A Memoir on the Anatomy and Life-History of the Homopterous Insect Pyrops candelaria (or „Candle-fly").

By

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With Plate 8—10.

[Although the "Candle-fly" or "Lantern-fly" of China, India etc. (*Pyrops candelaria* LINN.) has long been, as regards its general appearance, one of the best-known of Oriental Insects, its life-history has been very little observed, and Mr KERSHAW's account of its metamorphoses is quite new. The anatomy of the Auchenorrhynchous Homoptera has also been so fragmentarily investigated, that it is scarcely possible to institute fruitful comparisons with other species, so that it is better to leave the account here given uncommented upon except to note that it is usually considered that the labium of Hemiptera is 4-jointed, while Mr. KERSHAW maintains that in reality it is 6-jointed. The fact of the food-reservoir also extending to the tip of the snout, is also, I believe, novel. G. W. K.]

Pyrops candelaria [1]) is very common in Southern China (Pl. 8, Fig. 4),

1) The genus *Pyrops* has been also known as *Fulgora* and *Hotinus*, its true name having been diverted for the use of the species properly included in the genus *Zanna*. The type of *Pyrops* (i. e. *candelaria*) must be taken from the first section of SPINOLA, *candelaria* having been selected as type in a preliminary abstract in 1839. This I pointed out several years ago, and it has been accepted by the principal workers in the *Fulgoridae*. G. W. K.

where it is popularly known as the "Candle-fly", from an old idea that its snout was luminous, which is not the case.[1]) The adults feed almost entirely on Longan (Nephelium longana CAMB., N. O. Sapindaceae) and on the Mango-tree (Mangifera indica LINN., N. O. Anacardiaceae), but chiefly on the former, where a dozen or more may often be found on one trunk, and both nymphs and adults prefer to suck the thick bark of the trunk and larger boughs. The nymphs will, however, feed on various plants, some of which are enumerated later. Batches of eggs are probably laid as early as the end of March, and certainly at the beginning of April, but my Candle-flies laid at the end of the latter month. The male is a very long time courting the female; the latter sits on a tree-trunk, her head pointing upwards, while one or two males sit close on either side and slightly below her. The males do not fight, but now and again, one sidles threateningly towards another, whereon the latter quietly retreats, after which they resume their former station. But they are jealous

1) It is now pretty generally conceded that the *Fulgoridae* have no power of emitting any light, at least while living, though as late as 1898 PACKARD cited *Fulgora* in the category of Insects with phosphorescent organs (15). The story of the luminosity of the larger *Fulgoridae* appears to have originated with GREW who stated (7) that two or three specimens of *Fulgora laternaria* fastened to a stick would give sufficient light to travel with in the night; soon after, Mrs. MERIAN declared that some of these insects, on escaping from a box in the night, flew around, appearing like flames, the light each gave being sufficient for her to read a newspaper by (13). Her statement seems to have been the chief authority for the long continuance of this belief, the account of which the native tribes of Guiana treat as fabulous (9). The matter was for a long time fiercely discussed (4, 8, 10, 14, 22), but in light of the fact that observers such as KERSHAW (in this paper), CANTOR (10) and FLETCHER (6), in China, PRYER (18) in Borneo, PIFFARD (17) and CHAMPION (3) in South America, to mention only a few, have never found the slightest trace of luminous power either by day or by night, the negative side may be safely taken for granted. As early as 1792, OLIVIER doubted any luminosity (14a), and stated that in the south of France he had often found large species of *Cicadidae* entirely phosphorescent after their death, and this well known fact, that many animals become phosphorescent after death, may explain GREW and MERIAN's account. Still, it does not accord with the statement of the latter that the Fulgoras were alive and flew around the room while luminous, so that the only reasonable explanation lies, in my opinion, in the early and long continued confusion between the larger *Fulgoridae*, which look as if they ought to be luminous, and the Coleopterous Fireflies with are actually so. G. W. K.

of each other's attentions to the female, which consist in stretching out and vibrating the hind leg on the side nearest the female, and swaying the body from side to side. This exercise they continue all day long and appear to couple only at night, though I have twice seen them in cop. early in the morning, but they soon after uncoupled. They copulate in the usual way, like Heteroptera.[1]) The females lay several batches of eggs during the summer, the last laid by my Candle-flies being in the beginning of July. All the adults of the previous year seem to die off about August of the year following, and by the end of this month there are adults from the first eggs of the season, fresh from the last nymphal moult — their snout yellowish brown instead of red, and the chitinous parts of the genital organs still soft.

The trunk or one of the larger boughs of a Longan-tree or Mango is selected for laying — if a bough, the unterside thereof.[2]) Each ootheca contains 50—100 eggs, usually about 80. The egg (Pl. 8, Fig. 1) is smooth, of the palest yellow with a minute process at one end, and near this an elongate oval, flat patch — the lid of the egg, which in the natural position on the bark is on the outer side. The eggs are laid (Pl. 8, Fig. 3) in straight rows touching each other, and thinly covered with colleterial fluid, and finally brushed over with white waxy matter. The process of ovipositing is as follows: Taking up her position on the bark, the female, with a pulsating motion of the vagina, spreads a little colleterial fluid on the bark. The vagina is then slightly withdrawn from the bark Pl. 10, Fig. 24, an egg partly excluded, and the protruding end brought back against the fluid on the bark, to which it adheres; the vagina is then brought lower down and the egg is thus pressed backwards and adheres to the bark along the whole of its underside Fig. 25. More colleterial fluid is applied both over the whole egg and also on the bark in front, and the next egg is stuck end-on to the bark a little (an egg's length) in front

1) According to my observations, all Hemiptera copulate in the same way, viz. by the male mounting the female. The figures given by DE GEER and other older authors and copied by GADEAU DE KERVILLE et al., in which the sexes are represented as copulating end-on, sideways etc., merely show the situations assumed by them after copulation is finished, and before they have separated. G. W. K.

2) Apparently all the Fulgoroideae, so far as is known, deposit their eggs externally on tree-trunks, leaves etc., or under bark, except the *Asiracidae, Tropiduchidae* etc. which insert their eggs within the leaves and stems. G. W. K.

of the first. The backward movement of the vagina then brings the underside of the egg on to the bark, when its other end just touches that the egg just laid. The process is repeated till a whole row is completed, when the insect walks backwards down the bark to just below the last egg; she then walks forwards and feels with the tip of the labium till she finds the egg. Another row is then added, touching the first, and so on. The tarsus of one hind leg also touches the side of an egg-row, and thus acts as a guide. The colleterial fluid is yellowish-brown, not frothy, and is applied but thinly, though it entirely covers the egg-rows, thus forming a complete ootheca. The wax-rubbers (Pl. 9, Figs. 13 *Wr*, 24, 25 *R*) are every now and then much distended during oviposition. The bark is covered with colleterial fluid, an egg laid and also covered with fluid about every two minutes. The rows of eggs are usually added first to one side and then the other of the row first laid; egg-laying thus progresses from behind forwards, the insect starting each row at the bottom, finishing at the top, and walking back to start a new row. When ovipositing is finished, the insect straddles the ootheca with its legs and vigorously rubs the wax on the rubbers (first those of one side, then of the other, the abdomen rolling like a boat in a rough sea), on to the surface of the ootheca, walking backwards and forwards meanwhile and testing the surface with the tip of the labium. Before the waxy substance is rubbed on, the ootheca is light brownish in colour, but soon becomes whitened with the wax. The white over brown lends a purplish tint. This wax-rubbing process takes at least half-an-hour, and is very thoroughly done, though the covering of wax is very thin. An ordinary ootheca of 80 eggs takes about two hours and forty minutes to finish, exclusive of waxing; each row (say 20 eggs in a row) about forty minutes. The ootheca is made at any time during the day, but chiefly in the afternoon.

