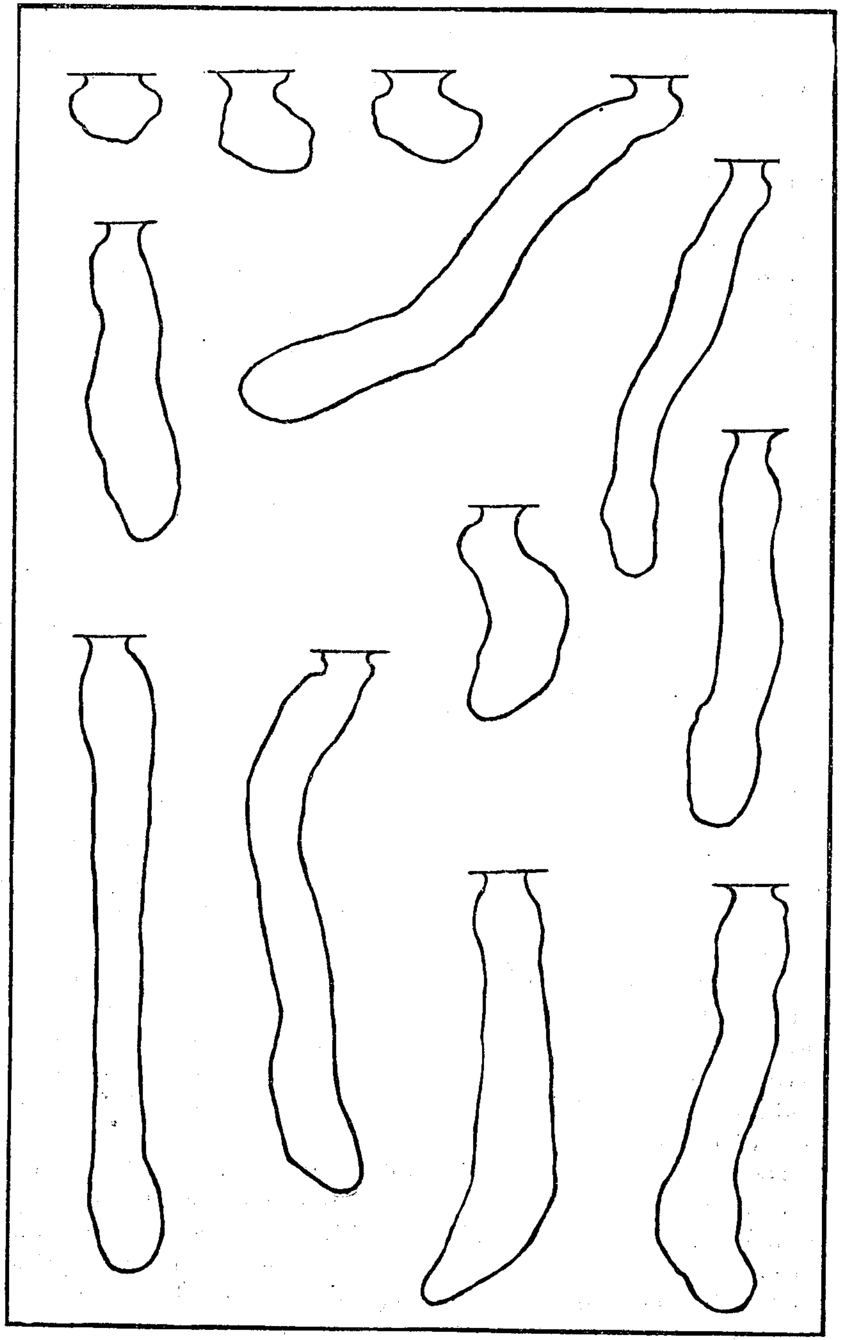


FIG. 1.—Outline of plaster casts from cicada pupal chambers in the ground (about one-half natural size).

but one the shaft has a diameter of about five-eighths of an inch, while that of the basal enlargement is seven-eighths of an inch. The neck averages about half an inch across. One cast is smaller, having the neck three-eighths of an inch in diameter, the shaft one-half, the lower swelling eleven-sixteenths. The individual that made this tube was most probably a pupa of the smaller form of the cicada, which will be described later in connection with the life of the adults.

The chambers are seldom straight, their courses being more or less tortuous and inclined to the surface, as the miner had to avoid roots and stones obstructing the path. The interior contains no débris of any sort, and the walls are smooth and compact. The largest chambers are many times the bulk of the pupa in volume, and the insect can easily turn around in them, though it can not quite sit crossways on the floor of the lower enlargement. Below the chamber there is always evidence of a narrower burrow going irregularly down into the ground, but this shaft is filled to the chamber floor with black granular earth. The burrows examined at Somerset were dug through compact red clay, so the filling of the lower tubes was probably discolored by the admixture of fecal matter. For this reason these tunnels always made a distinct black path through the red of the surrounding clay and could often be followed a considerable distance.

Before the emergence of the pupa the chambers are closed at the top by a cap of earth a quarter or a half inch in thickness, and this cap is the original earth surface. Where, then, is the material that was excavated in the construction of a hole of such size? Was it carried down into the tunnel beneath the lower rotunda? This tunnel is always much narrower than the diameter of the chamber and it would take a long section of its length to hold the excavations from the latter. Moreover, if the débris from the chamber was dumped into the hole below, what was done with the original contents of this cavity? Explaining one mystery by postulating another does not explain anything. As long as we have a hole to account for, we might as well account for the one we are sure of, and the best way to begin is by giving the insects themselves a chance to reveal their secrets.

Drop several pupae into glass tubes, fill the tubes with loose earth and watch the performance. Those pupae observed thus by the writer gave a very clear exhibition of their methods of work, which probably explains how they accomplish the seemingly impossible feat of digging a hole without throwing out any earth. They demonstrated first that they do not burrow by plowing through the earth with the conical nosepiece that caps their faces, though the earth in

the tubes was loose and might have been easily thus penetrated; nor did they claw their way along with the large front legs in any ordinary fashion. No; such is not the cicada's way; and what is not an insect's way it will not do even if it might. The cicada pupa has inherited different traditions in the art of digging. To understand its method of work we must first study the construction of its front legs, for these are its principal tools.

The front leg of the pupa is composed of the same number of parts as any other of its legs, as will be seen in figure 2 at *A*. The third joint from the base, called the femur (*F*), is large and swollen in the front leg, and has a pair of large spines and a comb of shorter ones projecting from its lower edge. The next joint is the tibia (*Tb*). It is curved and terminates in a strong hooked point. Finally, attached to the inner face of the tibia, well back from its distal end, is the slender foot or tarsus (*Tar*), which can be extended beyond the tibial hook when the insect is walking or climbing, but can also be turned in at right angles to the tibia, as shown at *B*, or bent back against its inner surface.

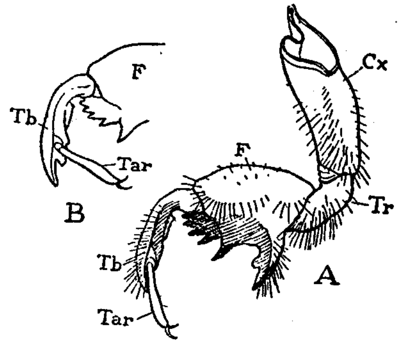


FIG. 2.—*A*, right front leg of mature pupa, inner side (4 times natural size); *Cx*, basal joint or coxa; *Tr*, trochanter; *F*, femur; *Tb*, tibia; *Tar*, tarsus, with two terminal claws. *B*, Showing the tarsus (*Tar*) bent inward at right angles to the tibia (*Tb*), the position in which it is used as a rake.

Let us now return to the insects laboring in the tubes. The use of the various implements on their front legs will be clearly shown. They are using the curved, sharp-pointed tibiae as picks with which to loosen the earth, the tarsi turned back and out of the way, the legs working alternately. When a small pile of loosened material accumulates a rake is necessary. This is furnished by the tarsus now turned inward at right angles to the tibia. A little pile is scraped back toward the body, and—here comes the important part, the cicada's specialty—the little pile of rakings is grasped between the tibia and the femur, the former closing up against the ventral spines of the latter, the leg strikes forcibly outward, and the fistful of loosened earth is mashed back into the surrounding earth. The process is repeated, first with one leg, then with the other. The digging cicada looks like a pugilist training on a punching bag. Now and then the worker stops and rubs its legs over the front of its head to clean them on the rows of bristles which cover each side of the face. Then it proceeds again, clawing, raking, gathering up the loosened particles, thrusting them back into the earth wall. Its back is firmly pressed against the opposite side of the growing cavity, the middle femora are bent forward till their knees are almost against the bases of the front legs, their tibiae lying along the wing pads. The hind legs assume a normal position, though held close against the sides of the body.

Thus, the secret is out, the cicada excavates a closed cavity by crowding the earth back into the surrounding earth. What a slow and laborious task the construction of one of the larger chambers must be to the insect working within! Imagine a person making a cave of proportional dimensions in such a manner. No records are at hand to show when the cicada begins its work or how long it takes to finish the task. Those that performed in the tubes never emerged. But they had already left their original chambers and their time was ripe for transformation. Their skins split in the midst of their labors.

From what we know of the cicada's spring habits underground, we can infer that the pupae construct their chambers on their arrival near the surface during April, that, when the chambers are completed, the insects await within for the signal that it is time to emerge and transform into the adult. Then they break through the thin caps at the surface and come out. It would be difficult to explain how they know when they are so near the top of the ground, and why some construct ample chambers several inches deep, while others make mere cells scarcely larger than their bodies. Do they burrow upward till the pressure tells them that the surface is only a quarter of an inch or so away, and then widen the débris-filled tunnel downward? Evidently not, because the chamber walls are made of clean, compacted clay in which there is no admixture of the blackened contents of the burrows. It is unlikely, too, that they base their judgments on a sense of temperature, because their acts are not regulated by the nature of the season, which, if early or late, would fool them in their calculations. But time is only wasted in trying to reason out the acts of any insect. The insect is almost sure to have ways of its own that our reason seldom hits upon.

An interesting feature in the development, described by Doctor Marlatt, is the change that takes place in the size of the front feet. The young larvae, which hatch from the eggs in the trees, have well developed front tarsi. (Fig. 9.) In the succeeding three larval stages each front tarsus is reduced to a mere spur on the inner face of the tibia. Finally, in the pupal stages, the tarsi reappear as well-developed feet. Both the larva in the first stage and the pupa in the last stage spend a part of their lives on the trees, and to them the front tarsal claws are important climbing instruments; but in its other stages the creature lives entirely underground, where it digs

with the claw-like tips of the front tibiae. Thus the change in the feet is significant in connection with the change in habits, though, as has been shown, the long tarsi of the mature pupa play an important part in its digging also.

Early in the spring, before the proper emergence season, pupae are often found beneath logs and stones. This is to be expected—to the ascending pupae the surface is at the top of the log or the top of the stone. As they burrow upward something impenetrable blocks their paths, and that is all. But a more curious thing often observed is that, in some localities, the insects continue their chambers up above the surface of the ground within closed turrets of mud several inches high. Where these towers occur it is likely that there is something about the nature of the soil that the insects do not like; perhaps it is wet and the normal chambers are damp and moldy or partly filled with water. The writer had no opportunity to study the turrets since none were to be found at Somerset. The most interesting description of them is that given by Dr. J. A. Lintner in his Twelfth Report on the Insects of New York, published in 1897. Doctor Lintner states that "The chambers are constructed by the pupae with soft pellets of clay or mud brought up from below and pressed firmly into place," and he records that Mr. I. H. Lawton caught a pupa at work with a pellet of mud in its claws. Hence, we may infer that, as a mason, the cicada's style of work is only a modification of its working methods as a miner. Yet what an interesting sight it would be to watch the actual building of one of these adobe huts. At emergence time the towers are opened at the top and the insect comes forth as it would from an ordinary chamber opening at the level of the ground.

