PSYCHE.

THE DEVELOPMENT OF THE ROSTRUM IN RHYNCOPHOROUS COLEOPTERA.— PLATES VI–IX.

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I. Introductory.

MUCH has been learned of late from the study of the development of parts which suddenly appear externally in insects at transformation. There remain a few such parts which have not as yet received the attention of investigators. One of these is the rostrum of rhyncophorous Coleoptera. Notwithstanding its size and singular appearance, and the interest bestowed upon it as an adult structure by systematists, I cannot discover that its development has received any attention whatever. Although it is long, often longer than legs or wings, and although appendage-like in appearance, it is not an appendage in the same sense as these, but is a prolongation of the front part of the head and carries the antennae upon its sides and the mouth parts at its tip.

Dr. Le Conte, in the preface to his synopsis of the Rhyncophora of North America, in enumerating important questions for further study in the groups, said, "The homologies of the parts of the head, by reason of which the front portion becomes extended into a beak, and the basal piece on the under surface (which separates the gular sutures in normal Coleoptera) disappears, are also worthy of attention." This study of the development of the rostrum has been undertaken because it seemed likely to yield answers to some of these questions of the systematist, and at the same time to throw some new light on the general problems of metamorphosis.

I have used, mainly, the two species of Rhyncophora, *Mononychus vulpeculus* Fabr. and *Balaninus nasicus* Say. The former lives its whole developmental life in the capsules of the blue flag — a period of about nine weeks.[1] *Balaninus nasicus* (Plate VI, fig. 1) is known as the acorn weevil. The adult bores a hole into the developing acorn and in it lays her egg. This takes place in the summer or early fall. It soon hatches into a small white larva and grows rapidly, living upon the

[1] A detailed life history of this species has been given by Professor Needham. *Biol. Bull.* Vol. I, pp. 179–191.

meat of the nut which, as a rule, it will have wholly consumed by the time it is grown (Plate VI, fig. 2). When the nut falls the larva leaves it, buries itself in the earth at considerable depth, which is probably to avoid freezing. Ordinarily but one larva lives in a nut, though two and even three are sometimes found. Since in this case they are invariably smaller there is an evident lack of nourishment.

The adults appear above ground any time after the first of June, some even as late as July or August.

My material, which abundantly represented all stages of metamorphosis, was obtained by collecting a large quantity of acorns of the white oak (*Quercus alba*) when they fell in autumn, and placing them on a box filled with earth and grass sod. In a very little while the larvae bored out, entered the earth and buried themselves near the bottom of the box. This was kept in the Laboratory where the normal temperature was about 21° C. and probably never lower than 18° C.

Specimens were taken out at weekly intervals and fixed. Through the winter there were no signs of metamorphosis. This suddenly took place in the spring.

The first imago was seen April 9th, and within the next two weeks they were abundantly found. April 23 the remaining specimens which represented all stages of development were taken out and fixed. This does not agree with Miss Murtfeldt's results, but if left undisturbed they might possibly not have emerged until much later.[1]

Balaninus nasicus Say (Plate VI, fig. 1), representing the extreme development of the Rhyncophorous rostrum, and, being the species I had under observation and control, has been the chief subject of study for the following paper. The account of the larva in particular is drawn wholly from *Balaninus* while *Mononychus* has served best for the study of internal metamorphic processes.

Methods — For fixation 70 % alcohol, first heated to boiling, was used with excellent results; paracarmine was used for staining *in toto* with a counterstain of orange or methyl blue on the slide; haematoxylin was mainly used for staining sections followed by eosin or picro-fuchsin as counterstain; whole preparations were stained with borax-carmine and differentiated with acidulated alcohol.

The development of the rostrum will be best understood by studying the parts concerned, firstly, in the larva, which has no rostrum; secondly, in the adult, which has it complete; and thirdly in transforming larvae and pupae, which show every phase of its growth.

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[1] Excellent accounts of the habits of *Balaninus* have been published by Dr. John Hamilton in *Can. Ent.*, Vol. 22, pp. 1–8, 1890, and Miss Mary E. Murtfeldt in *Insect Life*, Vol. VI, p. 318, 1894.

II. The Larva.

The larvae of *Balaninus nasicus* Say vary considerably in size. The average larva, however, is about 15½ mm. from tip to tip; measured over the back, as it lies in its ordinary curled position, about 18 mm.; and 4 mm. in diameter. It is uniformly white in color with brown mandibles and an imperfect dorsal prothoracic shield of yellowish chitin. On each side are four rows of very small setae, two on either side of the spiracles. The ventral setae arise from conspicuous prominences. A few scattering ones lie on the under side of the body.

This larva (Plate VI, fig. 2) is of a very degenerate type. It has no organs except those for feeding. It wholly lacks eyes, antennae and legs. Correlated with the absence of eyes, the brain is destitute of optic lobes. The head is unusually small and the short, and close-set face and mouth parts give no hint of the remarkable extension they will undergo at transformation.

Mouth Parts.