The eggs hatch in about 26 days. One end of the lid is forced up, and the nymph emerges sideways, dragging out part of the amnion of the egg (Fig. 22). The nymph is very flat in section and wholly dull whitish except the eyes, which are red-brown. Within an hour the nymph becomes very dark brown. The young nymphs (Pl. 8, Fig. 2) sit very upright, the tip of the abdomen almost touching the bark, the snout up in the air. They can run fast soon after hatching, especially sideways, and they already have considerable jumping powers. They have no trace of white waxy secretion, and are yellow-brown and very dark-brown in colouring, with many minute sensory organs scattered and grouped over head and body, which through a hand-lens look very much like the small ocelli on the heads of Lepidopterous larvae. The labium in the newly hatched nymph extends past the hind coxae nearly to the middle of the abdomen. The nymphs now sit in long and fairly ordered rows on the bark (Pl. 10, Fig. 26), remaining quiescent for hours, but occasionally one or another shifts its position and runs about at a great pace, afterwards returning to suck. If the end nymph of a row is threatened, he immediately sidles round the bough, the whole line following suit. When two nymphs meet on a small twig, they sometimes fight, grasping and striking with their forelegs, but they never seem to do any damage.

Amongst numerous herbaceous plants on which the nymphs will feed are Xanthium strumarium Linn. (N. O. Compositae) and Urena lobata Linn. (N. O. Malvaceae). The adults, as already mentioned, seem confined to Longan and Mango, but are occassionally found on Orange and Pumelo (Citrus decumana) and of course the nymphs will feed on all these. The colouring, during the whole nymphal period, varies but little, being lighter in the later instars, ochreous in various shades irrorated with black, and a few dark brown markings, chiefly in irregular lines on the abdomen. The cephalic extension which is very short and thick in the first instar (Fig. 27), inclines downwards in all the instars except the fifth, in which it is straight or very slightly curved upwards towards the tip. The nymphs, which grow very gradually between moults, undergo a surprising expansion at each moult, being nearly twice their former bulk as they issue from the old skin (Fig. 28). When nearing the fifth moult the nymphs have a slight secretion of wax on the posterior edge of the last abdominal segment, and on the abdomen generally.[1]) After the first moult the nymphs, which at first were very gregarious, become less so, and unless disturbed by Ants, Centipedes, Hunting-Spiders and the like, usually spend days in almost the same position, and generally moult there, the skin of the thorax splitting dorsally and the nymph squeezing out and mounting on the back of the old skin. It is at first very pale ochreous — almost white except the eyes, which are dark red brown. The Ants etc., generally seize the nymphs whilst the latter are moulting and therefore helpless. The nymphs

1) A few minutes before the 5th moult the abdomen is swollen, and the insect bends the tip up and down several times in succession.

turn to their ordinary colour within an hour. After the third moult (Fig. 29) the wings are easily distinguishable, and after the fourth (Fig. 30, Pl. 8, Fig. 5) moult the tegmina are long and narrow and still have on them the sensory organs which were formerly on the unexpanded mesonotum (Fig. 36). When emerging from the old skin at the first ecdysis, the snout is red, dotted with white and is curved upwards at about the same angle as the adult, and the whole insect is of a pale orange-red, but the tegmina in a few minutes become green spotted with yellow. This tegminal colouring however, disappears as the organs expand, and they also become pale orange, spotted with deeper orange. In an hour from the beginning of the moult, and after the wings have attained their full size, the green colour appears at the base of the tegmina, extends downwards and within two hours reaches the tips, and the wings, though pale, are of their natural colours. At the commencement of the moult, as soon as it has burst the cuticle of the thorax, the insect crawls out and begins to bend downwards till it hangs to the old skin by the hind tarsi. After a little time it bends upwards and catches hold of the old skin with the mid- and then the fore-legs, walks forwards till it reaches the bark, from which it hangs by the fore tarsi, and, by shaking, rids itself of the old skin, which clings to the tip of the abdomen. The wings are small and crumpled inwards like those of Lepidoptera at first. They attain their full size in an hour. In two hours and a quarter from the beginning of the moult the insect is in adult colouring, except that the wings are rather pale instead of brilliant orange, and the broad border not yet deep black, whilst the snout is not so red as at first — more yellow or red brown. The bright red colour of the snout is not attained till two or three weeks after the moult. Again the increase in bulk after the moult is very surprising. The insect begins to feed a day or two after the final moult. [1])

The wax of the *Pyrops* is formed in bundles or masses of thread or fibres. [2]) It melts with the heat, and dissolves in Benzine, but

1) The only figures or descriptions of nymphs of the larger *Fulgoridae* of which I know, are by Burmeister (1845, Gen. Ins., Fulgora subg. Pyrops), who figures a nymph of *Pyrops sp.*? (fig. 6), and myself, who have figured the nymph of an unknown Fulgorine in: Bull. Hawayian Plant. Entomol., Vol. 3, tab. 7, fig. 7—8; and have described and figured others in Bull. cit., Vol. 1, p. 389—390, tab. 29, fig. 11. G. W. K.

2) The development of the wax, or farinaceousness, is very remarkable in some neotropical genera, viz. *Phenax* etc., in which the tail may be

leaves a slight residue of fibres — much like the waste products of moulting. In this wax, which collects largely over the spiracles and in the wax-pockets, more than one kind of parasite, or rather, perhaps, inquiline, lives and obtains nourishment. One of these is a very tiny species of Mite, not uncommonly to be found in the wax filling the mouths of the spiracles; it is just visible to the naked eye as a speck, not so large as this fullstop. The larvae of the curious moth *Epipyrops anomala* WESTWOOD are parasitic on the adult *Pyrops*; often two or three larvae may be found on one Homopteron, though in the latter case two of these will be very young. They attach themselves to the dorsal part of the abdomen, shielded by the wings. In some seasons, practically all the *Pyrops* in certain Longan-Orchards will have these larvae on them.[1])

The eggs of *Pyrops candelaria* are parasitized, probably, by Chalcids, which, on emergence, leave a little round hole in the lid of the egg.