TRANSFORMATION.

By some feeling of impending change the pupa, waiting in its chamber, knows when the time of transformation is at hand. Somehow nature regulates the event so that it will happen in the evening, but once the hour has come no time is to be lost. The pupa must break out of its cell, find a suitable molting site and one in accord with the traditions of its race, and there fix itself by a firm grip of the tarsal claws. At the beginning of the principal emergence period, about the 21st of May, large numbers of the insects came out of their chambers as early as 6 o'clock by "daylight-saving time," which would be 5 o'clock by standard time; but after the rush of the first few days not many appeared before dusk.

It is difficult to catch a pupa in the very act of making its exit from the ground, and apparently no observations have been recorded on the manner of its leaving. At Somerset, in spite of closest scrutiny and long vigils with electric light and lanterns, we were never lucky enough to witness an emergence. Other watchers at Falls Church, Virginia, report no better success. Do the insects leisurely open their doors some time in advance of their actual need and wait below till the proper hour, or do they break through the thin caps of earth and emerge at once? Digging up many open chambers revealed a living pupa in only one. Another issued from one of several dozen holes filled with liquid plaster for obtaining casts. Add to this the fact that great numbers of fresh holes are to be seen every morning during the emergence season, and the evidence would appear to indicate that the insects open their doors in the evening and come out at once. Only one chamber was found in the daytime partly opened.

If the insects are elusive and wary of being spied upon as they make their début into the upper world, a witness of their subsequent behavior does not embarrass them at all. However, events are imminent, there is no time to waste. The crawling insects head for any upright object within their range of vision—a tree is the ideal goal if it can be attained, and since the creatures were born in trees there is likely to be one near by. Yet it frequently happens that trees in which many were hatched have been since cut down, in which case the returning pilgrims must make a longer journey perhaps than they anticipated. But the transformation can not be delayed; if a tree is not accessible, a bush or a weed, a post, a telegraph pole, or a blade of grass will do. On the trees some get only so far as the trunk, others attain the branches, but the mob gets out upon the leaves. Though thousands emerge almost simultaneously, they have not all been timed alike. Some have but a few minutes to spare, others can travel about for an hour or so before anything happens. Several that I buried in the ground hoping to watch them emerge, transformed in their graves.

The external phase of transformation, more strictly the shedding of the pupal skin, has been many times observed. It is nothing more than what all insects do. But the cicada is notorious because it does the thing in such a spectacular way, almost courting publicity where most insects are shy and retiring. As a consequence the cicada is famous; the others are known only to prying entomologists.

Let us suppose now that our crawling pupa has reached a place that suits it, say on the trunk of a tree, or better still on a piece of branch provided for it in a lighted room where its doings can be more clearly observed. Though the insects choose the evenings for emergence, they are not bashful at all about changing their clothes in the glare of artificial light. The progress of this performance is illustrated by figure 3. The first drawing shows the pupa still creeping upward; but in the next (*2*) it has come to rest and is cleaning

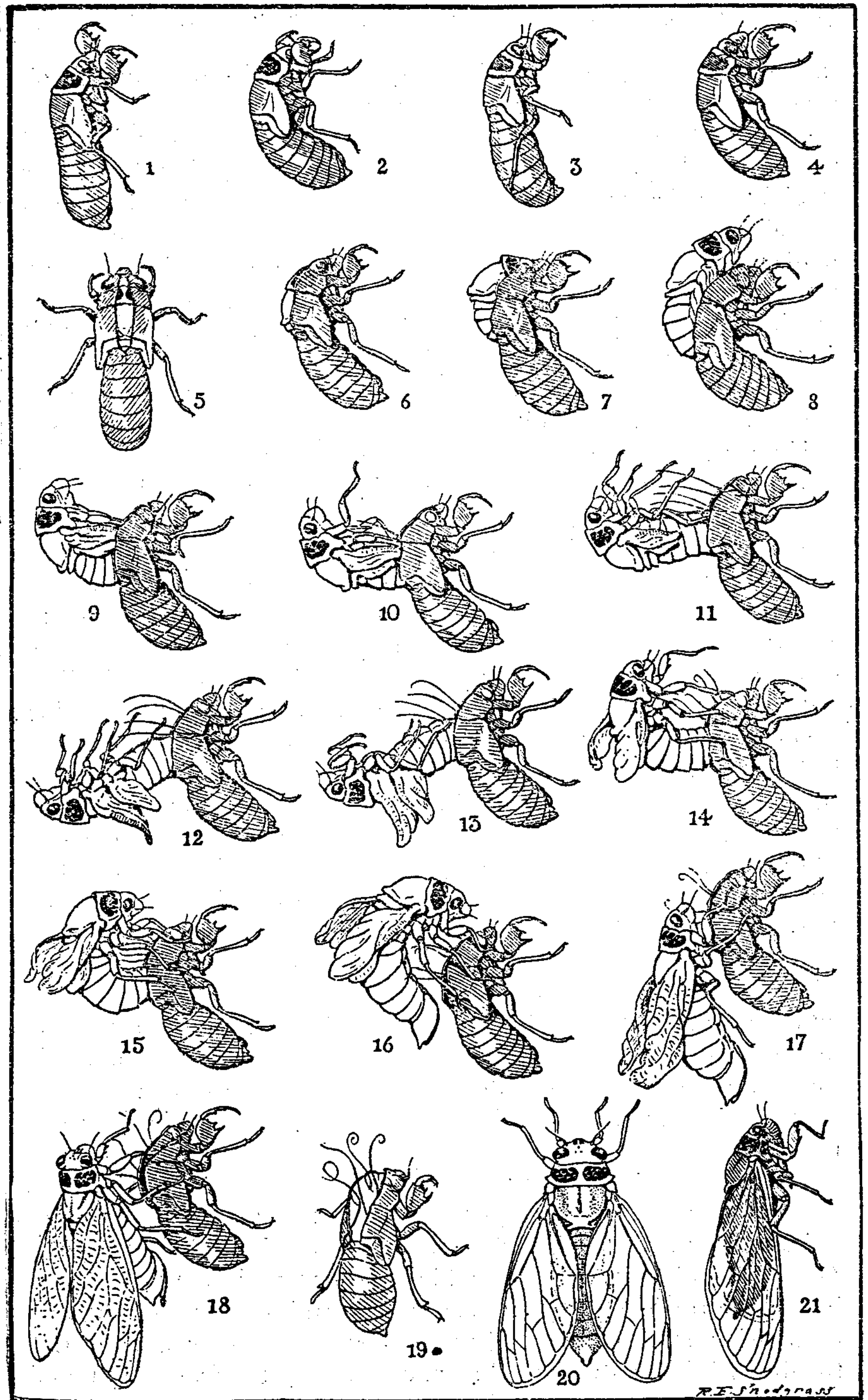


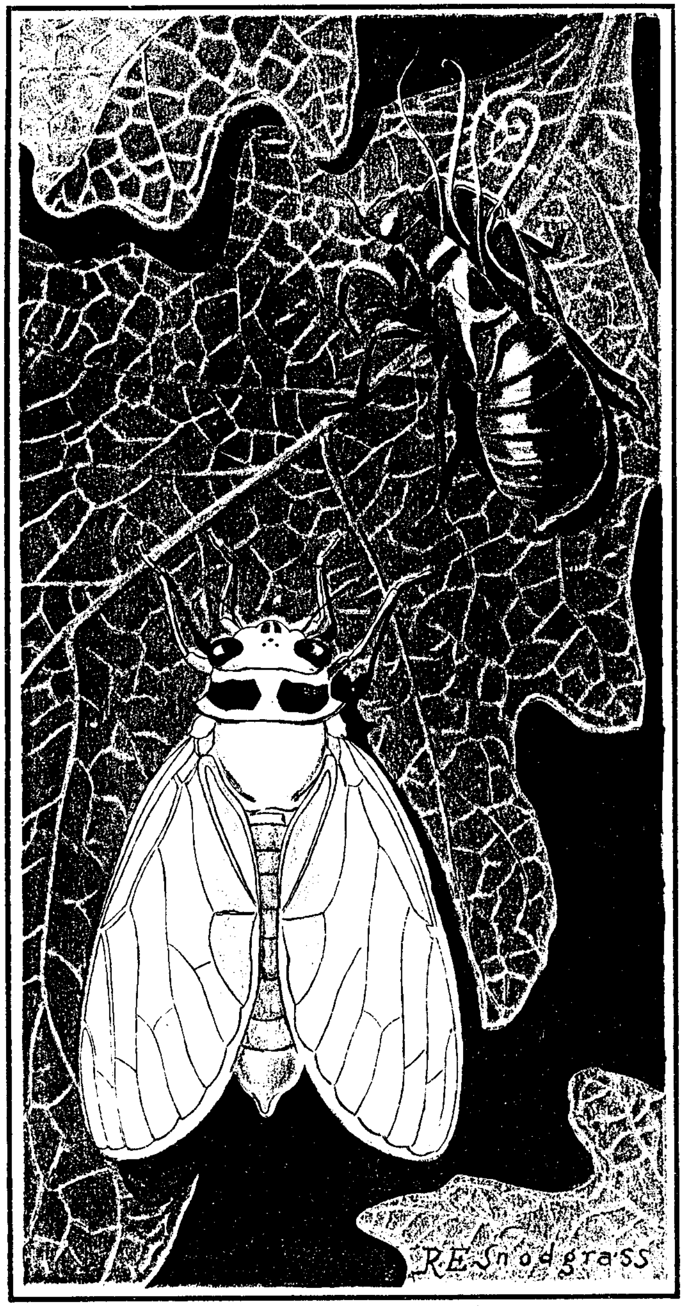
FIG. 3.—Transformation of the cicada from the pupa to the adult. At *1* the pupa is crawling upward. At *2* and *3* the feet are being cleaned against the head and body. At *4* the pupa assumes the molting position. At *5* the skin splits. From *6* to *15* the adult emerges from the pupal skin, becoming free at *16*. At *20* it has left the pupal skin (*19*) and finally assumes the mature form at *21*.

its front feet and claws on the curry combs of its face, just as did those confined to the glass tubes to give a demonstration of their digging methods. The front feet done, the hind ones are next attended to. First one and then the other is slowly flexed and then straightened backward (*3*) while the foot scrapes over the side of the abdomen. Several times these acts are repeated calmly and deliberately, for it is an important thing that the claws be well freed from any particles of dry earth that might impair their grip on the support. At last the toilet is completed, though the middle feet are always neglected, and the pupa feels about on the twig, grasping now here, now there, till its claws take a firm hold on the bark. At the same time it sways the body gently from side to side as if trying to settle comfortably for the next act.

Thirty-five minutes were consumed in the above preliminaries and there is now a 10-minute interval of quietude before the real show begins. Then suddenly the pupa humps its back (*4*), the skin splits along the mid line of the thorax (*5*), the rupture extending forward over the top of the head and rearward into the first segment of the abdomen. A creamy white back, stamped with two large jet black spots, now bulges out (*6*, *7*); next comes a head with two brilliant red eyes (*8*); this is followed by the front part of a body (*9*), which bends backward and pulls out legs and bases of wings. Soon one leg is free (*10*), then four legs (*11*), while four long, glistening white threads pull out of the body of the issuing creature, but remain attached to the empty shell. These are the linings of the thoracic air tubes being shed with the pupal skin. Now the body hangs back down, when all the legs come free (*12*), and now it sags perilously (*13*) as the wings begin to expand and visibly lengthen.