Save for a slight reduction in maxillae and labium the mouth parts are much like those of other beetle larvae. The labrum is broadly rounded and supports near its edge ten spines and on the dorsal surface two or three pairs additional. At the middle of its posterior edge it is slightly produced backward into the clypeus. The mandibles (Plate VIII, fig. 12 *md.*) are somewhat triangular in outline with an ill-defined tooth upon the inner edge and two larger ones at the tip. They are moved by two large muscles (Plate VIII, fig. 12 *ab.* $m.^2$ and *ad.* $m.^3$) which occupy the greater part of the head. The adductor is (*ad.* $m.^3$) larger and is attached through a stout tendon to the inner basal angle of the mandible. It is made up of numerous straight fibres, some of which arise from the wall of the head, others from a median dorsal chitinous endoskeletal ridge. The fibers of the abductor (*ab.* m^2.) are all attached to the latero-ventral wall of the epicranium. These unite into a short tendon which connects with the outer basal angle of the mandible.

Maxillae (Plate VIII, fig. 12, *mx.*) are comparatively simple. Cardo and stipes meet at a right angle. The latter is fused with the lacinia, which is armed on its edge with a row of ten spines. The galea is two jointed with four minute prominences on its tip. Palpus is wanting. Three sets of muscles serve to move the maxilla—two adductor and one abductor. The larger adductor (Plate VIII, fig. 12, *ad.* $m.^1$) is inserted near the tip of the lacinia. It is a compact band of fibers and takes its origin at the rear of the head. The lesser adductor (Plate VIII, fig. 12, *ad.* $m.^2$) springs from the ventral part of the tentorium and is inserted

near the middle of the stipes. The abductor (Plate VIII, fig. 12, *ab. m.*[1]) springs with the latter from the tentorium and is inserted on the external angle of the stipes beyond the basal hinge. Four large spines arise from the external face of the maxilla; one near the union of cardo and stipes; two near the base of the galea and one upon the basal segment of the galea.

The *labium* (Plate VIII, fig. 12, *l.*) is considerably reduced and its parts consolidated. The mentum is large. Paraglossae are broad; the glossa is triangular; the palpi are short and two jointed. Two pairs of muscles (Plate VIII, fig. 12, *l. m.*) take origin in the posterior region of the head and are inserted into the tip of the labium.

Thus there appear among the muscles that move the mouth parts two pairs springing from the tentorium and belonging to the maxillae; and five pairs springing from the hinder parts of the walls of the head:

Two large pairs belonging to the mandibles.

One lesser pair belonging to the maxillae.

Two still smaller pairs belonging to the labium.

The relations of these muscles will be found of importance when the shifting of parts in development is considered.

Anterior Parts of Alimentary Canal and Salivary Glands.

The *Alimentary Canal* agrees in general with that of other phytophagous beetle larvae. The esophagus is short, merging into the proventriculus at the end of the prothoracic segment. Numerous dilator muscles arranged along the esophagus are attached to the dorsal wall of the head immediately back of the labrum.

The *proventriculus* or crop is large and cylindrical in shape, slightly tapering at its posterior end into the long and twisted ventriculus, along each side of which is arranged in a longitudinal series a row of somewhat conic caeca, whose individual length is somewhat less than the diameter of the ventriculus.

The *Salivary Glands* consist of a single pair of long, tortuous, simple tubes lying at the sides of the esophagus. The tubes are slender, showing about two and a half cells in cross section, the individual cells rounded externally, giving an irregular outer surface to the gland, and internally the cavity winds a tortuous course between the internal prominences of the cells. The nuclei are more or less hemispherical, often more or less concave on the inner face and they always extend on that face numerous conic or jagged processes toward the lumen of the gland.

III. Imago.

The most striking peculiarity of the adult beetle, a characteristic of all Rhyncophorous Coleoptera, is a prolongation of the anterior part of the head which forms the rostrum. It is with this part that we are chiefly concerned. An understanding of its development will be best had if its structure in the adult beetle is first clearly understood and compared with that of the larva, just described.

The rostrum of Rhyncophora is unique in that it is not made up of elongated mouth parts as in Hymenoptera, Hemiptera, Diptera and Lepidoptera; not even in part, as in scorpion flies (Mecoptera); but it is the greatly elongated fore part of the head, the part between the eyes and the mouth; and it bears the mouth parts, which are similar in shape to those of other Coleoptera, at its apex. It varies from 3½ to 7 mm. in length in *Balaninus nasicus*, being generally longer than the entire body of the weevil. It is gently decurved and has a deep groove on each side for the reception of the reflexed scape of the antenna. In it the usual sutures between the head sclerites are entirely obliterated by fusion and the scanty external evidence as to its composition is derived from the position of eyes, antennae and the mouth parts. This alone indicates that it is composed of fused frons, genae and gula of the normal insect head — a view which ontogeny substantiates, as we shall see under a subsequent heading.

Mouth Parts.

In these two weevils at least the mouth parts, generally speaking, show rather close correspondence with those of the larvae. They are more elongate and have sharper cutting edges.

Each mandible bears also at its base a singular process as long as (Plate IX, fig. 18) or longer than (Plate IX, fig. 15) the body of the mandible. This process projects posteriorly down the pharynx to the entrance of the esophagus. It is thickly beset with posteriorly directed prickles similar to those of the surrounding pharyngeal wall.

This process doubtless serves for the propulsion of the food down the narrow passage-way of the anterior end of the alimentary canal. With the swinging of the mandibles upon their hinges the two pharyngeal processes appended to their inner basal angles, lying side by side in the pharynx are drawn forward and pushed backward. Such is the direction of the prickles that the backward movement carries the food along.