The following are the data for three Candle-flies:

Eggs laid	April 26th
„ hatched	May 22nd
First moult	June 15th
Second „	June 28th
Third „	July 12th
Fourth „	July 30th
Fifth „	September 8th, to adult.

Thus the eggs hatch in about 26 days, the first moult occurs in about 24 days from hatching, the next three moults at intervals of about 15 days, and the final moult in about 40 days, the entire nymphal period being about 109 days, and from laying of egg to adult insect about 135 days.

It is hardly necessary to add that the nymphs of *Pyrops candelaria* are exceedingly cryptic both in form and colour. They are

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twice as long as the insect itself; indeed in *P. auricoma*, these waxy processes are from four to five inches long (20 and 12). The wax of certain Poekillopteridae, viz. *Phromnia* etc., has been collected by the Chinese and employed in the manufacture of fine white wax (22). ROESEL (19) supposed that the waxy matter of the body was the cause of the supposed luminosity. G. W. K.

1) The first notice of caterpillars parasitic upon *Pyrops* was published by BOWRING in 1850; the subject has lately been investigated by PERKINS (16). G. W. K.

very much like the broken remnants of dead twigs jutting out from the bough, especially as they nearly always sit with the snout pointing away from the trunk, and often remain absolutely still for hours and sometimes even days together. Moreover Mango and Longan trees are very twiggy, especially the former, and are crowded with little broken stems. In fact, though the insects are very common here wherever their special trees are found, yet it is but rarely that one discovers a nymph in the open.

It may be added that the male is on an average smaller than the female, and that the sexes are about equal in numbers.

Judging from the effect on the plant produced by a number of nymphs as well as adults, feeding on small plants and trees, I think that there can be little if any harm done by *Pyrops* to large or moderate-sized trees, that is by the actual amount of sap they abstract. Whether their sucking induces fungus or other parasitic disease, I am not able to say.[1]

Part II.

Anatomical Notes.

The head of *Pyrops*, like that of most Homoptera, is greatly deflexed and inflexed; the epicranium is produced into a long snout-like process which projects forwards and slightly upwards; the labrum, with other parts of the head, forms a "beak" through the

1) Among other matters which may be alluded toxin connection with *Pyrops* are the following.

For observations on the use of the snout, cf. notes by FLETCHER (6) and especially by ANNANDALE (1).

Another fable connected with the large *Fulgoridae* was that they "sang" during the night-time. *Fulgora laternaria* was stated by STEDMAN (21) to be called "scare-sleep" by the Dutch in Guiana, but this was corrected by HANCOCK (9) who nevertheless said that the Fulgoras sang rarely. The real offender is a Cicadid [cf. KIRBY & SPENCE (10)]. Although some species of *Derbidae* and *Asiracidae* stridulate [cf. KIRKALDY (11)], the Lantern-flies do not do so, as is correctly asserted by CHAMPION (3).

In China, there is, or was, an edict issued against girls keeping "lanthorn-flies", but I know neither the reason nor the details [cf. WESTWOOD (22)].

For a coloured figure of a "luminous" *Pyrops*, cf. DONOVAN (5). G. W. K.

tip of which pass the setae. The clypeus (Pl. 9, Fig. 6 and 8 *cl*) and labrum (Fig. 6 *Lb*) are well developed and form a large triangular piece which projects far over the basal part of the labium (Fig. 6 *Lab*); the dorsal surface is slightly convex, the lateral margins turned down at right angles to the dorsal surface. On each side, and fitting along the lateral margins, of the clypeus, are two acutely triangular plates, which, although fitting closely against the edge of the clypeus, are free for their distal three-fourths. If these plates be turned back, the large hypopharynx comes into view, with the setae lying beside it. The lower pair of these, the maxillary setae (Fig. 8 and 11 *Mxs*) are in intimate connection with these plates, which I consider to be modified maxillae and shall call the maxillary plates (Fig. 8 and 11 *Mx*). A strong chitinous bridge that passes under the oesophagus and above the infraoesophageal ganglion, connects the basal parts of the maxillary plates and gives attachment to various muscles and supports the basal part of the hypopharynx. I call this the maxillary bridge (Fig. 6 and 11 *Mb*). The acutely-pointed tips of the maxillary plates fit against the sides of the pointed labrum and form a small channel through which the setae pass. The mandibles, or upper pair of setae (Fig. 7 *M*) form a pair of long, slender, chitinous rods, swollen towards their base and bent up at right angles and articulated to the head-capsule near the outer corners of the base of the clypeus. From the swollen basal portion, just anterior to the angular bend, a strong retractor muscle (Fig. 7 *Mr*) arises and proceeds to the dorsal and basal portion of the epicranium; a strong protractor muscle (Fig. 7 *Mp*) arises slightly anterior to the angular bend and proceeds to the head-capsule near the apex of the clypeus; the angular bend is constricted and differentiated, and forms a hinge. By the aid of these two opposing muscles the mandibles can be moved backwards and forwards. The maxillae, as stated above, form two acutely-triangular plates, the setae being probably greatly elongated palpifers. They are long, slender, chitinous rods (Fig. 11 *Mxs*), swollen towards their base, where is attached a large retractor muscle (*Mr*), which proceeds to the dorsal and basal portion of the epicranium; a protractor muscle (*Mp*) is attached to the swollen basal portion higher up, and runs up the maxillary plates (*Mx*); these opposing muscles move the maxillary setae backwards and forwards.[1])

1) If the maxillary seta is regarded as the entire maxilla, then what

The maxillae and mandibles are always described as being withdrawn into the head-capsule, but according to the above description their position of attachment is nearly normal. The apposition of the maxillary plates against the lateral edges of the clypeus has forced the mandibles slightly within, but this is the only withdrawal of these organs into the head-capsule.

To illustrate this view of the position of the mouth-organs, which was first brought to my notice by Mr. F. Muir, and demonstrated by him in this particular insect, we can consider a circular oral margin with the trophi in the normal position, consisting of labrum, elongated mandible and maxillae with elongated palpifers, as is found in certain Diptera. If in such a mouth the maxillae and labrum were to become triangular and their edges met from base to tip, then the mandibles and palpifers would become internal and the mouth become beak-like, similar to the Homopterous mouth.

The labium (*Lab*) forms a long six-jointed proboscis having a deep trough along the dorsal surface, into which pass the setae after leaving the "beak". The ventral portion of the first segment is produced into a chitinous process (Fig. 6 *bp*), the tip of which is bent upwards and forms the attachment of the protractor muscle of the proboscis, the other end attaching to the framework of the salivary syringe. Near the foot of the basal process arises a pair of retractor muscles attached at the other end to the maxillary bridge (Fig. 6 *Mb*). By the aid of these opposing muscles the proboscis can be thrust out or drawn into its membraneous base. The tip of the labrum (*Lb*) fits into the dorsal groove and forms a guide for the proboscis.