Here another rest intervenes; perhaps 25 minutes may elapse, while the soft new creature, like an inverted gargoyle supported only by the rear end of its body, hangs motionless far out from the split in the back of the shell. Now we understand why the pupa took such pains to get a firm anchorage, for should the dead claws give way at this critical stage the resulting fall most probably would prove fatal.

The next act begins abruptly. The gargoyle moves again, bends its body upward (*14*), grasps the head and shoulders of the slough (*15*), and pulls the rear parts of its body free from the gaping skin (*16*). The body straightens and hangs downward (*17*). At last we behold the free imago, not yet mature but rapidly assuming the characters of an adult cicada. The new creature hangs for a while from the discarded shell-like pupal skin, clinging by the front and middle legs, sometimes by the first alone, the hind ones spread out sideways or bent against the body, rarely grasping the skin. The wings continue to unfold and lengthen, finally hang flat, fully formed, but soft



THE CICADA JUST AFTER EMERGING FROM THE PUPAL SKIN.

(Twice natural size.)

and white (*18*). Here the creature usually becomes restless, leaves the empty skin (*19*), and takes up a new position several inches away (*20*).

At this stage the cicada is strangely beautiful. Its creamy-yellow paleness, intensified by the great black patches just behind the head and relieved by the pearly flesh tint of the mesothoracic shield, its shining red eyes, and the milky, semitransparent wings with deep chrome on their bases, make a unique impression on the mind. There is a look of unreality about the thing, which, out of doors (pl. 2), becomes a ghostlike vision against the night. But, even as we watch, the color changes, the unearthly paleness is suffused with bluish gray, which deepens to blackish gray. The wings flutter, fold against the back, and the spell is broken—an insect sits in the place of the vanished specter.

The rest is commonplace. The colors deepen, the grays become blackish and then black, and after a few hours the creature has all the characters of a fully matured cicada. Early the next morning it is fluttering about, restless to be off with its mates to the woods.

The time consumed by the entire performance, from the splitting of the skin (fig. 3, *5*) to the folding of the wings above the back (*21*), varied with different individuals, observed at the same time and under the same conditions, from 45 minutes to 1 hour and 12 minutes. Most of the insects had issued from the pupal skins before 11 o'clock at night, but occasionally a straggler might be seen in the last act as late as 9 o'clock the following morning. Such were probably belated arrivals who overslept the night before.

Thus, to the eye, the burrowing and crawling creature of the earth becomes transfigured to a creature of the air; yet the visible change is mostly but the final escape of the mature insect from the skin of its preceding stage. Aside from a few last adjustments and the expansion of the wings, the real change had been in progress within the pupal skin perhaps for years. We do not truly witness the transformation; we see only the throwing off of the shell that concealed it, as the circus performer strips off the costume of the clown and appears already dressed in that of the accomplished acrobat.

THE ADULTS.

The adult cicada bears the stamp of individuality; he does not closely resemble any of our everyday insects; he has a different personality; he impresses us as a " distinguished foreigner in our midst." Of course, he has near relations; there are numerous other members of his family, the insects commonly called " locusts," whose shrill voices are more familiar to us than their faces, but whose empty pupal skins almost everyone has seen adhering to fence posts and tree trunks in late summer. Most of these cicadas probably go through their underground changes in one year, but there are periodical species whose lives we as yet know nothing about.

The 17-year cicada has a thick-set body (fig. 4), the forehead is wide, with the eyes set out very prominently on each side. He is distinctively but not strikingly colored. The back is plain black (pl. 3); the eyes bright red; the wings shiny, transparent amber with strongly marked orange-red veins; the legs and beak are reddish and there are bands of the same color on the ventral rings of the abdomen. Each front wing is branded with a conspicuous brown W toward the tip. Superstition, of course, must explain this only as meaning "war," but the 1919 brood evidently miscalculated what was going on above ground.

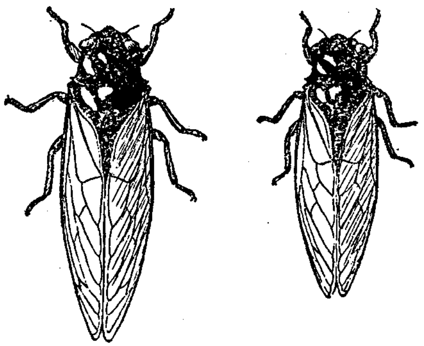


FIG. 4.—Males of the large and the small form of the cicada (natural size).

The male cicada is noted for his "song," yet his music is of an instrumental order rather than vocal. He carries a pair of large drumheads beneath the bases of his wings, the ridged, parchment-like surfaces of which are thrown into rapid vibration by a pair of pillarlike muscles in the front part of the abdomen (fig. 7, *TmMcl*). Below the drums, between the thoracic and abdominal divisions of the body on each side, is a large cavity with tense membranes on its walls, which most probably act as resonators. The cavities are closed below by a pair of large flaps projecting back from the thorax, but they can be opened by the elevation of the abdomen.

The female has no drums, and consequently is doomed to keep silence; but no one has yet discovered that she possesses ears, so it seems she also does not have to listen to her noisy mates. Her chief distinction is her ovipositor, a swordlike instrument used for inserting her eggs into the twigs of trees and bushes. Ordinarily it is kept in a sheath beneath the rear half of the abdomen, but when used (pl. 3) can be turned forward by a hinge at its base. The ovipositor consists of two lateral blades and a guide rail above. The blades excavate the egg nests in the wood and then the eggs are passed into the nests through the space between the blades.

Entomologists call the 17-year cicada *Tibicena septendecim.* But there are two forms (fig. 4), distinguished by their size and by their song. The smaller form has been given the name *Tibicina cassini* or *Tibicena septendecim cassini*, according to whether it is regarded

FEMALE CICADA DEPOSITING EGGS IN APPLE TWIG.
(Twice natural size.)

as a distinct species or only as a variety of the larger form. The two kinds occur together, but they are not known to intermarry; they occasionally intergrade in size, and no constant physical differences have so far been found between them.

It was formerly supposed that the cicadas take no food during the brief time of their adult life, but we now know, from the observations of Mr. W. T. Davis, Dr. A. L. Quaintance, and others, and from a study of the stomach contents recorded in this paper, that they do feed abundantly by sucking the sap from the trees and bushes on which they live. The cicada is a large relation of the aphids, the scales, and other insects of the sucking order, and like them has a beak for piercing the plant tissues and drawing the sap up to its mouth. But, unlike the aphids and scales, the cicadas seldom cause any visible damage to the plants by their feeding. Perhaps this is because their attacks last such a short length of time and come at a season when the trees are at their fullest vigor.

The details of the head structure and the exposed parts of the beak are shown in figure 5, A, which is a side view drawn from the head of a fully matured adult, detached from the body by the torn neck membrane (*mb*) with the long slender beak (*Lb*) projecting below. The cicada has no jaws. Its mouth is shut in between a large front lip (*Clp*), and the base of the main part of the beak (*Lb*), which is really the prolonged lower lip, or labium. The narrow spaces on the sides between the bases of the lips are closed by the soft, slender pieces marked *Lm* and *c*.

If these outer parts can be separated, we find some other very important parts hidden from view within them. But it is difficult to separate them on the hardened head of a fully matured specimen. However, if we take an insect in the act of emerging from its pupal skin, when it is still soft, the parts are easily spread out, exposing all the structures shown in figure 5, B. In the front half of the space between the lips (*Clp* and *Lb*) there is exposed a large tongue (*Hphy*), the hypopharynx, which is connected by a flaring wing (*a*) on each side with the first side plate (*A*) of the head. Between this tongue and the front lip (*Clp*) is an open cleft (*Mth*) which is the cicada's mouth. It opens into the pharynx, whose roof (*e*) bulges in and almost fills its cavity. The lobe (*b*) behind the tongue is the same thing as *b* on figure *A*, being merely a downward extension of the second side plate (*B*) of the head, and carries the soft appendage (*c*), already noted, at its lower end. Between this lobe (*b*) and its mate on the opposite side of the head are two deep pouches, from each of which there issues a pair of long, slender, bristlelike rods (*1 Set* and *2 Set*), which are called the setae. (Only the left pair is shown in the drawing.)

Now, if these separated parts be put together again we get a pretty clear idea of how the cicada takes its food. The setae (*1 Set* and *2 Set*), normally lie deep in a groove along the front side of the labium (*Lb*), which groove, of course, does not show in the drawing made from the side. The upper ends of the setae have arms extending into the head cavity which have two sets of muscles attached to them—

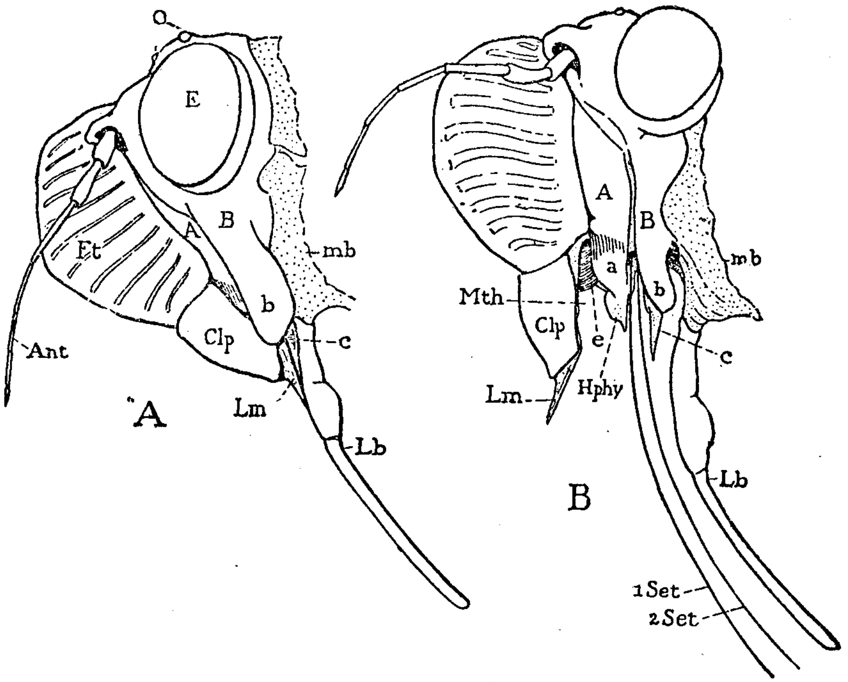


FIG. 5.—Showing the anatomy of the head of an adult cicada (7 times natural size). *A*, First side plate of head; *a*, attachment of hypopharynx to the head; *Ant*, antenna; *B*, second side plate of head; *b*, lower lobe of *B*; *c*, appendage of *b*; *Clp*, clypeus; *E*, compound eye; *e*, roof of the pharynx; *Ft*, front; *Hphy*, hypopharynx; *Lb*, labium; *Lm*, labrum; *mb*, neck membrane; *Mth*, mouth; *O*, simple eyes or ocelli; *1 Set*, first seta; *2 Set*, second seta. A, The mature head with the parts in natural position. B, Soft head of a transforming adult with the parts separated, showing the mouth (*Mth*) wide open, the tongue or hypopharynx (*Hphy*) suspended behind it, and behind the tongue the setae (*Set*) inserted into pouches of the head. Only the left setae are shown. In the normal head (*A*) they are concealed in a groove on the front side of the labium (*Lb*).

the fibers of one set, going up to the top of the cranium, draw the setae up by contraction; those of the other, coming down and sideways from the tops of the arms to the inner faces of the head plates *A* and *B*, push the setae out when they contract. Thus, by these muscles, the tips of the setae can be worked in and out at the end of the beak and made to pierce the bark of the tree. As they enter, the labium (*Lb*), which incloses them like a sheath, can be drawn up into the flexible membrane (*mb*) at its base, so that the setae can be

pushed a long distance down into the sap-carrying tissues of the tree. Next the sap must be drawn up to the mouth. To serve this function two of the setae, the rear one of each lateral pair, are hollowed along their inner faces and united lengthwise by interlocking grooves and ridges. Thus a closed channel is formed between them, and it is through this tube that the sap reaches the mouth, going up probably by the mechanical force that makes all liquids flow up through hairlike tubes.