After discovering these pharyngeal processes, I searched for some account of

them in such entomological literature as was accessible. The mouth parts of the Coleoptera having been so much used in classification I could scarcely believe that these were undescribed, yet I have not discovered any mention of them.

Maxillae have the same parts as in the larva, though more highly differentiated. The edge of the lacinia is covered with a dense fringe of hairs. The galea is four jointed and the palpus is wanting.

The *labium* (Plate IX, fig. 19) is quite different in its shape from that of typical Coleoptera. The sub-mentum is long and broader at the middle than at the ends. The mentum is of about the same length but more slender. The paraglossa is short and widens at the anterior end beyond which a long narrow glossa projects. Both are tipped with numerous small spines. The palpi are small and simple.

The *Hypopharynx* is well developed, at least in *Mononychus* (Plate IX, fig. 14, *hy*), with a free tip and covered with recurved prickles.

The *muscles* which move mouth parts lie in the more convex part of the head in very much the same positions as in the larva. The tendons which are there either short or altogether wanting, have developed with the rostrum. They lie upon the ventral side and connect the muscles in the head proper with the appendages at the apex. (Plate IX, fig. 14, *t*.)

The *antennae* are situated upon the beak from one to two mm. from the more convex part of the head. The scape is very long. The slender pedicel has seven segments. The ovate club consists of three or four, more or less, consolidated segments.

Two sets of muscles move each antenna. Their fibers originate in the tentorium and shortly unite into four uniformly thread-like tendons which are inserted upon the round basal piece of the scape; two, probably used for making the forward movements, upon the inner side; and two, which make the opposite backward movements, upon the outer side (Plate IX, fig. 14, *am.* and *ant.*).

The Shifting of Mouth Parts in Balaninus.

The relative positions of mouth parts differ considerably in these two species. In *Mononychus* the order is that of normal Coleoptera. During the metamorphosis of *Balaninus*, however, a curious shifting in positions of mandibles and maxillae takes place. The exterior sides of the mandibles turn ventrally, approximating the normal positions of maxillae. The maxillae, in turn, are pushed dorsally between mandible and mouth, the brush-like edges of their laciniae protruding between mandible and labrum. The mandibles then move vertically as described by Dr. Horn (Amer. Philos. Soc. Trans., p. 457, 1873), who conceived them as working upon each other like the blades of a pair of shears.

Alimentary Canal, Salivary Glands, etc.

These have considerably altered the proportions they have in the larva. The salivary glands are not the same, but a new development; new armature has been differentiated in the walls of the proventriculus, and new tracheal branches have penetrated the rostrum.

The pharynx passes over into the esophagus (Plate IX, fig. 14, *oe*) which extends as a slender tube back into the prothorax and there abruptly widens into a barrel shape proventriculus (*pv*). This in *Mononychus* is lined with eight double rows of transversely placed sharp edged plates of chitin; each row containing about sixty plates. The ventral wall of the pharynx (Plate IX, fig. 17) is made of thick chitin and is incapable of contracting or expanding. That is the function of the dorsal wall which is lined with but a thin coat and covered with prickles. The short elevator muscles (Plate IX, fig. 14 *m*, and figs. 16 and 17) are attached in two longitudinal rows to this wall and aid in swallowing by drawing out the folds of the dorsal wall and enlarging the cavity. Around this side are several rows of semi-circular muscle bands which contract it again into its position of rest. The esophagus is wholly surrounded by circular muscles.

Close beside the mandibular abductor tendons lie a pair of simple tubular salivary glands which extend directly through the rostrum to the dorsal part of prothorax where their ends are twisted with many convolutions (Plate IX, fig. 14; *s. gl.*).

A single pair of tracheae distribute their branches through the beak.

IV. Metamorphosis.

External Features of the Metamorphosis of the Head.

A comparison of larva and imago shows great changes in both internal and external anatomy. The larva merely exists to eat and grow and accumulate fat for its metamorphosis. It lives a sequestered, inactive life and only the organs necessary for such a life are developed. The adult, on the contrary, lives the active life of ordinary beetles. It possesses wings, legs, eyes and antennae in addition to the larval structures.

The transformation from the degenerate larva to the highly organized adult beetle, whether it occurs immediately at the end of growth, as in *Mononychus*, or after a long period of quiescence with suspension of all vital activity, as in *Balaninus*, when it does begin takes place rapidly.

As a preliminary, certain of the old larval structures are gradually broken down. The fat in the anterior end of the body disintegrates and is made ready to be used in building up the new structures of the imago.

As the old muscles of the head disintegrate the whole anterior end shrinks away from the chitin and the new head begins to take shape. If the chitin be removed at this stage we find the condition shown in Plate VI, figs. 3, 4 and 5. The antenna and mouth parts have begun to form but are still very crudely shaped; the rostrum is already apparent, though broad and short and with walls transversely corrugated.

The antennae also are forced into many folds by reason of their rapid increase in length. The folds suggest the segmentation of the adult antenna. Real internal segmentation, however, does not take place until the pupal stage.

More folds occur on that part of the rostrum immediately back of the labrum than posterior to the base of the antenna. This in the adult is the longer part of the beak.