The oesophagus (*Oe*) is a slender, delicate tube, slightly swollen and bent at right angles behind the oesophageal nerve-ring. Anteriorly the walls are flattened horizontally, the lateral margins being turned slightly upwards; the walls become chitinized, especially the ventral one, which is attached anteriorly to the clypeus by a strong chitinous process. This forms the pharynx (*P*). Powerful muscles (Fig. 6 *Pm*) connect the dorsal plate with the clypeus, whose contraction draws the dorsal from the ventral wall, and on relaxing allows the plate to resume its former position by its own elasticity. The alternate contractions and relaxations induce a

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have called the maxillary plate must be looked upon as a development of the gena.

pumping action. The anterior edge of the dorsal plate of the pharynx is produced into a small membranous process, the epipharynx, which is in intimate connection with and very difficult to separate from the labrum. The anterior ventral edge of the pharynx is produced into a highly chitinized V-shaped organ, the hypopharynx. The salivary glands, operated by a complex syringe, open at the tip of the hypopharynx.

The salivary glands are highly developed; a pair of large white glands (Fig. 13 and 14 Sg^1), each one like a double string of pearls, pass down the dorsolateral surface of the food-reservoir into the abdomen, where each gland divides into two branches which reach beyond the end of the abdomen and are therefore recurved, forming a large mass lying on the top of the genitalia. Besides these two large glands there is a pair of large white branched thoracic glands (Fig. 13 and 14 Sg^2); also a pair of membranous sacs (Fig. 13 and 14 Sg^3) with long ducts. The ducts of these three pairs of salivary glands meet in a common junction on each side of the oesophagus, and the resulting pair of ducts descend into the rostrum or "beak", where they unite to form a single duct discharging into the barrel of the syringe.

The syringe (Fig. 17) consists of a chitinous, circular barrel (*Sb*) into which enters at one side the end of the salivary duct (*Sd*), a valve (*V*) allowing ingress of fluid to the barrel, but preventing its exit. At the opposite side a corkscrew duct (*Sd*) leads the saliva to the end of the hypopharynx. About the mid-height of the syringe-barrel is a cup shaped flexible plunger (*Pl*) attached all round the edge to the wall of the barrel; to its centre is attached the stiff, chitinous plunger-rod (*Pr*). The upper end of this rod terminates in a thick disc of chitin, to which are attached on the upperside, the protractor muscles (*Prm*), and on the under side the retractor muscles (*Rm*). The other ends of the protractor muscles attach to the maxillary bridge (Fig. 6 *Mb*), whilst the other ends of the retractor muscles surround the exterior of the syringe-barrel and attach around its base. Thus by means of these opposing muscles the plunger is capable of a pumping action, the inverted top of the syringe barrel serving as a guide (*Pg*) to the plunger-rod.

Posteriorly the oesophagus continues as a very slender tube to the anterior part of the abdomen, where it joins the stomach and gives off a very large diverticulum which I have called the food-reservoir (Fig. 6, 7, 14 *Fr*); this food reservoir passes backwards into the abdomen, where it dilates into a large, more or less globate, and delicate sac, with indications of a smaller lateral sac on either side, i. e. the whole sac is somewhat trilobed. Forwards the food reservoir extends as a large but delicate tube to the end of the snout-like epicranium, which it entirely fills. Within the mesothorax, and on the lateroventral surface, the food-reservoir emits several smaller diverticula which pass between the muscles of the thorax; one pair passing down into the coxae of the middle legs, and apparently ending blindly. These diverticula are not shown on the drawings.

The great size and numerous diverticula of the food-reservoir scarcely seem to justify the use of this term; it probably fulfils some physiological function — perhaps separating the wax-products from the food, before the latter passes into the stomach. The great deposit of wax over the interior of the snout could then be accounted for.

From the junction of the oesophagus and food-reservoir the stomach (Fig. 14 *St*) passes as a long, convoluted tube, varying but little in size, to the junction of the urinary tubes (*Ur*), where there is a well marked constriction. Behind this is a short intestine (*In*), without any well defined colon or rectum. The intestine continues into the hard, chitinous and very mobile anal style (Fig. 16 *As*) and tube (*At*). From the food-reservoir-junction to the anal tube the stomach, with intestine, is about sixteen times the length of the abdomen. The four urinary tubes are rather large in diameter, and about eight times the length of the abdomen; the basal part is colourless the rest (in old adults) orange-brown. They lie in a mass, tangled with tracheae and other ducts, chiefly under and amongst the genital organs.

The heart and dorsal vessel (Fig. 12 *H*) is a long simple tube, reaching from near the anus to the brain. It is of large diameter and slightly swelled at each segment of the abdomen; where it passes into the thorax it inclines downwards rapidly and narrows to a very slender tube, which passes forwards over the food-reservoir in the median line and, inclining to the right to clear the latter organ, dips toward the brain. The abdominal portion of the heart is of a rather bright light green during life — the rest is colourless.

The male has each testis (Fig. 14 *T*) composed of six lobes, the two testes being enclosed in a common membrane of a whitish colour, the lobes themselves being red. Each vas deferens (*Vd*) into which the lobes secrete, is about eight times the length of the abdomen, and is colourless. The pair of accessory glands (*Ag*) is each about sixteen times the length of the abdomen, and of a tallowy white. The vasa deferentia and accessory glands unite at the same point to form the ejaculatory duct (*De*) which, near the penis, enlarges into a flask-shaped vessel whose rapidly narrowing neck enters a short tubular part at the top of the penis-guide, and so into the duct of the penis. This latter is a complicated structure, having a pair of chitinous but flexible, transversely ridged, distensible sacs, one on each side of the penis and forming the walls of the duct and exterior walls of the organ. The whole penis is capable of a slight endwise motion on two slightly curved, chitinous and hard guide-rods which project one on each side, from the tubular penis-guide. The sacs are perhaps dilated by blood-pressure, and aid in holding the female during copulation (see Fig. 15 and 18).

The female has ten tubes in each ovary (Fig. 13 and 16 *Ov*), much ramified by fine tracheae; the two ovaries extend upwards and forwards slightly within the thorax, where the ends meet and are tied together with ligaments and tracheal capillaries. Each ovary discharges into the common oviduct by a curved tube (Fig. 16 *Ovd*), and just beyond the junction of the two oviducts is a small pair of globate accessory glands (*Ag*), one on each side. On the anterior wall of the common oviduct and between the pair of accessory glands is the spermatheca (*Sp*), consisting of a globate vessel emitting from the end a tube with one turn in it, beyond which are two dilatations close together, the anterior and smaller one emitting two slender ducts, each of which farther on branches into three long and very slender tubes which lie tangled up between the body of the colleterial gland and its large neck. Some distance behind the spermatheca, the neck of the colleterial gland opens dorsally into the oviduct; this gland is a large flask-shaped rather chitinous sac (*Cg*), lined over the interior with large secretory cells, the interior of the large duct or "neck" leading from the gland into the oviduct being thrown into longitudinal chitinous folds. In its natural position the colleterial gland, by means of its long neck, lies doubled over on the top of the oviducts and other organs. Behind the colleterial gland the common oviduct continues as a large and nearly straight passage to the Vagina (*Vag*). On each side of the vaginal orifice is a little, hard, chitinous, four-fingered, palm-like piece, which perhaps corresponds to the parts of Lepidoptera termed "harpes" by Sharp. They probably aid in the placing of the egg in its exact position in the ootheca.