The immature adult cicada has the mouth open, or easily opened; but when fully matured the mouth is always tightly closed by the tongue (*Hphy*) and its wings (*a*) which press firmly against the roof of the mouth. The middle part of the tongue then fits snugly into a depression of the palate or epipharynx, as the roof of the mouth is called in insects. Hence, there would be no mouth opening at all if it were not for a small median groove on the front surface of the tongue. This groove is now converted into a tube which opens below at the pointed tip of the tongue, and above into the cavity of the pharynx. The pair of united setae carry the liquid food up to the mouth, but, right at the point of the tongue, they flare apart and embrace the tongue tip. This allows the liquid stream between them to pass on without interruption into the mouth pore through which it is sucked up into the pharynx. The sucking apparatus consists of the collapsed roof of the pharynx (*e*) which can be elevated by a

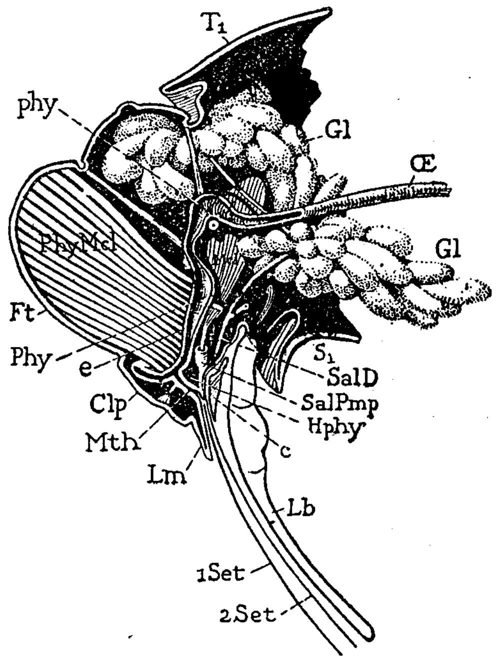


FIG. 6.—Median vertical section through head of an adult cicada showing the sucking pharynx (*Phy*) and the salivary glands (*Gl*, *Gl*). The liquid food goes up to the mouth between the second setae (*2 Set*), all being normally enclosed in the groove of the labium (*Lb*). The pharynx muscles (*PhyMcl*) contract and pull out the front wall (*e*) of the pharynx, thus sucking in the liquid from between the bases of the setae through the mouth pore (*Mth*). When the muscles relax the pharynx wall (*e*) collapses again and forces the liquid up into the bulb (*phy*) from which it goes into the gullet (*Œ*). The salivary duct (*SalD*) opens at the tip of the hypopharynx (*Hphy*), the saliva being forced out by the salivary pump (*SalPmp*). *Ft*, *Clp* and *Lm* are the front, clypeus and labrum shown on figure 5, while *c* is the appendage of head plate *B*. T_1 and S_1 are the dorsal and ventral plates of the first thoracic segment.

special set of large muscles attached to the front of the head. A sectional view of it is shown by figure 6.

Insects that devour the leaves or any kind of solid food, as do grasshoppers, beetles and caterpillars, have a pair of large strong jaws for biting and chewing and a second pair of softer jaws with movable appendages that serve a variety of purposes accessory to the first pair. Since the cicada and its relations, constituting the order of insects called Hemiptera, have no jaws like those of the biting insects, it has usually been assumed that the pair of setae on each side are their representatives and this appears to be confirmed by a study of their development.

SONG.

During the first two weeks of June the woods were full of the "locusts" and the noise of their singing. The song has no resemblance whatever to the shrill, undulating screech of the annual locusts so common in August and September and known as the dog-day cicadas. The song and all the notes of the larger variety of the 17-year cicada are characterized by a burr sound and at least four different utterances may be distinguished. First, there is the prolonged burring sound of their ordinary song, the individual notes of which become lost in the continuous hum of the multitude, and I never heard one singing this song in solo. Next there is the so-called "Pharaoh" note, which requires some imagination to interpret it thus, for it is characterized by the same burr tone as the chorus song. The Pharaoh sound is usually sustained only about five seconds, when it terminates with an abrupt falling. Then it is repeated indefinitely at intervals of two to five seconds. When each note is begun the singer lifts his abdomen to a rigid, horizontal position, evidently thus opening the ventral drum chambers. As the sound ends the abdomen drops again to the usual somewhat sagging position, seemingly thus cutting off the sound by closing the drums; but, of course, the two are coincidental, since the sound terminates when the tympanal muscles cease to vibrate.

The males are easily observed uttering the Pharaoh song as they sit in the bushes or on low branches of the trees, but the community singing is always done in the tops of the trees, where I never observed an individual musician at close range while performing.

Their third note is a soft purring sound of one syllable, which is often heard from those sitting low in the bushes. It is shorter than the Pharaoh sound and lacks the abrupt terminal drop. Finally, when a male appears to be surprised or frightened, he often, as he darts away, utters a loud, rough burr sound. They utter the same note when picked up or otherwise handled. This seems to be their

note of "primitive passion," and if so is perhaps the one from which the more melodious ones have been developed.

The smaller form, variety, or species, the one called "cassini," differs from the larger form in the character of its notes always, if in no other way. The regular song of the little males much more resembles that of the annual summer cicadas, though not so long and less continuous in tone. It commences with a few chirps, then there follows a series of strong, shrill sounds like *zwing*, *zwing*, *zwing*, etc., ending again in a number of chirps. The whole song lasts about 15 seconds. Several of these males kept in jars sang this song repeatedly and sang no other. It was common out of doors, but always heard as a solo, never in chorus.

When handled or disturbed the little males utter a series of sharp chirping notes very suggestive of a miniature wren angrily scolding at an intruder. Never does this form utter notes having the burr tone of the larger one. The contrast between the vocal tones of the two is strikingly evident when several males of both kinds are kept together in a jar. If disturbed each produces his own sound, one the burr, the other the chirp, and there is never any suggestion of similarity or gradation between them.

Of all animal songs, the song of the cicada must prove one of the worst stumbling blocks to those who would explain animal music on the theory of sexual selection. Where thousands of males are singing all at once it would be a very delicate ear that the female must have to choose amongst them; and, furthermore, as has already been mentioned, the female is not known to have any ear at all. On the other hand, probably no one is able to give any very satisfactory reason why an insect should have acquired such an elaborate music box as that of the cicada's merely for the purpose of emotional expression.

EGG LAYING.

The cicadas lay their eggs in the twigs of trees and shrubs and frequently in the stalks of deciduous plants. They show no particular choice of species except that conifers are usually avoided, though Mr. W. T. Davis says that he has observed them ovipositing in pines on Staten Island, but he did not examine the eggs later to determine whether they hatched or not.

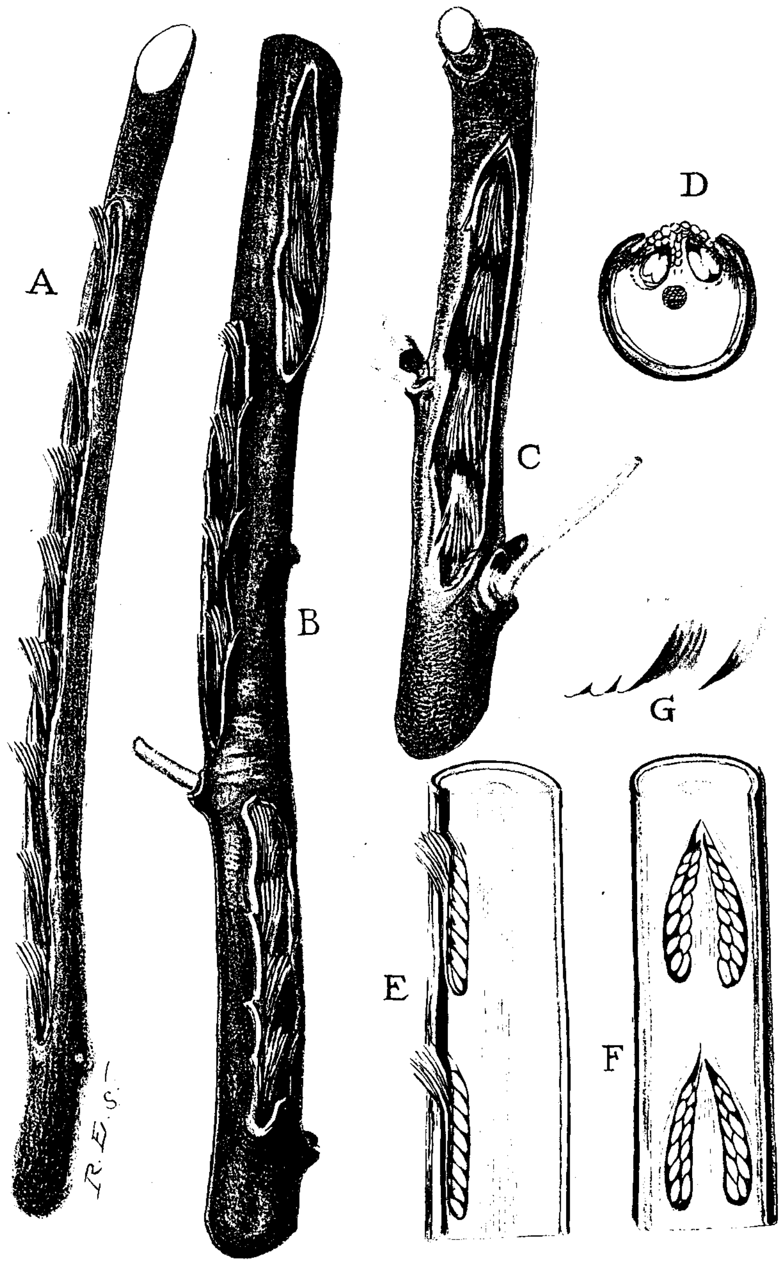
The eggs are not stuck into the wood at random, but are carefully placed in skillfully constructed nests which the female excavates in the twigs with the blades of her long, curved ovipositor. (Pl. 3.) These nests are perhaps always on the undersurfaces of the twigs, unless the later are vertical, and usually there are rows of from half a dozen to twenty or more of them together.

Egg laying begins in the early part of June. The first evidence the writer noticed in 1919 was on June 6, when a number of punctured twigs were found on several varieties of trees and shrubs at Chevy Chase Circle, but no particular search was made for them earlier than this date. By June 10 egg laying was at its height. The females could easily be watched at work, taking flight only from actual interference. They usually select twigs of last year's growth, but often use older ones or green ones of the same season. In the majority of cases the female works outward on the twig; but if this is a rule, it is a very loosely observed one, for many work in the opposite direction.

Each nest is double; that is, it consists of two chambers having a common exit, but separated by a thin vertical partition of wood (pl. 4, *D* and *F*). The eggs are placed on end in the chambers in two rows, with their head ends downward and slanted toward the door. Generally there are 6 or 7 eggs in each row (*E*), making 24 to 28 eggs in the whole nest, but frequently there are more than this. The wood fibers at the entrance are very much frayed out by the action of the ovipositor and make a sort of fan-shaped platform in front of the door, where the young shed their hatching garments on emerging from the nest. The series of cuts in the bark eventually runs together into a continuous slit, the edges of which shrink back so that the row of nests comes to have the appearance of being made in a long groove (*A*, *B*, *C*). This mutilation kills many twigs, especially those of oaks and hickories, the former soon showing the attacks of the insects by the dying of the leaves. The landscape of oak-covered regions thus becomes spotted all over with red-brown patches which often almost cover individual trees from top to bottom. Other trees are not so much injured directly, but the weakened twigs often break in the wind and then hang down and die.