The mouth parts of the old larva are thick, broad and shapeless, yet resemble in general outline homologous parts in the adult. The labrum is short and slightly bilobed. In the very old larva the large mandibles, always very prominent, are somewhat, though not deeply, serrated on their inner edges and otherwise quite similar in form to the stout biting jaws of the adult. Ventral views of the developing rostrum (figs. 4 and 5) show the bilobed maxillae and trilobed labium. The labial glossa and paraglossae at this stage are large and distinct. In *Mononychus* (fig. 4) the hypopharynx protrudes beyond the labrum.

A faint differentiation of tissue upon each side of the epicranium shows the outline of the large compound eye. Near the center of this is a small opaque spot where the optic lobe of the brain is developing.

The Development of the Beak.

In its general characteristics the hypodermis is the same for all the parts of the head. From the beginning of metamorphosis it is very thick. The cells are large, multiply rapidly and become closely crowded together and elongate. The nuclei are oblong and large, occupying fully one-third of the cell. They are filled with large chromatin granules.

With the multiplication of cells and increase in size of the parts the hypodermis is forced into folds. In this way the entire beak and antennae are crowded under the old larva skin. When the pressure is removed by the shedding of this skin these parts stretch out (Pl. VIII, figs. 10 and 11), assuming suddenly more than half their final length, and the pupal stage is entered upon.

Plate VIII, fig. 10, is a semidiagrammatic optic section of the head of a newly formed pupa of Mononychus, seen from the front. It will be seen that the rostrum is relatively short and broad, narrower in the middle portion than in its apical third. At its tip are the crudely shaped mouth parts. The mandibles as yet show no development of their pharyngeal processes. The hypopharynx is an elongate ridge upon the pharyngeal floor. The salivary glands of the imago are just making their appearance as little sacculated ingrowths from the floor of the mouth. Fig. 13 is a section of a similar but slightly older specimen, showing the cellular structure. Here the pharyngeal processes (*m*) of the mandibles are budding. The upturned salivary gland is cut obliquely off, and the tubular ingrowths that will constitute the adductor (t^1) and adductor (t^2) tendons of the mandibles are clearly shown. While these are clearly ingrowths of hypodermis, and therefore quite distinct in their nature from the muscle fibres inserted upon them, it is very probable that they are being formed in the larva, and are drawn out to great length *pari passu* with the extension of the beak, and maintain throughout their connection with the muscle fibers in the head. The hypodermis of the mandibles and of the adjacent parts of the distal end of the rostrum show the characteristic peaked cells with nuclei settled down against the chitin, characteristic of hypodermis generally when its cells have been greatly crowded and thereafter greatly stretched apart.

Fig. 11 is an optic section of a somewhat older pupal head. Aside from the progress seen in the development of the antennae (which will be discussed under another heading), several changes are seen: the salivary glands are rapidly extending toward the head, one a little in advance of the other, the beak is increasing in length, and the mandibles are becoming toothed. At this age the tendons, which, as shown in fig. 13, are not tendonous at all, but distinctly cellular in structure, begin to show that wasting away of the cells with the deposition of chitine in the lumen, which will ultimately result in the disappearance of these cells altogether.

The further progress of the development of the salivary glands will consist in their prolongation backward beneath the esophagus around the sub-esophageal ganglion, and up into the dorsal side of the prothorax, where they become convoluted, as seen in Plate IX, fig. 14. Figs. 16 and 17 of Plate IX are cross sections of the beak in pupa and imago respectively, but taken at different levels. In fig. 16 the tendons have much the same appearance as the glands; but in fig. 17 the tendon that is to be, shows no cavity, but instead a central chitinous rod surrounded by a thin peripheral layer of cells. The salivary glands, on the other hand, are distinctly glandular in both stages but distinctly more slender in the imago than in the pupa, owing doubtless to their stretching out. There is another kindred structure seen here also. The beak is penetrated by two tracheae which enter from the ventral side of the prothorax as shown in figure 14, pass to the dorsal side at the base of

the beak and extend to the tip giving off branches en route. A cross section of these tracheae as they appear in the pupa (fig. 16 *tr.*) is remarkably like a section of tendon or of salivary gland: but in the adult (fig. 17 *tr.*) they are seen to be lined with chitin — not filled with it, as are the tendons.

The further development of the beak consists in the thickening and proper shaping of its chitinous walls, the appearance of scales developed from mother-cells early differentiated in the hypodermis, the shaping and perfecting of the armature and articulations of the mouth parts, the elongating of the pharyngeal processes of the mandibles and the development of the prickles upon their surfaces, and the differentiation between dorsal and ventral walls of the pharynx in which they lie, as already described under the account of the adult, and as shown in fig. 17, the developing of the semicircular muscles on the dorsal side of the pharyngeal wall, and the circular muscles about the esophageal wall, and the two rows of elevator muscles attaching to the chitin of the dorsum of the beak in both regions.

The Development of the Antennae.

The antennae of Rhyncophora show considerable differentiation of segments, being geniculate at base and clubbed at apex — a condition that is attained by them in early pupal life as shown in Plate VIII, fig. 11. At this stage the composite nature of the club is apparent and the segments of the pedicel lack much of their definitive length and slenderness and complexity of structure. In the pupa when first formed (fig. 10) these parts are hardly differentiated: the scape is exceedingly short, and segmentation is incompletely indicated, even in the pedicel. But the younger specimens (larvae) already referred to (Plate VI, figs. 3–5) show already indications of a terminal club and a geniculate base. It is doubtful whether all the transverse constrictions and convolutions that appear at this time really represent the segments that will appear later, for these are probably due in a large part to growth within the narrow confines of the loosened head capsule.