The main nervous system (Fig. 13) is entirely cephalo-thoracic, there being no abdominal ganglia. There are three large ganglia — the brain (*B*), the infraoesophageal (*Bi*) and the thoracic ganglion (*Tg*). The two former ganglia are connected by very short and thick commissures, forming the oesophageal ring, through which the oesophagus passes. The thoracic ganglion is connected with the infraoesophageal by moderately long commissures. Besides other nerves, the thoracic ganglion emits two long commissures (*Nc*) which travel right down the abdomen, one on each side of the median line and on the ventral floor; they send out a nerve to each of the abdominal segments to the genitalia and other abdominal organs. In the newly hatched nymph the brain has a deep median, longitudinal constriction, as if the organ was really formed of two lobes (Fig. 19).

The only features of the musculature calling for special mention are the thoracic muscles (Fig. 12 *Lm*) of the hind legs. These muscles are enormously developed, and attach at their lower end to a strong, chitinous, mushroom-shaped piece, the thick stalk of which descends into the coxa.

In the median line and on the ventral side of the abdomen, held in position by tracheae and lying between the stomach and the genital organs, is a reniform glandular body of a rather bright red, connecting on either side with long tubular glands with many irregular constrictions, the glands being partly lobed and bilobed. These organs are present in both sexes, though much larger in the female. The long tubular and lobed glands are usually pinkish in colour. I have been unable definitely to make out the function of the glands (Fig. 13, 14 *Ug*), or a definite connection with any internal organ or with the hypodermis. They are in intimate connection with the small tracheae which arise from the basal part of the tracheae, which open by the spiracles onto the wax-pockets, and they are also in intimate connection with the fat-bodies. There are many points about the body [1]) besides the wax-pockets, where wax collects — on the dorsolateral part of the base of the abdomen, whence it rubs off into the underside of the wings; on the anal style and tube; on

1) The white dots on the cephalic prolongation are caused by minute dermal wax-glands.

the coxae, in fact wherever the junctions of the body-sclerites form crevices where the wax can lodge. The spiracles especially are usually quite covered with wax-fibres. The blood of this insect, judging from its appearance on a slide, seems to be more or less charged with wax.

The wax-pockets (Fig. 13 *Wp*) are deep invaginations of the pleural region of the cuticle between the abdominal segments; the wax-rubbers (Fig. 13 *Wr*) are cushion-like evaginations of the cuticle of the pleural region of the abdominal segments. Whilst the insect is ovipositing, the wax seems to be squeezed out of the wax-pockets onto the rubbers, probably by muscular movements of the pockets aided by blood pressure.

Although the general arrangement or pattern of the nymphal sensory organs is very similar on either side of the body, yet it is seldom identical. Nor are many nymphs exactly the same as regards the number and disposition of these organs. Each of the little cuticular craters has, standing up in its interior, a chitinous rod or bristle the base of which connects with a nerve, but this I did not trace any further (Pl. 10, Fig. 34).

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Explanation of figures.

Ag accessory gland
An antennal nerve
As anal style
A anal tube
B brain
Bi infraoesophageal ganglion
Cf chitinous framework
Cg colleterial gland
Cl clypeus
De ductus ejaculatorius (anterior part cut away in Fig. G)
Ep epicranium
Fr food reservoir
Gs genital style
H heart
In intestine
Lab labium
Lb labrum
Lm thoracic margin of hind leg
M mandible
Mb maxillary bridge
Mds mandibular setae
Mp protractor muscle of mandible
Mps protractor muscle of maxillary setae
Mr retractor muscle of mandible
Mrs retractor muscle of maxillae
Mx maxillary plate
Mxs maxillary setae
Nc abdominal nerve cord
On ocular nerve
Ov ovary (right hand one cut away in Fig. L)
Ovd oviduct
P pharynx
Pg guide to plunger rod
Pl plunger
Pm pharyngeal muscles
Pn pronotum
Pr plunger rod
Prm protractor muscle
Rm retractor muscle
Sb syringe barrel
Sd salivary ducts
Sg^1, ^{2}, ^{3}, salivary glands
Sp spermatheca
St stomach
T testes (only the left hand one shown in Fig. J)
Tg thoracic ganglion
Vag vagina
Vd vas deferens
Ur urinary tubes
Wp wax pockets
Wr wax rubber
a base of maxillary plate broken off
ap attachment of protractor muscles of proboscis

b torn membrane (in Fig. F)
bp basal process of labium
oe oesophagus
tr trachea
v valve

Plate 8.

Fig. 1. Egg, natural size and enlarged.

Fig. 2. Nymphs, just recently hatched, enlarged.

Fig. 3. Ootheca, natural size.

Fig. 4. Adult female, natural size.

Fig. 5. Nymph after 4th moult, natural size.

Plate 9.

Fig. 6. Longitudinal section through head and part of thorax.

Fig. 7. Basal part of mandibular seta.

Fig. 8. Transverse section through rostrum (or beak), showing pharynx open.

Fig. 9. Pharynx shown closed.

Fig. 10. Section of labium showing channel in which the setae lie, and grove in which tip of labrum fits.

Fig. 11. Maxillary plate and seta.

Fig. 12. Longitudinal vertical section of male.

Fig. 13. Longitudinal horizontal section of female.

Fig. 14. The same of the male.

Fig. 15. Longitudinal vertical section of the end of the abdomen of the male.

Fig. 16. The same of the female.

Fig. 17. Longitudinal section of salivary syringe.

Fig. 18. Transverse section and exterior views of penis; the genital styles not shown.

Fig. 19. Cephalo-thoracic nerve-ganglia during the first nymphal instar, just after hatching.

Fig. 20. Longitudinal section through a row of eggs.

Fig. 21. Transverse do.

Plate 10.

Fig. 22. Portion of egg patch, showing some of the eggs hatched out, the lids open, end the amnion dragged out.

Fig. 23. Egg enlarged.

Fig. 24. Posterior end of abdomen of female; an egg just stuck to back and vagina slightly withdrawn.

Fig. 25. Egg being shoved backwards, to lie along bark and touch end of egg already laid.

In Fig. 15 and 16 *R* wax rubbers; *A* anal style.

Fig. 26. Nymphs moulting, other side row of nymphs not long hatched.

Fig. 27. Nymph before 1st moult of first instar. a = tibia and tarsus.

Fig. 28. Nymph of 2nd instar.

Fig. 29. Nymph of 3rd instar. a = looking on end of tip of snout; x = lateral view of snout.

Fig. 30. Nymph of 4th instar. b = fore tarsus of 4th instar; c = fore tarsus of adult.

Fig. 31. Nymph of 5th instar.