An ovipositing female finishes each egg nest in about 25 minutes; that is, she digs it out and fills it with eggs in this length of time, for each chamber is filled as it is excavated. A female about to oviposit alights on a twig, moves around to the undersurface, and selects a place that suits her. Then elevating the abdomen, she turns her ovipositor forward out of its sheath and directs its tip perpendicularly against the bark. As the point enters it goes backward, and when in at full length the shaft slants at an angle of about 45°.

The following detailed observations were made on a female who had already finished several nests of a series. In beginning the new nest she first made three partial insertions of the ovipositor, drawing it out entirely after each slow penetration. At the end of the first five minutes she finally worked it in to its full length. Then, during five minutes more, it was pulled out and worked in again



A, B, C, twigs of dogwood, oak, and apple containing rows of cicada egg nests; *D,* cross section of twig through an egg nest showing the two chambers, each containing a double row of eggs; *E,* vertical section through two egg nests showing the rows of slanting eggs and the frayed lip of the opening; *F,* horizontal section showing each chamber filled with double row of eggs.

a number of times. Finally the ovipositor was sunk so deep that the abdomen came up close against the bark and egg-laying began, as indicated by the regular contractions of the plates of the ninth abdominal segment that operate the ovipositor blades. At short intervals the instrument was drawn out nearly to the tip and then thrust in again, but each time not so deep as the time before. This stage lasted another 5 minutes, 15 minutes in all having elapsed since the start. Now the abdominal pulsations ceased and the ovipositor was again sunk full length into the wood; repeated probings occupied the next 7 minutes. This was followed by a second period of egg laying, lasting 3 minutes, while the thrusts became shorter and shorter. Finally, the ovipositor was withdrawn, snapped back into its sheath, and the female flew away. The whole operation had taken 25 minutes.

In a number of other cases the females were frightened away at different stages of their work, and an examination of these unfinished nests showed that each chamber is filled with eggs as soon as it is excavated; that is, the insect completes one chamber first and fills it with eggs, then the other chamber is dug out and in turn receives its quota of eggs, when the whole job is done. The female then moves forward a few steps and begins work on another nest, which is completed in the same fashion. Some series consist of only 3 or 4 nests, while others contain as many as 20 and a few even more, but perhaps 8 to 12 are the usual numbers. When the female has finished what she deems sufficient on one twig she flies away and is said to make further layings elsewhere, till she has disposed of her 400 to 600 eggs, but the writer made no observations covering this point. Probably the cicada feels it safer not to intrust all her eggs to one tree, on the principle of not putting all your money in the same bank.

DEATH.

From the time that egg laying was at its height, about the 10th of June, the din of the singing in the woods began to diminish. Many insects were from the first killed or mutilated by birds or small mammals; now the ground became strewn with dead bodies or with insects still living, but hopelessly injured and dismembered. By the 13th and 14th of the month the colony was reduced to a very miserable condition. Great numbers were dead or dying, and a large percentage of the living were walking around on the ground in various stages of disfigurement. Wings were torn off; abdomens were broken open or gone entirely; mere fragments crawled about, still alive if the head and thorax were intact. It was almost a gruesome sight to see these half creatures, the males often with the great muscle columns of the tympana exposed and visibly quivering.

Many, game to the end, even in their depleted condition still uttered purring remnants of their song.

On June 15 at Somerset I heard one solitary male singing, but by the 17th all was over; the great horde of insects that emerged from the earth and underwent such spectacular transformations only three or four weeks ago was gone. Mutilated remains and dried bodies could still be found, but a thorough search revealed not one living insect. On June 29 a belated male was heard near Riverdale, Maryland, faintly but distinctly singing the Pharaoh song, then he ceased and was heard no more.

From now on till the 24th of July there was no evidence of the late swarm of visitors except that of the scarred twigs on the trees and bushes and the red-brown patches of dying leaves that everywhere disfigured the oaks and hickories.

INTERNAL ANATOMY.

In observing those mutilated cicadas, with their abdomens wide open clear up to the thorax, it strikes one as remarkable that a bird could do such a neat job of evisceration on a living subject. It seems that an insect here and there should have a piece of intestine trailing behind or should retain at least some remnant of its vitals. But the vivisection is never messed by so much as a protruding shred, and the cavity is always as clean and bare as if it never had contained anything. One's curiosity is aroused to know what might have been there in the natural state. The live cicada looks like a plump catch for any predaceous creature. So the writer was led to investigate its abdominal anatomy, and eventually dissected many specimens to be sure there was no nature faking—each was as empty as a rubber ball, as empty as those walking shells that so arouse one's pity and curiosity. If I was surprised, one can imagine that the feelings of the birds were something worse—where they expected a juicy meal, they found only an empty dish!

After considerable study the facts were ascertained as follows: The abdomen is almost filled by a great air chamber (fig. 7) whose anterior end narrows between the pillars of the tympanal muscles and tapers to a point in the prothorax! The reproductive organs (*Rpr*) and the terminal part of the alimentary canal (*Rect*) are crowded into a small space in the rear part of the abdomen. Otherwise the walls of the chamber appear to form an inner lining against the hard abdominal rings, so closely are they applied to them. Yet this is not really the case. If the dissected specimen be placed in water, a transformation appears; a complicated intestinal tract swells up along the back; muscles, tracheæ, and nerves come into view, all packed about the outside of the thin, transparent walls of the air chamber.

The alimentary canal, when once its numerous tubes are disentangled, shows the remarkable arrangement depicted on plate 5.

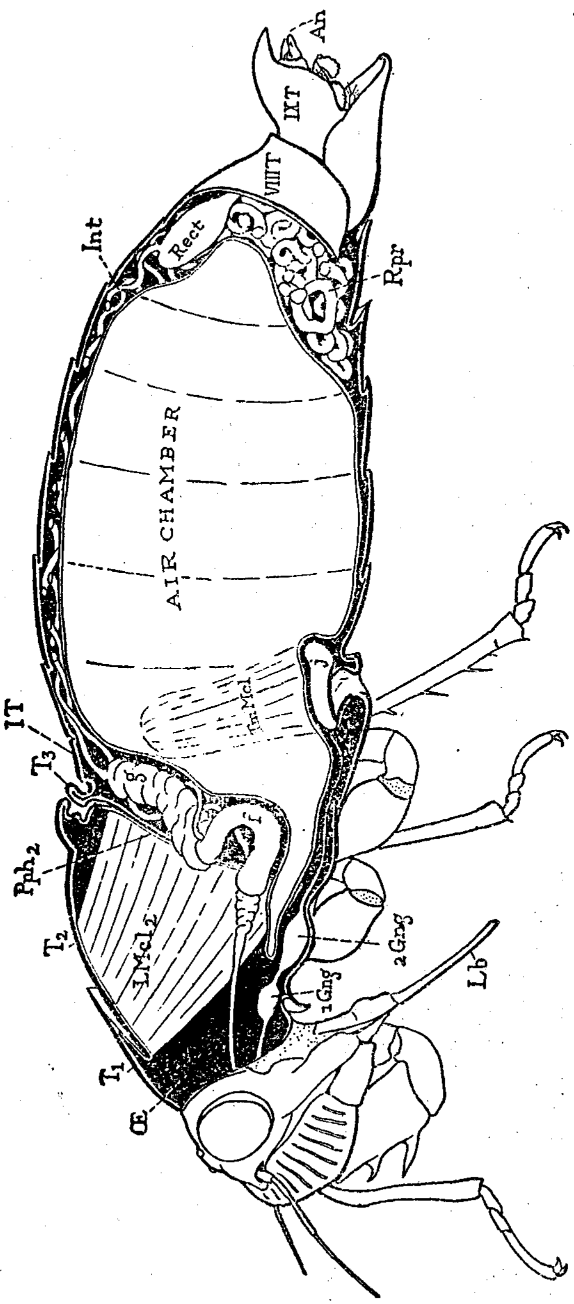


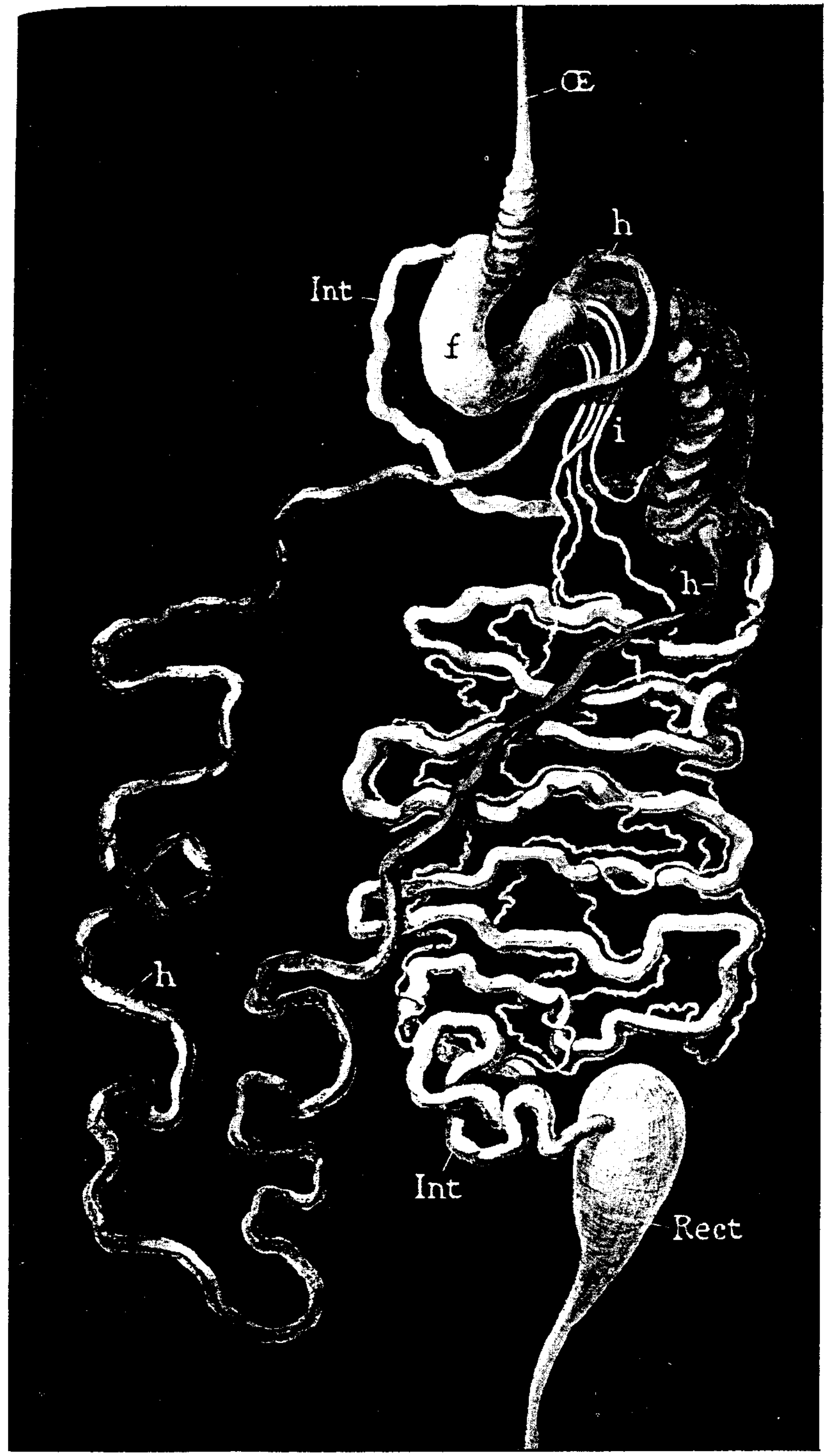
FIG. 7.—Vertical section of a male cicada's body through the middle line, showing the large, empty, internal cavity formed by the great air chamber, with the viscera crowded into the narrow spaces around it. *An*, anus; *f*, *g*, the two compartments of the stomach; *1Gng*, *2Gng*, first and second nerve ganglia in the thorax; *Int*, intestine; *IT*, back plate of first abdominal segment; *IXT*, back plate of ninth abdominal segment; *j*, plate bearing attachment of the tympanal muscles (*TmMcl*); *Lb*, the beak (labium); *LMcl*, longitudinal muscles of middle thoracic segment; *Œ*, oesophagus; *Rpr*, reproductive organs; T_1, T_2, T_3, back plates of the three thoracic segments; *TmMcl*, tympanal muscle of the right singing drum; *VIIIT*, back plate of the eighth abdominal segment.