To find the beginnings of the antenna one must study sections of the head of the full grown larva before metamorphosis has begun, and before the chitinous head capsule has been loosened. Then one may find in the position of the base of the larval antennae in other coleopterous larvae the antennal buds — mere disks of thickened hypodermis, not invaginate nor in any way removed from the surface, surrounded by a circular groove and a circular ridge of hypodermis (the equivalent of the peripodal membrane of "imaginal discs") as shown in Plate VII, fig. 6. The shallow internal cavity is filled with fat cells and leucocytes. Already there appears a thin layer of neuroblast (?) cells, attached to the inner ends of the hypodermis

within the cavity. With the beginning of metamorphosis, and the disintegration of larval fat providing material for growth, and the loosening of the larval cuticle allowing room for expansion, the antenna rapidly extends itself, and the transverse wrinkling begins. Fig. 7 is from a section of the antenna of a larva in an early stage of metamorphosis. The hypodermis still appears composed of closely crowded elongate and compressed cells with elongate nuclei filled with chromatin granules, the cell layer being thickest at the distal end. It shows within more abundant fat and leucocytes, a better development of the neuroblastic layer, and the beginning of the development of muscle fibres. Fig. 8 is from an older larva, nearer the time of pupation, and shows the same features throughout, a little better developed. Fig. 9 is from a section of the club after the extension that takes place when the larval skin is cast. It shows at once the transition in form of the cells of the hypodermis to the peaked type, with the nucleus settled down upon the chitin layer and a long internal process reaching the basement membrane—a type entirely characteristic of such conditions of crowding and subsequent extension,[1] best exemplified here at the place where the extension has been greatest as in the segment at the base of the club.

The neuroblastic layer here is still better developed, and the segmentation of the club is still very distinct. The further development of the antenna consists in the elongation of the scape, the better differentiation of the segments of the pedicel, the consolidation of those of the club, the perfecting of the articulations, and the development of the abundant sense organs which are presumably associated with the neuroblastic lining cell layer.

The Question of Homologies.

What has become of the gula, so constant in normal coleoptera? What has become of the labrum? What are the limits of the lateral sclerites of the head? These questions have grown out of the fact that in the adult distinct sclerites are not discoverable; and the evidence derived from the development of these parts has not proved as clear and complete as might have been wished. Several features of the newly formed beak already alluded to (Plate VIII, fig. 10), seem to bear upon these questions. The constriction at about two thirds its length marking as it does internally the transition from pharynx to esophagus, probably marks also externally the proper base of the mouth parts, the junction of labrum and clypeus above and of labium and gula below: that is, this dilated front end probably corresponds with the periphery of the mouth opening in other coleoptera. At this level there begins

[1] See on the mechanics of this process, Comstock and Needham, *Amer. Nat.*, vol. XXXIII, pp. 856–857.

on the floor of the beak within two longitudinal chitinous ridges separated by a distance equal to one third the diameter of the beak and extending backward to the head. These would seem to represent the fusion of the gula at its lateral edges with the genae, and thus to mark the position of gular sutures. Thus the gula would seem to be better marked off from neighboring sclerites than these are from each other.

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EXPLANATIONS TO THE PLATES.

PLATE VI.

Fig. 1. Adult beetle, *Balaninus nasicus* Say.

Fig. 2. Full grown larva of same.

Fig. 3. Dorsal view of head end of pre-pupa of *Mononychus vulpeculus* Fabricius, removed from the larval skin, showing foldings of rostrum and antennae, outlines of the developing compound eye, and the fore wing

Fig. 4. Ventral view of mouth parts, antennae and rostrum of same.

Fig. 5. Similar view of *Balaninus nasicus.*

PLATE VII.

Figs. 6, 7 and 8. Three stages in the development of the antenna in the larva of *Mononychus vulpeculus.* Fig. 6 is from an old but still active larva; fig. 7 is from a larva in process of metamorphosis; fig. 8 is from a larva near transformation to pupa.

Fig. 9. Longitudinal section of the club of the antenna of a newly formed pupa of *Mononychus vulpeculus.*

n, neuroblastic cell layer, in all the figures of this plate.

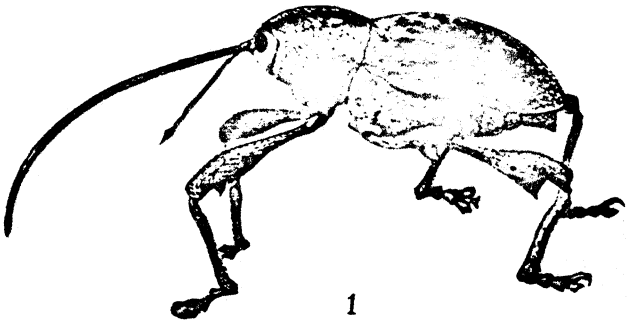
PLATE VIII.