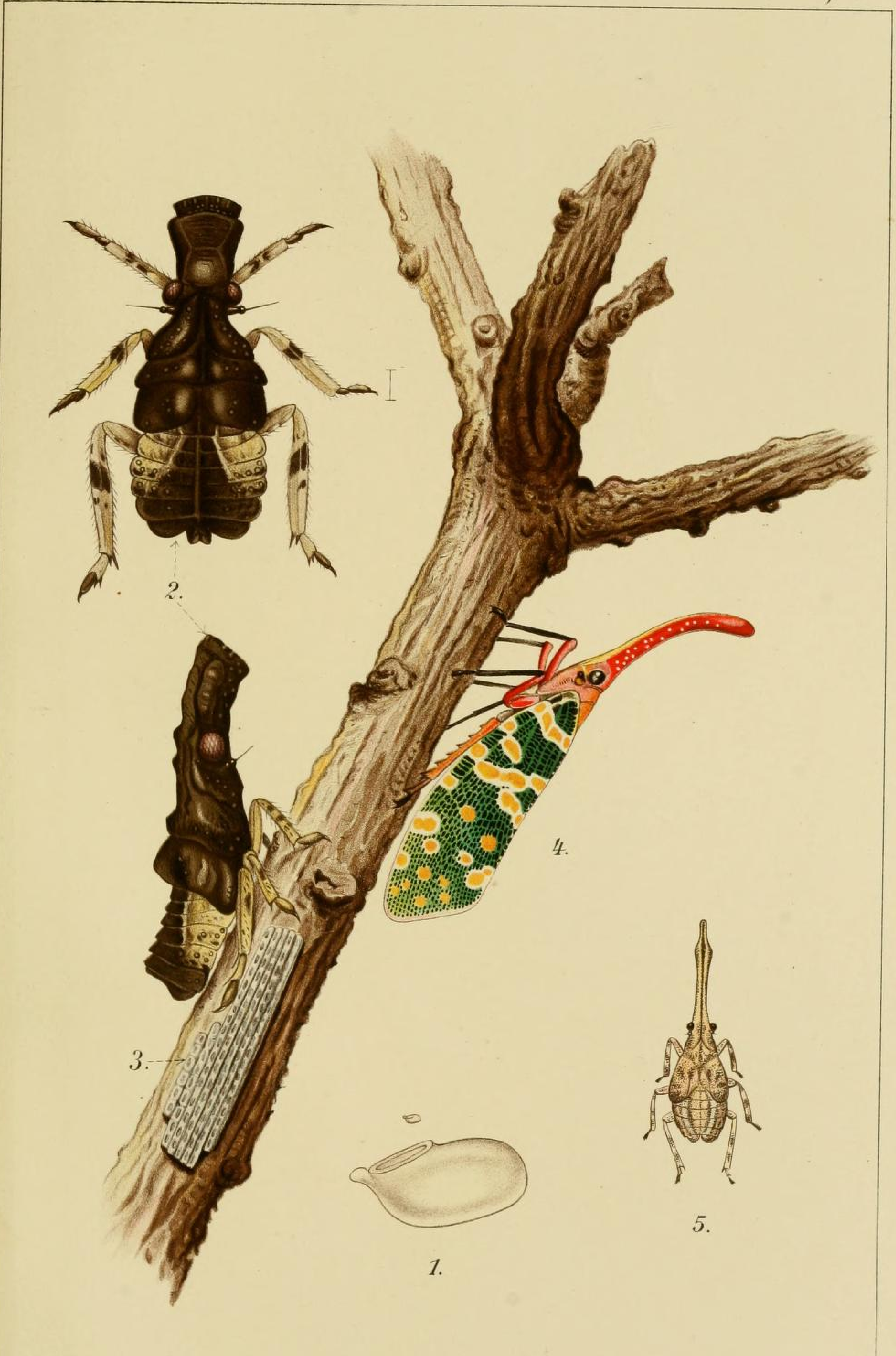
Fig. 32. Tegmen in 5th instar, showing sensory organs. = section of same.

Fig. 33. Lower wing during 5th instar, showing sensory organs.

Fig. 34. Tegminal sensory organs, much enlarged.

Fig. 35. Sensory organs during 5th instar, just before final moult to adult.

Fig. 36. Nymph (during 3rd instar) in natural position on bark.



