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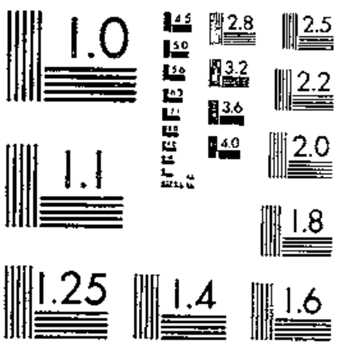

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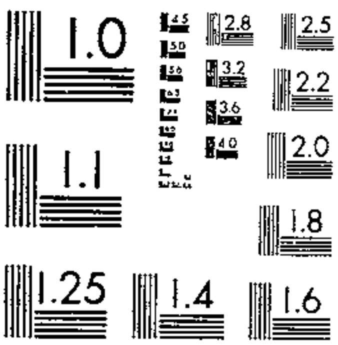

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TECHNICAL BULLETIN No. 693 — AUGUST 1939

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE EXTERNAL ANATOMY OF THE LARVA OF THE PACIFIC COAST WIREWORM[1]

By H. P. LANCHESTER,[2] *junior entomologist, Division of Truck Crop and Garden Insect Investigations, Bureau of Entomology and Plant Quarantine*

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INTRODUCTION

The study of the external anatomy of the larva of the Pacific coast wireworm (*Limonius* (*Pheletes*) *canus* Leconte)[3] is a part of the general program of investigation directed toward the economic control of wireworms in the Pacific Northwest. It is preliminary to comparative studies of the several species of wireworms found in this section of the United States. These later studies will be primarily taxonomic, but based on this morphological study.

The necessity for such a series of studies arises because of the presence in each district of a number of species of wireworms of economic importance. These species differ ecologically and physiologically more than they do anatomically. Much of the effectiveness of past work on wireworm control has been handicapped, and in some cases invalidated, by the lack of knowledge of the species, or collection of species, of wireworms represented in the experiment.

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[1] Submitted for publication January 30, 1939.

[2] The work was done at Walla Walla, Wash., as a part of the Pacific Northwest wireworm investigations under the direction of M. C. Lane. The writer wishes to thank Mr. Lane for his helpful assistance and encouragement, C. E. Woodworth for the use of histological material and for his advice, and R. E. Snodgrass for his helpful review of the manuscript and additional suggestions.

[3] Order Coleoptera, family Elateridae. (The adult female was described as *Limonius discoideus* Lec.)

PURPOSE OF THE WORK

The purpose of this study was to lay a foundation for the comparison of the morphological structures of wireworms in order that the characters of taxonomic value might be found and the various economic species determined from the larvae collected in the field. The determination of the species of wireworms by rearing them to adults has proved very unsatisfactory for either qualitative or quantitative records. This is due to the long life cycle and the unfavorable response of the larvae to laboratory rearing. At best, months elapse before any adults are obtained, and rearing records indicate that some larvae have lingered on for 12 years before pupating or dying. Certainly the interest in the experiment or the value of the recommendation would be lost before definite information could be obtained by the rearing method.

The difficulties encountered in a taxonomic study of the larvae of the family Elateridae have not been overemphasized by past workers. Schiödte (*15*),[4] Henriksen (*7*), Hyslop (*9*, *10*), Roberts (*14*), Horst (*8*), Van Zwaluwenburg (*20*), McDougall (*13*), Subklew (*19*), Guéniat (*5*), Glen (*4*), and Hawkins (*6*) are some of the workers who have studied the family or a portion of it. In nearly every instance the approach has been economic, and the purpose has been to find a simple way to separate the species of larvae which may be found together in the local fields where damage is occurring. Laboratory studies of the larvae of the four species of the genus *Limonius* of economic importance in the Pacific Northwest have shown the impracticality of expecting any person outside the technical staff to separate the species by any description or key that has been made by normal taxonomic procedure.

Systematic experience readily illustrates the incompleteness of any taxonomic description. Any author in preparing a description has compared the new species with a written description or a mental picture of the most nearly related species with which he is acquainted at the time. The description is, therefore, made up of the variations in the characters found in the earlier descriptions or in the mental image. The taxonomist has developed a group of characters at which to look when examining specimens of a certain group, and even when examining representatives side by side under the binocular he may overlook differences because they are characters which he has not been including in his mental image.