Fig. 10. Dorsal view of head of newly formed pupa of *Mononychus vulpeculus*, semi-diagrammatic optic section; *ant*, antenna; *t*, *t*, tendons of antennal muscles; *s*, tip of the chitinous pupal sheath enveloping the entire body; *oe*, esophagus; *hp*, hypopharynx; *s*, *gl*, salivary gland; *md*, mandible; *mx*, maxilla; t^1 and t^2, adductor and abductor tendons of the mandible; *hy*, hypodermis.

Fig. 11. Similar view of a somewhat older pupa, showing progress in the development of the salivary glands, mandibles and antennae; lettering as before.

Fig. 12. A divided dorsal view of a dissection of the head of a grown larva of *Balaninus nasicus;* the right side shows the mandible and its muscles in place; the left side shows these removed, exposing the maxilla and its muscles, the brain and the labial and esophageal muscles. *br*, left cerebral ganglion; *c*, nerves going to the mouth parts; *1*, *2*, *3*, *4*, esophageal muscles, detached; *ad.* m^1 and *ad.* m^2, adductors of the maxilla; *ab.* m^1, abductor of the maxilla; *ad.* m^3, adductor of the mandible; *ab.* m^2, abductor of the mandible; *l*, labium; *l. m.* labial muscles other lettering as in fig. 10.

Fig. 13. Frontal section of the tip of the beak in a young pupa of *Mononychus vulpeculus*; t_1, abductor, and t_2, adductor tendons of the mandible in process of development as invaginations of the hypodermis, hy; *c*, chitin; *m*, pharyngeal process of the mandible budding; other lettering as in fig. 10.



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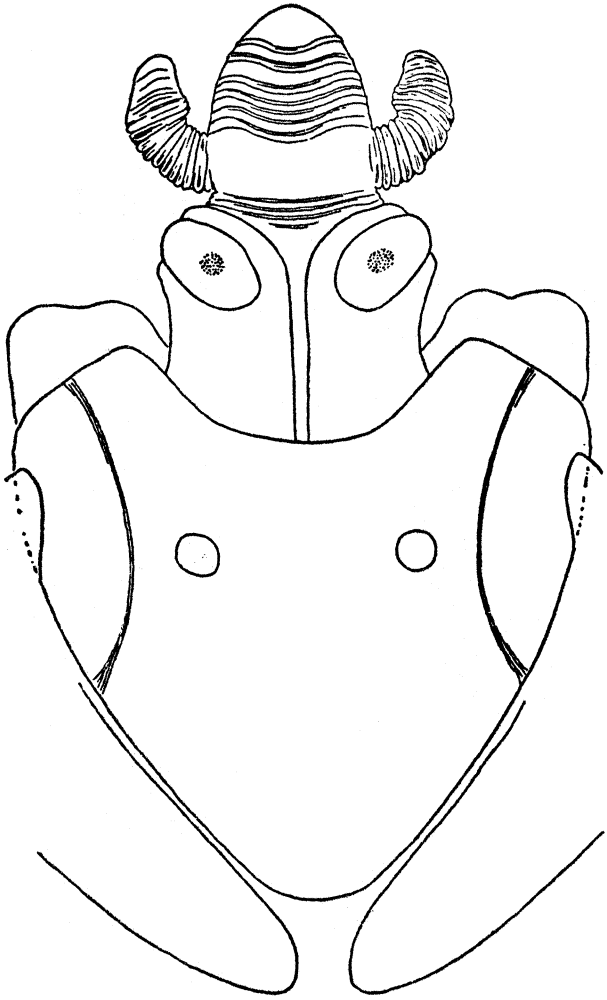

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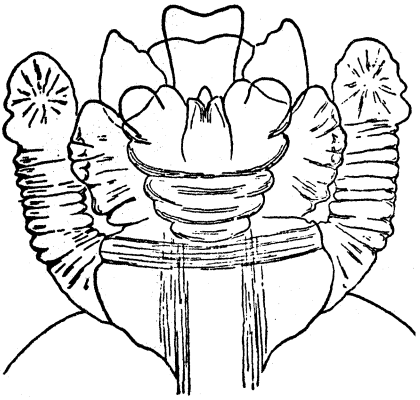

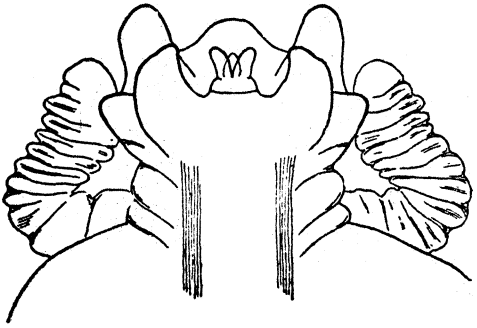

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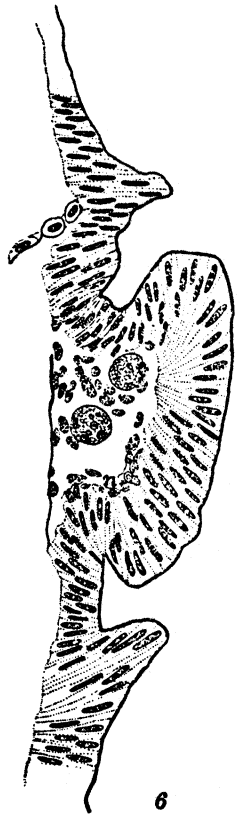