The esophagus (*OE*) is a slender tube enlarging at its rear end into a distensible crop. The crop is followed by a long **S**-shaped stomach of two compartments (*f* and *g*). Six tubes appear to leave the stomach. The first (*Int*) issues from the anterior end of the front stomach compartment and goes rearward in many crosswise loops along the back till finally it ends in the pear-shaped rectum (*Rect*), which opens to the exterior through the anus. This tube (*Int*) must, therefore, be the true intestine. From the rear end of the second stomach compartment, which is of an orange-brown color, there issues a tube (*h*) of the same color, which goes backward in many loops and folds but eventually turns forward again and penetrates the stomach at the constriction between its two compartments. On the same line there issue four very small whitish tubes (*i*) which form two loops inextricably tangled amongst the folds of the intestine.

At first sight this alimentary structure is a puzzle—the intestine issues from the front end of the stomach, while the tube arising from the rear end of the stomach, where the intestine should begin, turns back on itself and reenters the stomach. The explanation is simple, however, and is easily found by dissecting the first stomach compartment. The tube (*h*), entering the rear end of this compartment, does not open into the stomach cavity but merely penetrates between its muscular wall and its interior lining, where it goes forward in many zigzag loops and issues at the top as the tube *Int*. The tubes *i* arise from the enclosed end of the intestine (*Int*) in two pairs from two short basal tubes and go backward in the stomach wall from which they issue, as shown on the plate, at the front of the second stomach compartment. These are the Malpighian tubules which function as the kidneys in insects.

Thus the puzzle of the anatomy is solved, but we are not sure of any reason for such an unusual state of things. Some entomologists, however, have supposed that the arrangement affords a short-cut to the intestine for some of the waste matter in the stomach, which can soak through into the upper end of the tube *h* and thus go direct to the intestine (*Int*), while the nutritive material goes on by way of the long loop (*h*, *h*, *h*). They would, hence, name the first compartment of the stomach the "filter chamber." But it is not clear how the tubes can select waste matter in solution from nutritious matter in the same liquid.

Both the stomach and the sac of the rectum are usually filled, and frequently tensely distended, with a clear liquid. The presence of such an elaborate digestive system, with its retaining parts thus filled with liquid, only adds confirmation to the observed facts of the cicada's feeding already recorded. The two stomach sacs (*f* and *g*) lie in the narrow, almost vertical, space between the posterior phragma (fig. 7, Pph_2) and the anterior end of the air chamber. The tubular parts are packed into the flat space above the chamber, a



THE ALIMENTARY CANAL OF THE CICADA.

Œ, the œsophagus; *f*, *g*, the two compartments of the stomach; *h*, *h*, *h*, tubular continuation of the stomach entering the walls of the first compartment where it unites with the small intestine (*Int*), which issues from near the front end of the stomach and finally opens into the rectum (*Rect*); *i*, Malpighian tubules arising from end of small intestine inclosed in the stomach walls.

space no thicker than a piece of paper in those individuals examined toward the end of their natural lives. The rectum (*Rect*) lies in a freer space again behind the air chamber and above the reproductive organs (*Rpr*).

The great air chamber is a part of the respiratory system. It receives its supply of air directly through the spiracles of the first abdominal segment, which lie just before the drums in the male, as described by Vitus Graber in 1876. At least two tracheal tubes open from it on each side close to the spiracle, and its own walls are abundantly supplied with fine branching tracheae. It is present in the last pupal stage where it is to be found at the time of emergence as a collapsed bag with rather thick walls lying lengthwise amongst the abdominal viscera (or at least it is thus in alcoholic specimens). It is distended in the imago when the latter first comes out of the pupal shell, and is present in both males and females, enlarging toward the end of adult life as the reproductive organs shrink into the rear extremity of the abdomen. In the young female, before egg laying has exhausted the ovaries, these organs occupy a much larger space at the expense of the air sac than they do toward the end of life. If the air chamber occurred in the male alone it would easily be explained as part of his musical equipment. The dry, hollow, thin-walled abdomen would be enthusiastically described as a marvelous adaptation for giving resonance to the vibrations of the tympana. But the female contradicts this theory, unless it be that her body is set into sympathetic vibration by the song waves from the male. We shall probably have to fall back on the old prosaic explanation that bulk of body is maintained with corresponding weight eliminated—a combination specially favorable to aerial life.

In the narrow space about the sac there are, besides the alimentary canal, abundant strands of fat tissue, the heart, tracheal trunks from the spiracles and their numerous branches, nerves, and the muscles of the body wall. So, indeed, the cicada is a complete insect after all in spite of its deceptive appearance of emptiness.

The central nervous system consists of four main ganglia, the two usual ones in the head, one in the prothorax (fig. 7, *1 Gng*), and a larger one in the mesothorax (*2 Gng*). This explains why the loss of the abdomen is a matter of such little consequence to these insects, and also why the cicada appears to be such a perfect automaton.

HATCHING.

Knowing from printed records that the cicada eggs were due to hatch almost any time after the middle of July, the infested trees in the yard of the Office of Apiculture were daily inspected from the 15th on, but no evidence of hatching was found until the 24th. Egg laying had been at its height about the 10th of June, so fully seven weeks had elapsed already and no nymph had yet been seen. Possibly the normal hatching was retarded by the heavy rains that fell almost continuously during the 10 days previous. Many eggs examined were found dead and turning brown, but the percentage of such was small. On the 24th there was no rain and the sky was only partly cloudy. The usual search revealed two nymphs on a punctured twig of a small chinquapin, but that was all. Some of the nests examined showed a few empty shells, but, judging by their proportion, the great majority were still unhatched.

The next day, the 25th, was hot and bright all day. The trees were inspected in the afternoon. Their twigs had been bare the day before. Now, at the entrance holes of the egg nests were little heaps of shriveled skins, thousands in all, and each so light that the merest breath of air sufficed to blow it off; so, if according to this evidence thousands of nymphs had hatched and gone, the evidence of as many more must have been carried away by the winds. An examination of many egg nests themselves showed that over half contained nothing but empty shells. Whole series were thus deserted, and usually all or nearly all of the eggs in any one series of nests would be either hatched or unhatched. But often the eggs of one or more nests would be unhatched or mostly so in a series containing otherwise only empty shells. Delay appeared to go by nests rather than by individual eggs.

As a very general rule the eggs nearest the door of an egg chamber are the ones that hatch first, the others following in succession, though not in absolute order. But unhatched eggs, if present, were always found at the bottom of the nest, with the usual exception of one or two farther forward. Only occasionally an empty shell would be found in the middle of an unhatched row. If the actual hatching of the eggs was observed in an opened nest several nymphs would usually be seen coming out at the same time, and in nearly all cases they were in neighboring eggs, though not always contiguous ones. So this rule of hatching, like most rules, is general but not binding.

The procedure of the female in placing the eggs leaves no doubt that the first laid ones are those at the bottom of the cell, showing that the order of laying has no relation to the order of hatching, except that it is mostly the reverse. It seems hardly reasonable to suppose that the eggs nearest the door are affected by greater heat or by a fresher supply of air, so I would suggest that the order of hatching may be due simply to the successive release of pressure along the tightly packed rows, giving the compressed embryos a chance to squirm and kick enough to split the inclosing shells. When hatching once commences it proceeds very rapidly through the whole nest, showing that the eggs are all at the bursting point when the rupture of the first takes place.

In each lateral compartment of an egg nest the eggs (pl. 4, *E* and *F*) stand in two rows with their lower or head ends slanted toward the door. (It must be remembered that the punctures are made on the lower sides of the twigs, so that the eggs are inverted in their natural position in the nests.) On hatching, each egg splits vertically over the head and about one-third of the length along the back, but for only a short distance on the ventral side. As soon as this rupture opens the head of the young cicada bulges out, and then, by a bending of the body back and forth, the creature slowly works its way out of the shell, which, when empty, remains behind in its original place. The nymphs nearest the door have an easy exit, but those from the depths of the cell find themselves still in a confined space between the projecting ends of the empty shells ahead of them and the chamber wall, a passage almost as narrow as the egg itself, through which the delicate creatures must squirm to freedom.

Now, a newly hatched Orthopteron, or a newly hatched or newly born aphid, is done up in a tight-fitting garment with neither sleeves nor legs, and a young grasshopper hatching under the ground has a difficult journey to the surface. But nature has been more considerate in the case of the young cicada. It, too, comes out of the egg clothed in a skin-tight jacket, but this garment is not a mere bag, as with the other insects mentioned. Each is provided with special pouches for the appendages, or a part of them (fig. 8, *2*). The incased antennae and the labrum project backward as three small points lying against the breast. The front legs are free to the bases of the femora, though so tightly held in their narrow sleeves that their joints have no independent motion. The middle and hind legs are also incased in long, slim sheathes, but they always adhere close to the sides of the body. Thus the creature newly hatched much resembles a tiny fish provided only with two sets of ventral fins, but when it gets into action its motions are comparable with the clumsy flopping of a seal stranded on the beach and trying to get back into the water (fig. 8, *3*).