Since normal taxonomic procedure and the suggestions afforded by literature did not provide any means of ready separation of the larvae of the species of *Limonius* associated in the farm land of the Pacific Northwest, a different approach was deemed advisable. The external anatomy of the larva of *Limonius canus* has been studied and both descriptions and drawings have been made in some detail of all the parts of the body surface. This is to serve as a basis for the descriptions of the other species. It will be necessary to mention only those characters that differ, and if this study has achieved its aim, no character will be found on any nearly related wireworm whose counterpart has not been described and illustrated for this species.

[4] Italic numbers in parentheses refer to Literature Cited, p. 39.

METHODS

The methods employed in this study have little to offer that may be new. The species selected was the one whose larvae were most readily available in large numbers, and several hundred larvae were used during the study. The large number of larvae used has so added to the completeness of the study that individual variations might be noted and yet not receive the value of characters of the species. The uniformity of the larvae was remarkable, however, and little variation was noted except in the ninth abdominal segment, where very minor variations in tergal proportions and in the size of certain "warts" were observed.

Drawings were made by two methods. Most of them were made by the aid of an eyepiece micrometer and cross-section paper. All measurements were carefully transferred to the paper and the completed sketch bearing the location of all the features transferred by carbon paper to the bristol board where the drawing was completed and inked, with continual reference to the specimens being used as models. Nearly transparent structures, or small ones that needed considerable detail, were drawn by means of a microprojector. This consisted of little more than a strong light focused up through a compound microscope equipped with a right-angle prism attached to the eyepiece. This latter only changes the direction of the light beam and directs it upon the paper used for the drawing. The microprojector is of value only when the material is thin, nearly transparent, in a single plane, and mounted on a microscope slide so that it can be held on the stage of the microscope; otherwise the measurement of the object and the making of the sketch upon the cross-section paper yielded the more satisfactory results.

The method practiced was to make the sketch of the part being studied, then write a description as detailed as possible, complete the drawing using other specimens as models, and then rewrite the description in the form desired for the completed study. The preliminary studies were all completed prior to any of the rewriting. The final work was checked so that the relationship of external features to inner structures might be learned. This was made possible through the use of the very excellent microscope slides made in this laboratory by improved methods of histological technique.

Living larvae, larvae killed in hot water, larvae killed by drowning, larval casts, and larval skins macerated in boiling alkaline solutions were used. The various parts were dissected out, and in many of these instances a saturated solution of chloral hydrate in glycerine was used as a medium. This made it possible to keep the minute mouth parts, for example, on an uncovered microscope slide and examine them from every angle with a compound microscope and the aid of a fine dissecting needle. Material so prepared was stored away from dust for several days at a time, and was very valuable for comparison with permanent mounts. Mounts made of the macerated larval skin flattened out to show all surfaces were of considerable value in the study of the thoracic and abdominal segments.

SYMBOLS USED IN ILLUSTRATIONS

a, anus.
ads, distal segment of antenna.
ais, intermediate segment of antenna.
amg, anterior marginal groove.
ant, antenna.
aps, proximal segment of antenna.
as, antennal socket.
asj, supplementary joint of antenna.
at, abdominal tergum.
c, cardo.
ca, alacardo.
cc, cavity in cuticula.
cos, coronal suture.
cp, closing plate.
cs, subcardo.
csu, cardinal suture.
cx, coxa.
cxa, coxal articulation.
cxp, posterior coxal suture.
cxs, anterior coxal suture.
dls, dorsolateral suture of head.
eph, epipharynx.
epm, epimeron.
eps, episternum.
f, femur.
fn, "frons with nasale."
fs, frontal suture.
g, galea.
gen, gena.
gso, supra-oesophageal ganglion.
gu, gula.
h, hypostoma.
hph, hypopharynx.
hs, hypostomal suture.
im, intersegmental membrane.
lac, lacinia.
lb, labial brush.
lj, "lower jaw".
lp, labial palpus.
lpe, prelabium.
lpo, postlabium.
ltg, laterotergite.
man, mandible.
mb, mandibular brush.
mda, dorsal articulation of mandible.
mdc, dorsal condyle of mandible.
mdl, distal lobe of mandible.
mla, lateral apodeme of mandible.
mlp, lateral projection of mandible.
mma, mesal apodeme of mandible.
mpl, proximal lobe of mandible.
mps, maxillary palpus.
ms, median suture.
msn, mesonotum.
mtn, metanotum.
mva, ventral articulation of mandible.
mvc, ventral condyle of mandible.
n, nasale.
nd, nasal depression.
nlw, lateral wing of nasale.
nmp, median projection of nasale.
ns, subnasale.
nso, nasal sensory organs.
o, oesophagus.
p, pleuron.
pa, prosternal apophysis.
pam, anterior mesopleurite or metapleurite.
par, parietal.
pcs, postoccipital suture.
pes, presternum.
pn, pronotum.
pos, prosternum.
ppm, posterior mesopleurite or metapleurite.
pr, postoccipital ridge.
prb, precoxal bridge.
ps, pleural suture.
pta, pretarsus.
s, stipes.
sd, dististipes.
spi, spiracle.
st, sternum.
t, tibia.
ta, tarsus.
tel, telson.
tp, posterior tentorium.