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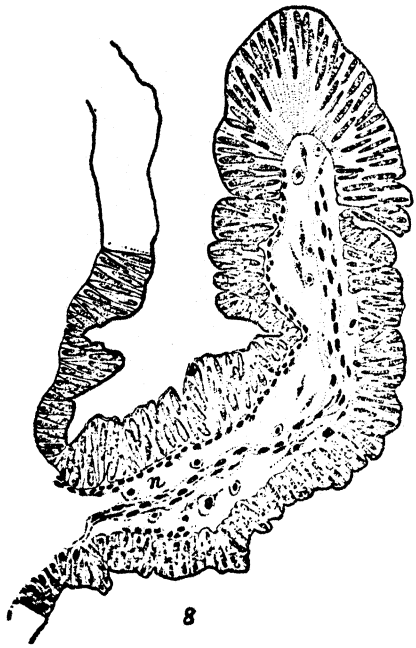

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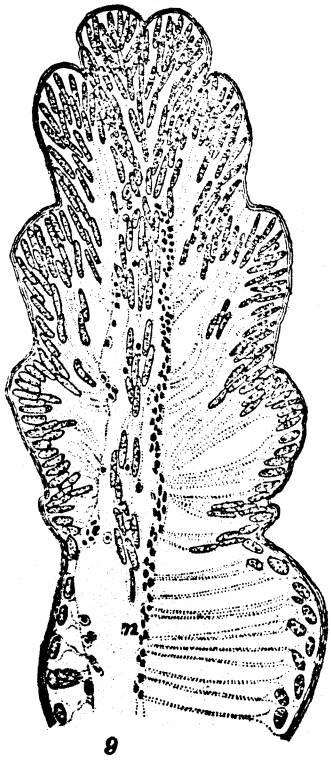

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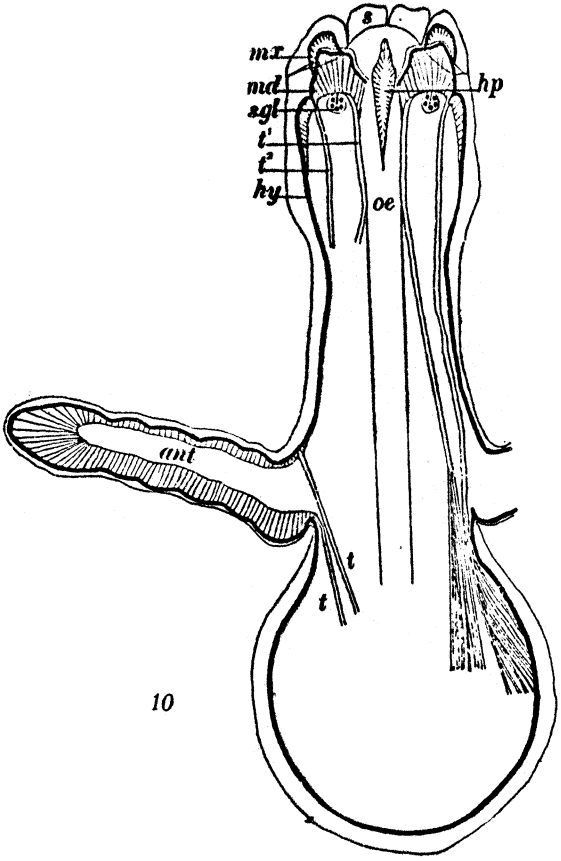

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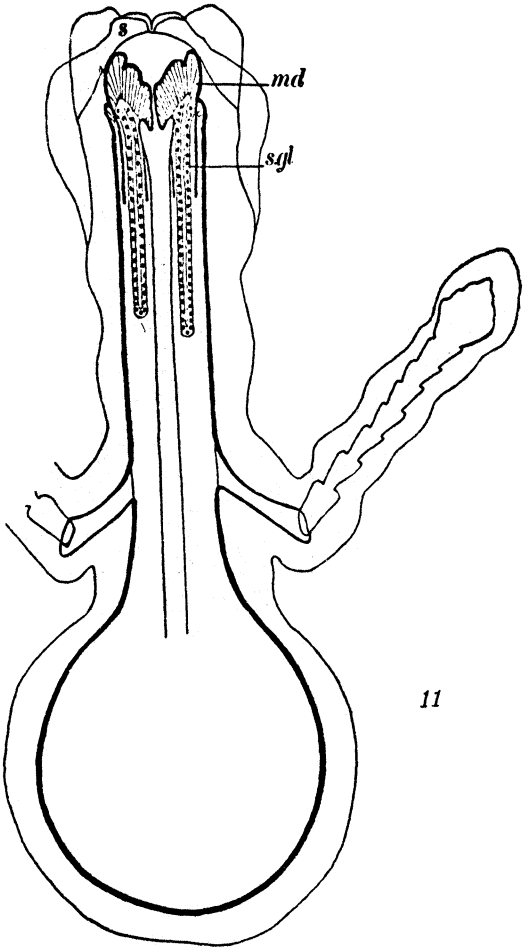