The infant cicada knows it is not destined to spend its life in the narrow cavern of its birth, or at least it has no desire to do so. With its head pointed toward the exit, it begins at once contortionistic bendings of the body, which slowly drive it forward. By throwing the head and thorax back the antennal tips and the front legs are made to project so that their points may take hold on any irregularity in the path. Then a contractile wave running forward through the abdomen brings up the rear parts of the body as the

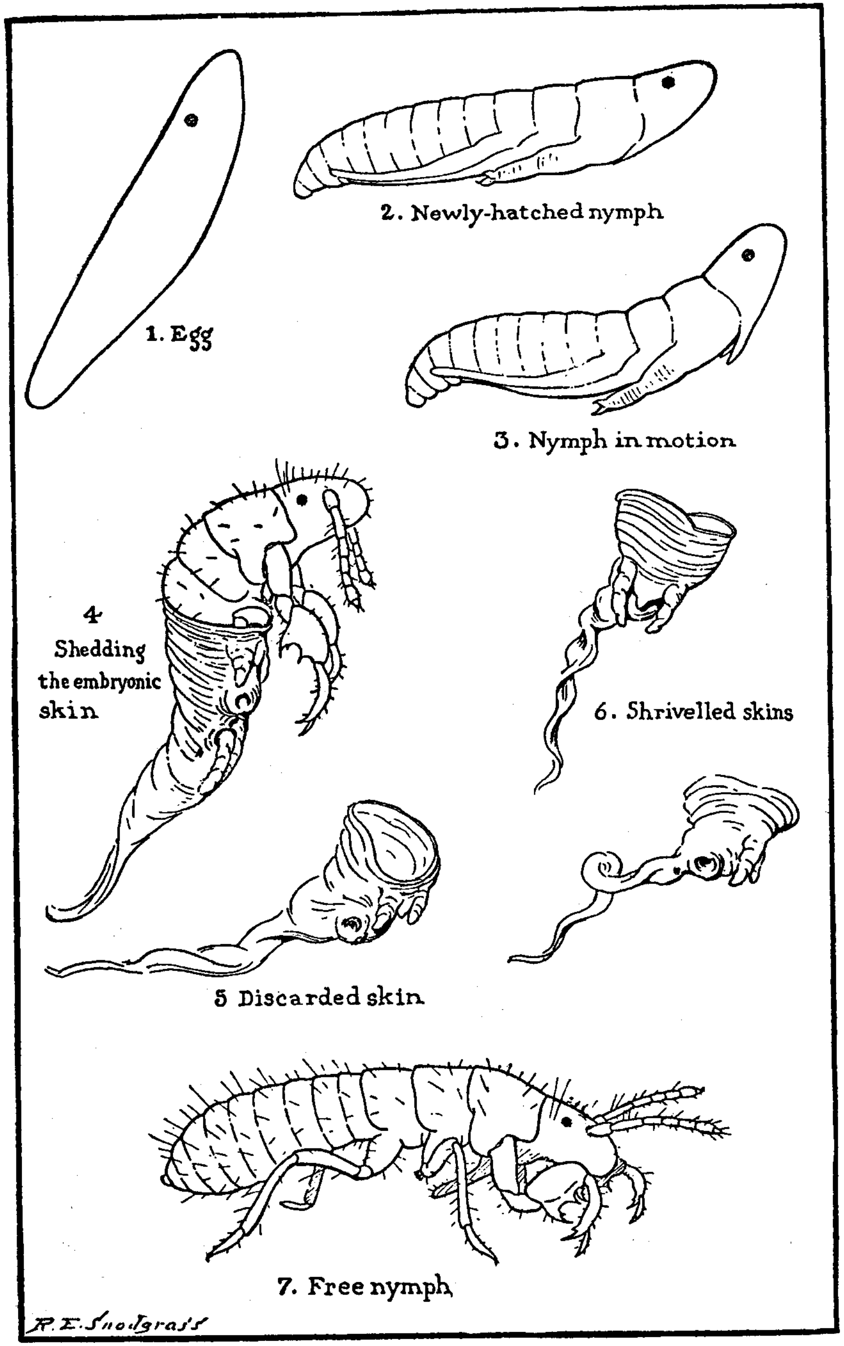


FIG. 8.—From the egg to the free nymph (greatly enlarged). The egg (*1*) shows the eye of the embryo near the upper end. The newly hatched nymph (*2*, *3*) is enclosed in a tightly fitting skin which is shed (*4*) as soon as the creature emerges from the egg chamber. The discarded skin (*5*) shrivels (*6*) as the free young cicada or nymph (*7*) runs away.

front parts are again bent back, and the "flippers" grasp a new point of support. As these motions are repeated over and over again, the tiny, awkward thing painfully but surely moves forward, perhaps helped in its progress by the inclined tips of the flexible eggshells pressing against it, on the same principle that a head of barley automatically crawls up the inside of your sleeve.

Once out of the door no time is lost in discarding the encumbering garment, but it is never shed in the nest, under normal conditions. If, however, the nest is cut open and the hatching nymph finds itself in a free, open space, the embryonic sheath is cast off immediately, often the shedding begins while the posterior end of the insect's body is still in the egg and the skin may be left sticking in the open end of the shell. Probably where this has been recorded as the normal process the observations were made on eggs in opened chambers. If the young cicada did not have to gain its liberty through that narrow corridor, it might be born in a smooth bag as are its relations, the aphids.

Watching at the door of an undisturbed nest during a hatching day we soon see a tiny pointed head come poking out of the narrow hole. The threshold is soon crossed, but no more; this traveling in a bag is not a pleasure trip. A few contortions are always necessary to rupture the skin and sometimes several minutes are consumed in violent twistings and bendings before it splits. When it does break a vertical rent is formed over the top of the head, which latter bulges out till the cleft becomes a circle that enlarges as the entire head pushes through, followed rapidly by the body (fig. 8, *4*). The appendages come out of their sheaths like fingers out of a glove, turning the pouches outside in. The antennæ are free first, they pop out and hang stifly downward. Then the front legs are released and they hang stiff and rigid but quivering with a violent trembling. In a second or so this has passed, the joints double up and assume the characteristic attitude while they violently claw the air. Then the other legs and the abdomen come out and the embryo is a free young cicada (*7*). All this usually happens in less than a minute and the new creature is already off without even so much as a backward glance at the clothes it has just removed or at the home of its incubation period. Sentiment has no place in the insect mind.

As the nymphs emerge from the nest one after another and shed their skins the glistening white membranes accumulate in a loose pile before the entrance where they remain till wafted off on the breeze. Each discarded sheath has a goblet form (*5*, *6*), the upper stiff part remaining open like a bowl, the lower part shrivelling to a twisted stalk. The antennal and labral pouches project from the skin as distinct appendages but those of the legs are usually inverted during the shedding and disappear from the outside of the slough, though the holes where they were pulled in can be found before the membrane becomes too dry.

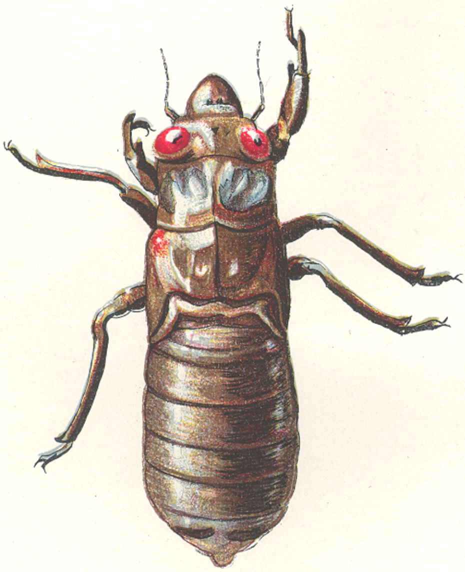
The nymph usually runs about at first in the groove of the twig containing its egg nest and then goes out on the smooth bark. Here any current of air is likely to carry it off immediately, but many wander about for some time, usually going toward the tips of the twigs, some even getting clear out on the leaves. But only a few nymphs are ever to be found on twigs where hundreds have recently hatched, as shown by the piles of embryonic skins; so it is evident that the great majority either fall off or are blown away very shortly after emerging. Many undoubtedly fall before the shedding of the egg membrance, for the inclosed creature has no possible way of holding on and even the free nymph has but feeble clinging powers. Those observed on twigs kept indoors often fell helplessly from the smooth bark while apparently making real efforts to retain their grasp. Their weak claws could get no grip on a hard surface. Instead, then, of deliberately launching themselves into space in response to some mysterious call from below (as usually described) the young cicadas simply fall from their birthplace by mere inability to hold on. But the same end is gained—they reach the ground, which is all that matters. Nature is ever careless of the means so long as the object is attained. Some acts of unreasoning creatures are assured by the giving of an instinct, others are forced by taking away the means of acting otherwise.

The cicada nymphs, like young scales, are at first attracted by the light. Those allowed to hatch on a table in a room left the twigs and headed straight for the windows 10 feet away. This instinct under natural conditions serves to entice them toward the outer parts of the tree, where they have the best chance of a clear drop to earth; but even so, adverse breezes, irregularity of the trees, underbrush and weeds can not but make their downward journey one of many a bump and slide from leaf to leaf before the earth receives them.

The creatures are too small to be followed with the eye as they drop, and so their actual course and their behavior when the ground is reached are not recorded. But several hatched indoors were placed on loose earth packed flat in a small dish. These at once proceeded to get below the surface. They did not dig in but simply entered the first crevice that they met in running about. If the first happened to terminate abruptly, the nymph came out again and tried another. In a few minutes all had found satisfactory retreats and remained below. The avidity with which they dived into any opening that presented itself indicates that the call to enter the earth is instinctive and imperative with them once their feet have touched the ground. See, then, how within a few minutes their instincts shift to opposites. On hatching, their first effort is to extricate themselves from the narrow confines of the egg nest. It seems unlikely that enough light can penetrate the depths of this chamber to guide them to the exit, but once out and divested of their encumbering embryonic clothes they are irresistably drawn in the direction of the strongest light, even though this takes them upward, just the opposite of their destined course. But when this instinct has served its purpose and has taken the creatures to the port of freest passage to the earth, all their love of light is lost or swallowed up in the call to reenter some dark hole, narrower even than the one so recently left by such physical exertion.

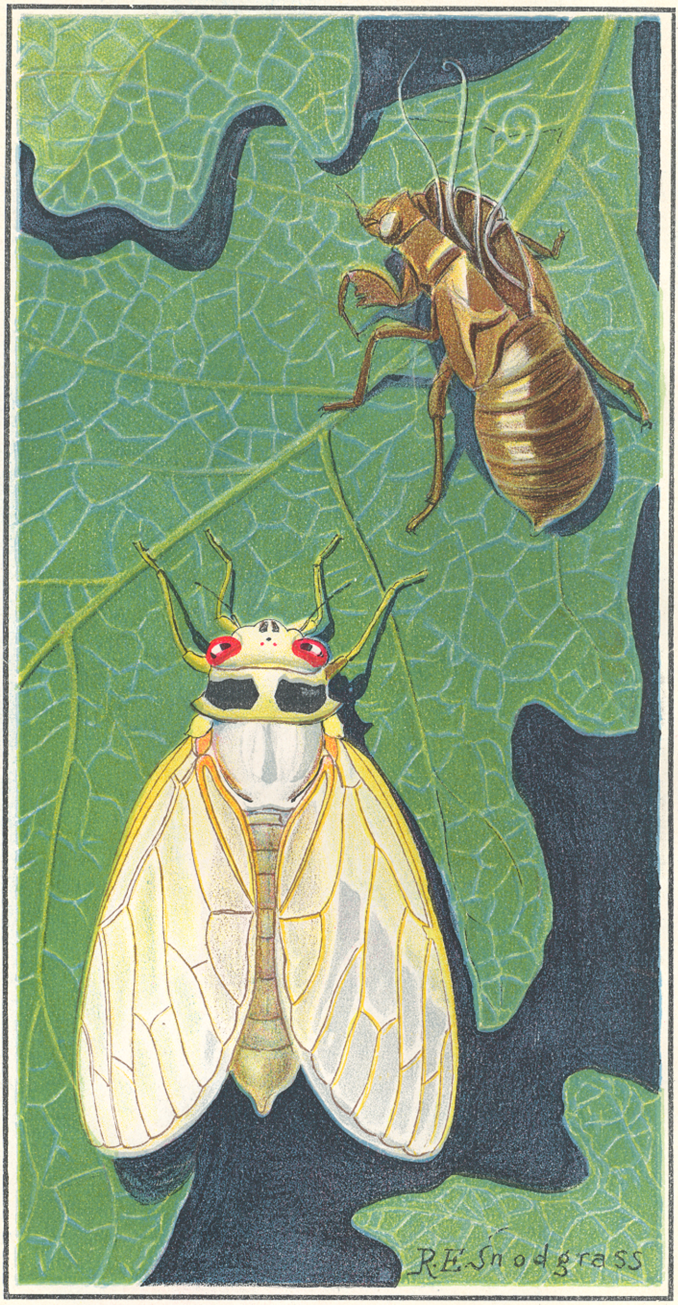
When the young cicadas have entered the earth we practically have to say good-by to them till their return. Yet this recurring event is ever full of interest to us, for, as much as the cicadas have been studied, it seems that there is still plenty to be learned from them each time they make their visit to our part of the world.