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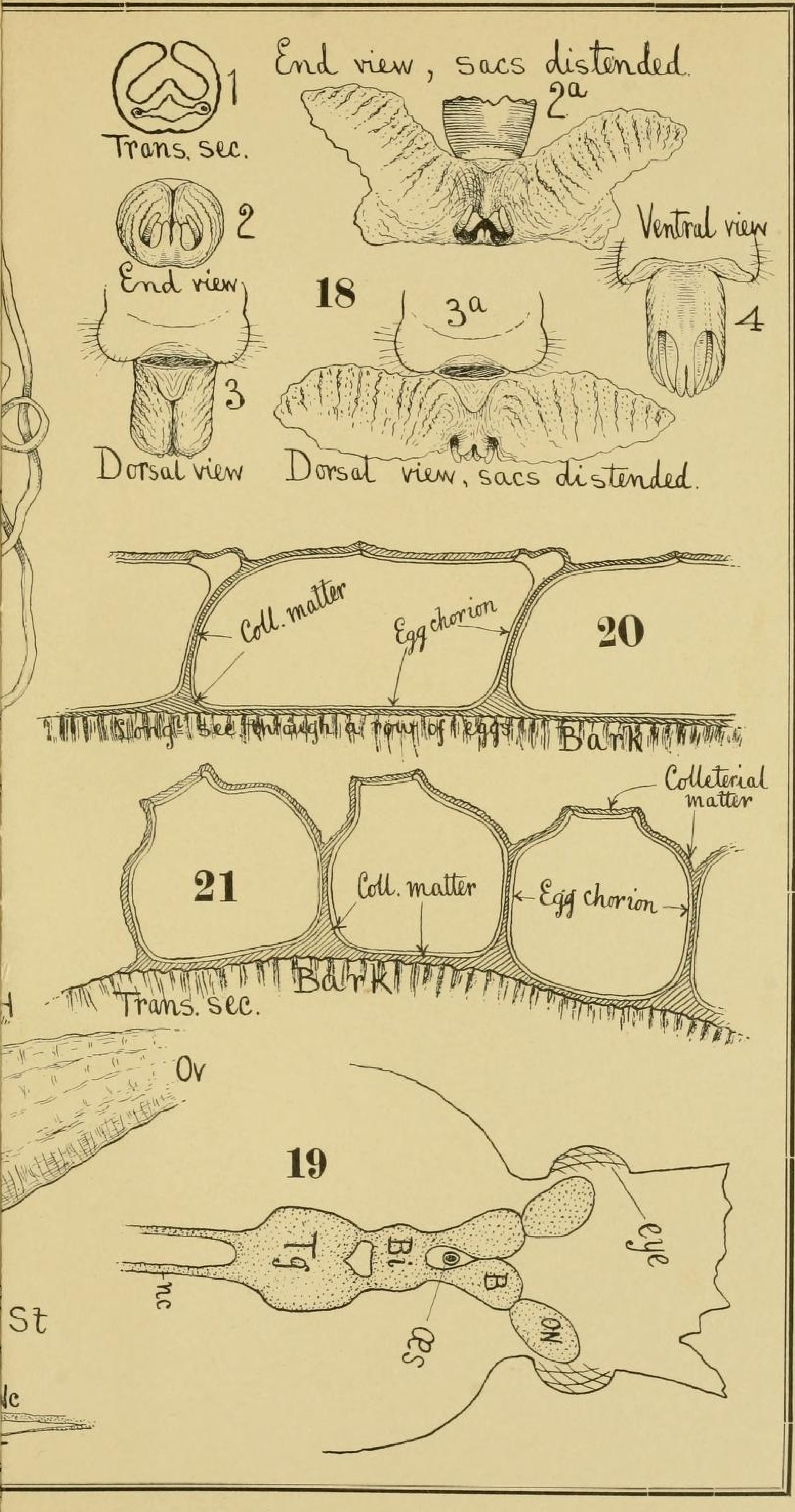
1
Trans. sec.
End view, sacs distended.
2a
2
End view
Ventral view
18
3a
4
3
Dorsal view
Dorsal view, sacs distended.
Coll. matter
Egg chorion
20
Bark
Colleterial matter
21
Coll. matter
Egg chorion
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Trans. sec.
19
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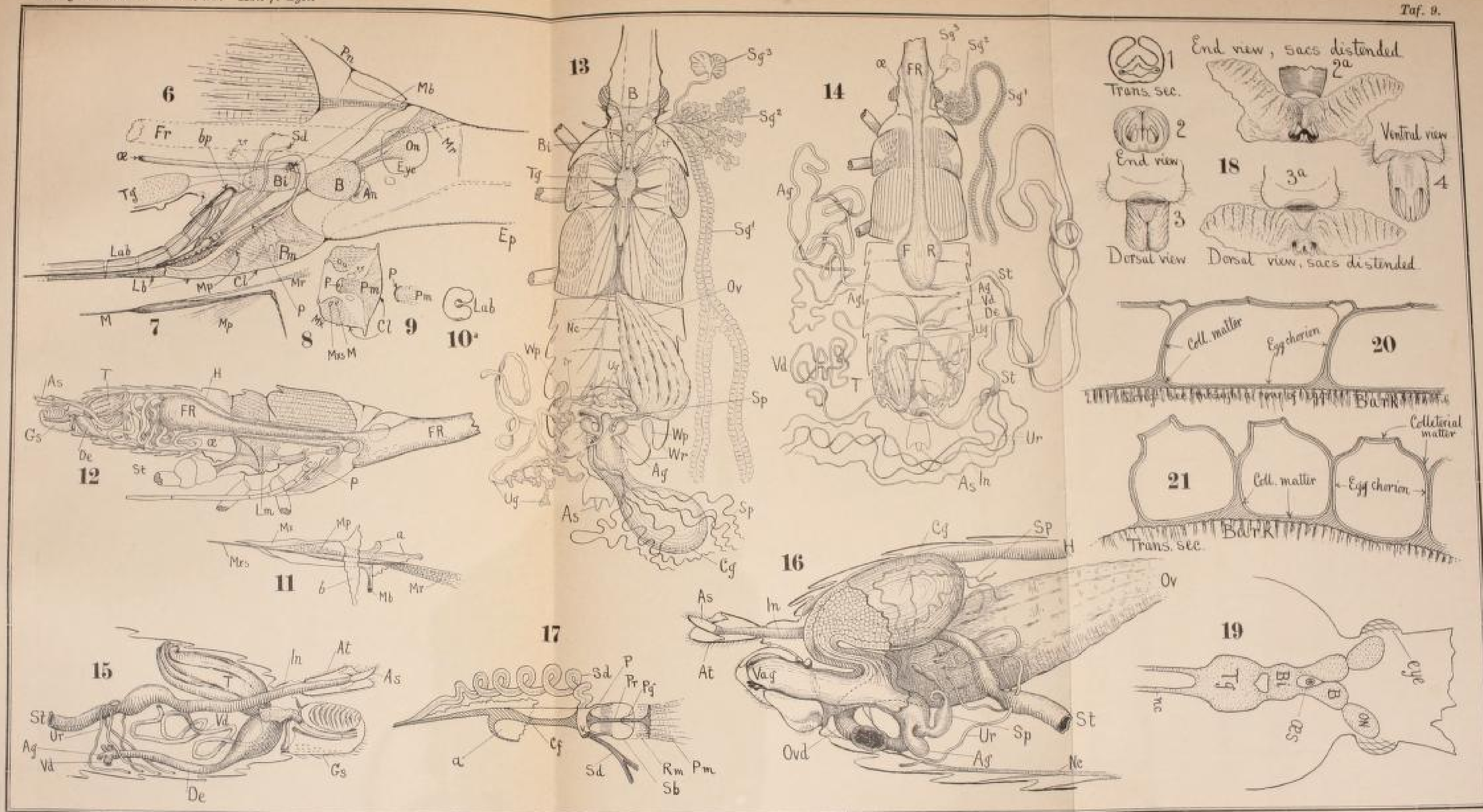
6
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10a
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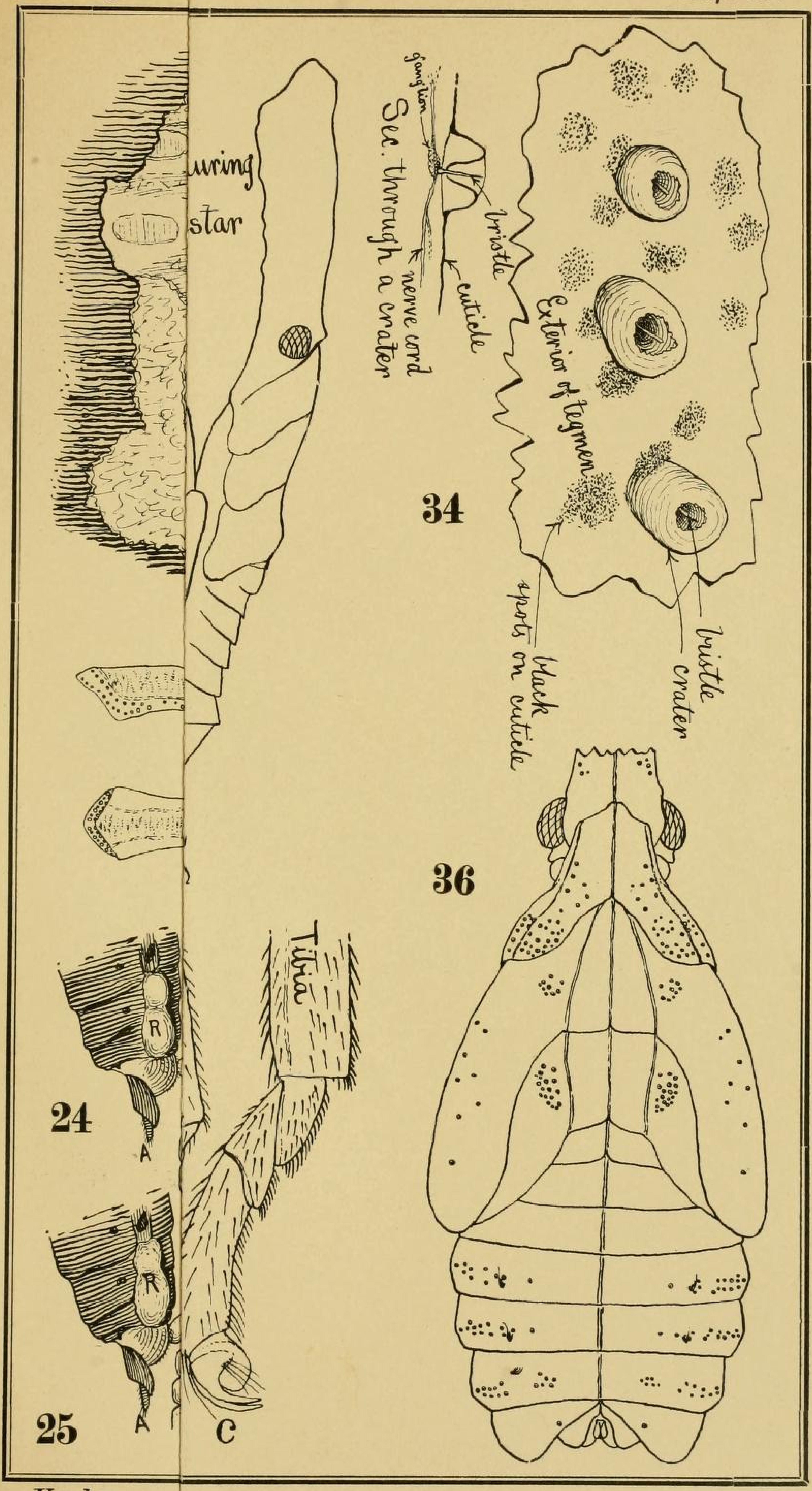