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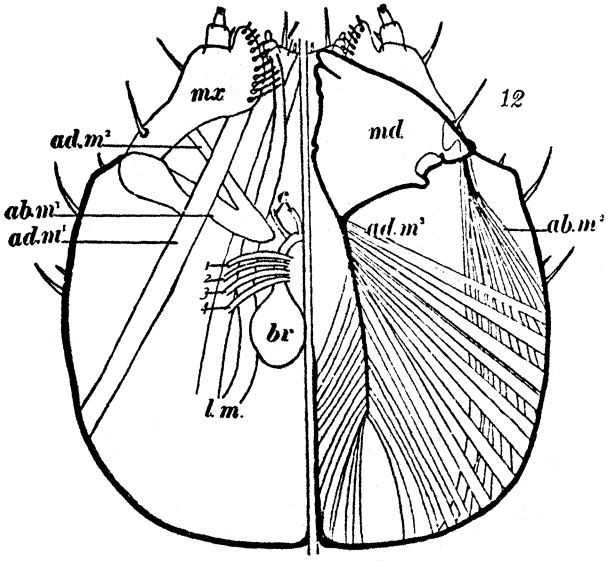

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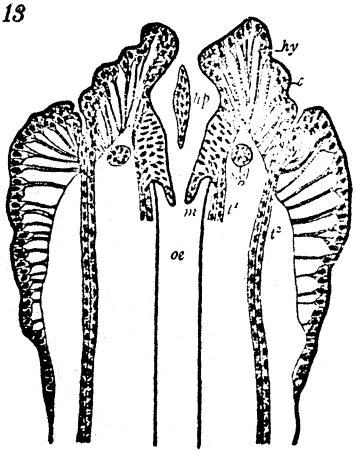

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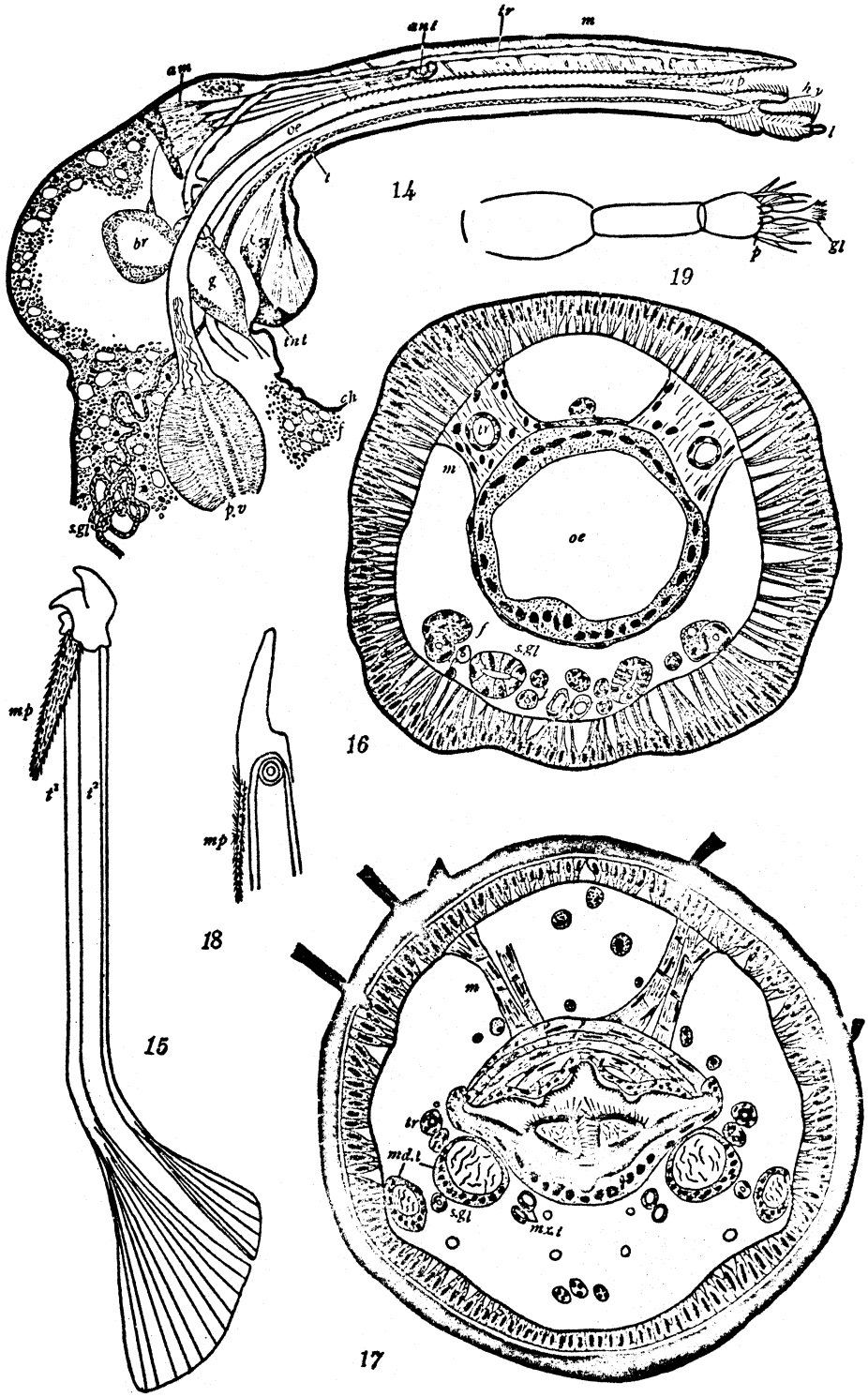

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