FIG. 9.—Young cicada larva, or nymph, ready to enter the ground (greatly magnified).



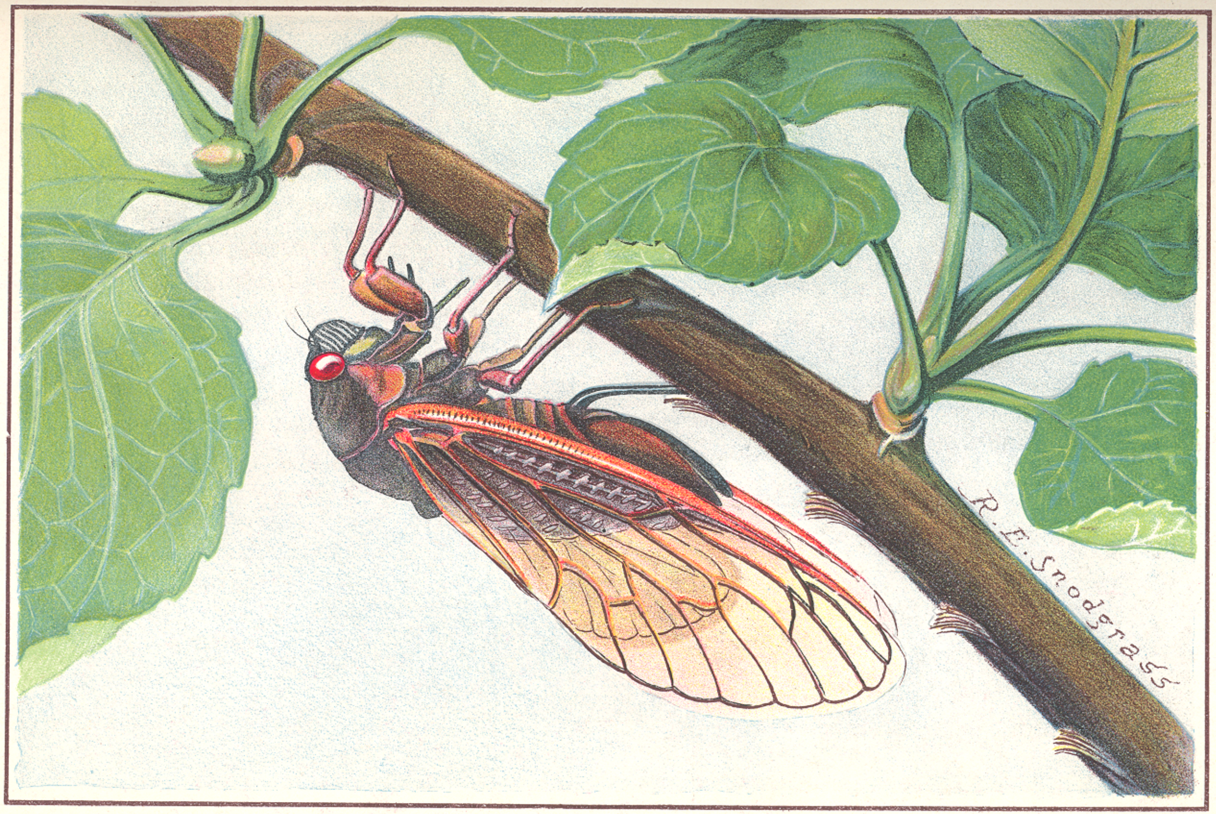
THE FULL-GROWN YOUNG CICADA, THE MATURE PUPA, AS IT EMERGES FROM THE GROUND.

(Twice natural size.)



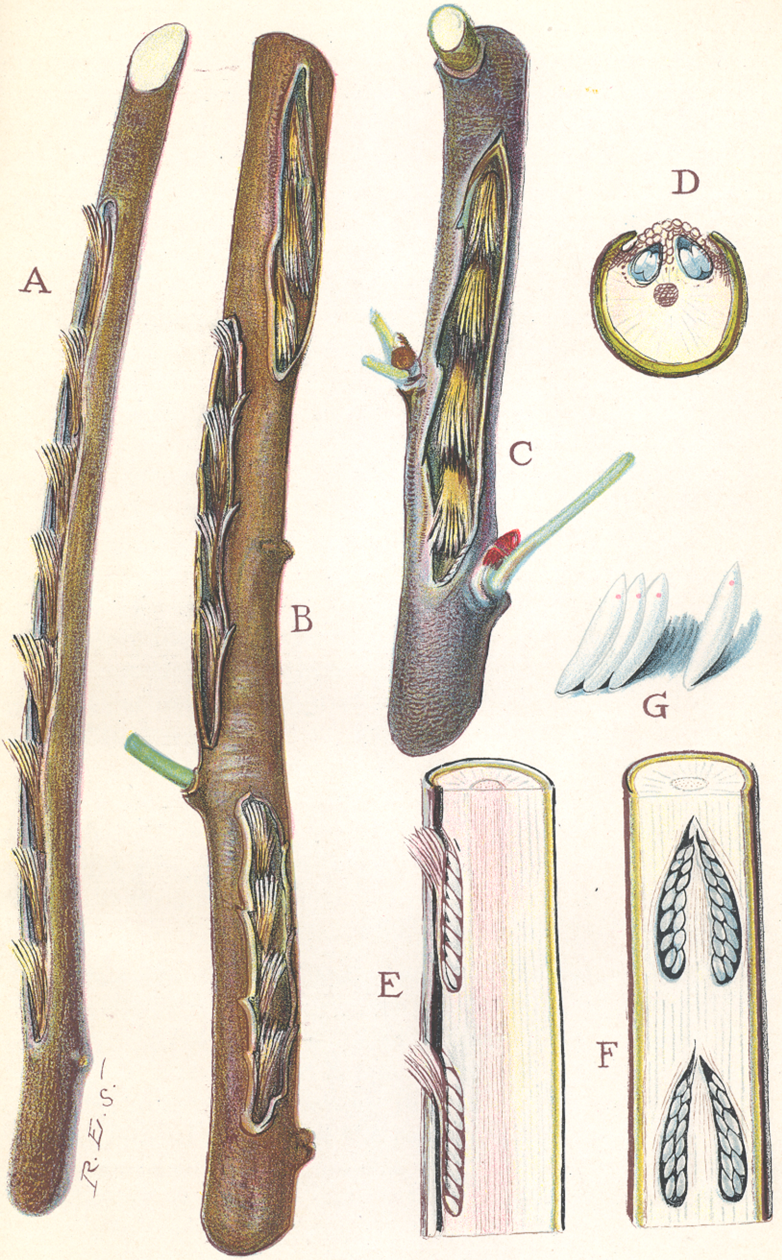
THE CICADA JUST AFTER EMERGING FROM THE PUPAL SKIN.

(Twice natural size.)

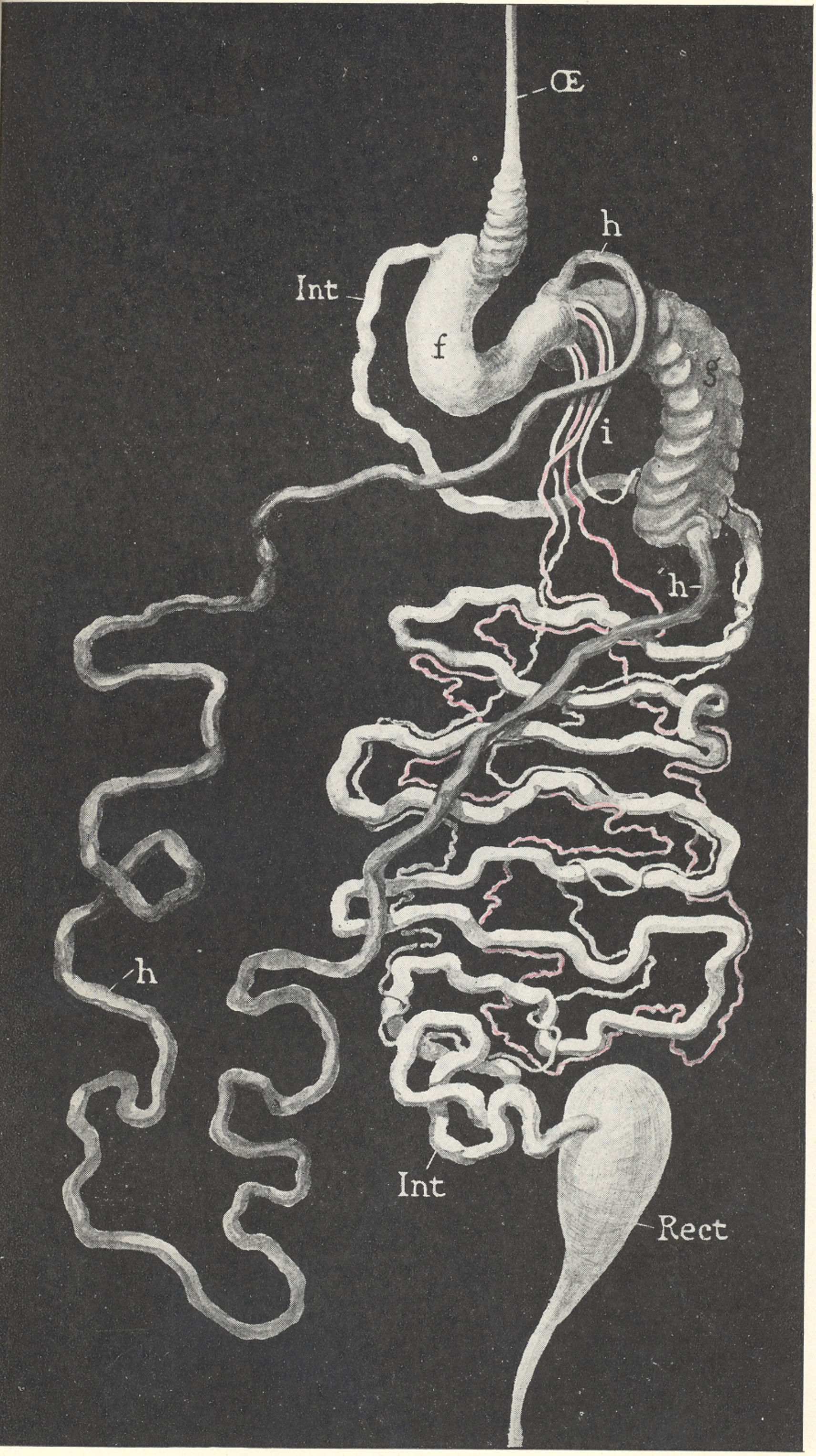


FEMALE CICADA DEPOSITING EGGS IN APPLE TWIG.

(Twice natural size.)



A, B, C, twigs of dogwood, oak, and apple containing rows of cicada egg nests; *D,* cross section of twig through an egg nest showing the two chambers, each containing a double row of eggs; *E,* vertical section through two egg nests showing the rows of slanting eggs and the frayed lip of the opening; *F,* horizontal section showing each chamber filled with double row of eggs.



THE ALIMENTARY CANAL OF THE CICADA.

Œ, the œsophagus; *f*, *g*, the two compartments of the stomach; *h*, *h*, *h*, tubular continuation of the stomach entering the walls of the first compartment where it unites with the small intestine (*Int*), which issues from near the front end of the stomach and finally opens into the rectum (*Rect*); *i*, Malpighian tubules arising from end of small intestine inclosed in the stomach walls.