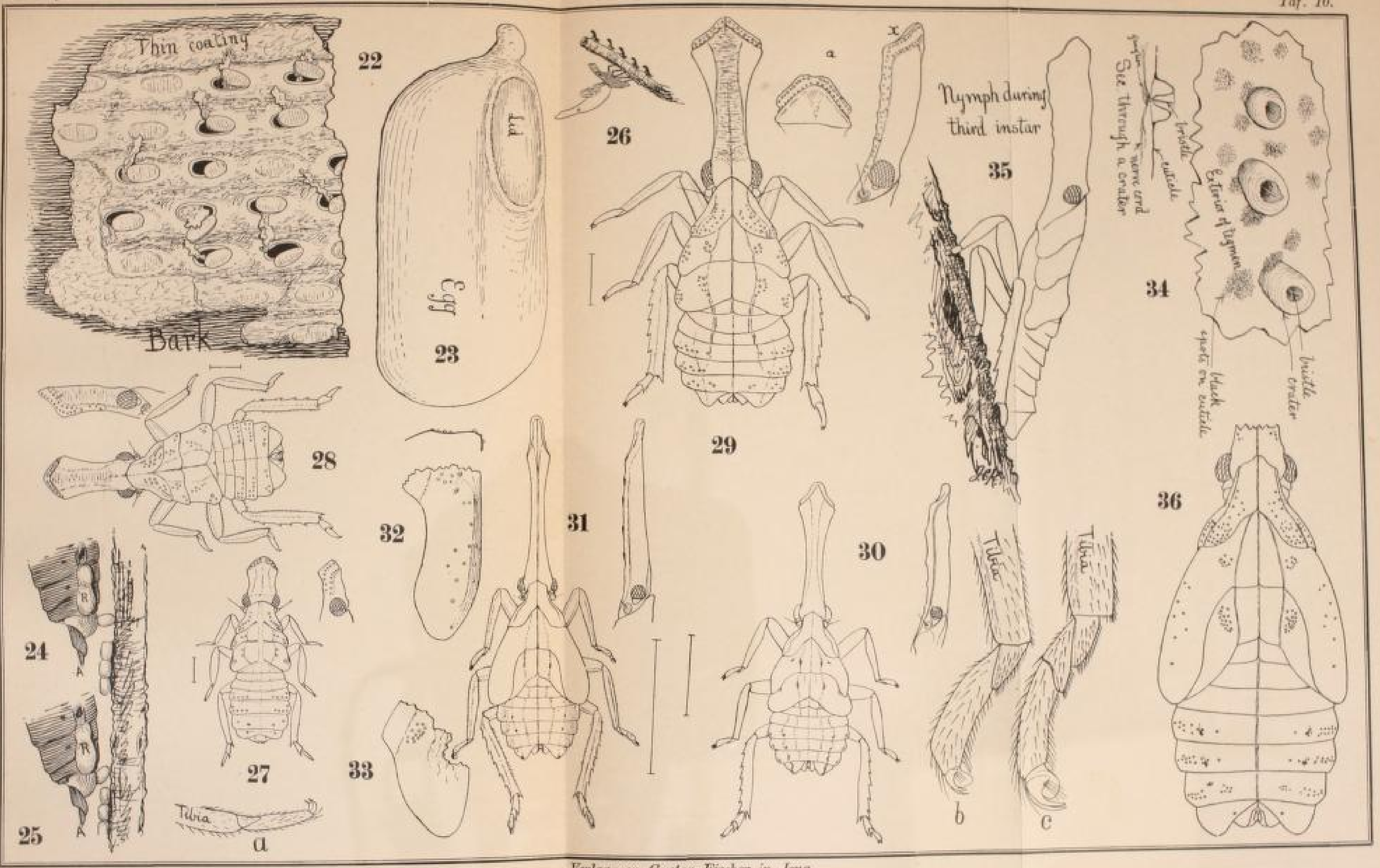
Trans. sec.
End view
Dorsal view
End view, sacs distended
Ventral view
Dorsal view, sacs distended
Coll. matter
Egg chorion
Bark
Colleterial matter
Trans. sec.


uring
star
ganglion
Sec. through a crater
bristle
cuticle
nerve cord
Exterior of tegmen
bristle
crater
black spots on cuticle
34
36
Tibia
R
24
A
R
25
A
C

Kershaw.


Thin coating
Bark
22
Lid
Egg
23
26
a
x
29
Nymph during third instar
35
See through a crater
nerve end
cuticle
bristle
34
Exterior of tegmen
black spots on cuticle
bristle crater
28
32
31
30
Tibia
b
c
36
24
25
27
33
Tibia
a