THE LARVA

The larvae of *Limonius canus* are among the most destructive wireworms of the Pacific Northwest. They are adapted to move about through the soil and find their food in the roots and seeds in the ground. Only an active larva could subsist on the relatively small food sources so widely distributed throughout the soil. The high resistance to movement offered by the soil makes the form and the hardened covering of the wireworm important factors in its ability to move through the soil. Thus the larva under consideration has a slender body, tough covering, tapered head, small and short legs adapted to work close to the body, and an anal structure that assists in the movement of the body. The separation of head, thorax, and abdomen is not so apparent as in some of the less uniformly slender coleopterous larvae, yet their functions are as distinct, and the three portions of the larval body will be described separately.

THE HEAD

The head is of the prognathous form with the preoral cavity (mouth) at the anterior extremity and directly opposite the foramen magnum on the posterior surface of the head. This modification of the larval head from the perhaps more primitive hypognathous form with the preoral cavity on the ventral surface of the head appears to be quite common among the more active of the coleopterous larvae, especially among the predacious forms.

The main framework of the head may be considered the head capsule, while other features of importance would be the preoral cavity, the antennae, and the various moving parts associated with the mouth.

THE HEAD CAPSULE

The head capsule consists of the immovable sclerotized areas of the head. In the larva of *Limonius canus* the head capsule is so modified as to be somewhat wedgelike. This wedge is pointed anteriorly, with the opening of the preoral cavity, guarded by the mandibles, at the tip. The flattened surfaces of the wedge are dorsal and ventral, with much of the ventral surface occupied by the various parts of the maxillae and labium which are rather intimately united to form a large movable plate termed the "lower jaw." The fusion of frons, clypeus, and labrum has resulted in an immovable and highly sclerotized plate termed the "nasale," a portion of which projects anteriorly between the mandibles and forms the most noteworthy feature of the dorsal surface of the head capsule. Since the larva is entirely blind and the antennae are situated very close to the base of the mandibles and immediately laterad of them, the antennae, mandibles, and "lower jaw," together with the preoral opening, occupy the single opening in the visible part of the head capsule. The only other opening in this sclerotized capsule is the occipital foramen found in the posterior wall. Instead of the comparatively small size of the occipital foramen, or foramen magnum, as sometimes seen in insects, the opening is large, as was noted by Stickney (*18, p. 27*) in the adult of *Alaus oculatus* (L.). This large foramen magnum occupies nearly the entire posterior surface of the head capsule, and its size may, in part, be the result of the heavy musculature present in the reduced head and the probably related migration of the ganglia of the brain into the prothorax.

The head capsule of the larva of *Limonius canus* is thus seen to consist of little more than a flattened dorsal plate sloping anteriorly, and rounding lateral walls which narrow anteriorly and curve onto the ventral surface for a comparatively short distance except at the posterior end, where a gular area unites the sides of the head capsule posterior to the "lower jaw."

Segmentation lines may be considered as absent in the head capsule, and the various irregularities, sutures, and indentations are largely due to the invaginations of the body wall which supply the necessary supports and points of attachment for the internal organs and muscles. The hypothesis that the wedge shape of the head is of value to the larva in its movement through the soil is further supported by the smoothness of the surface of the capsule, the roundness of corners, and the location of all sensory spines in depressions of the wall.

The epicranial suture and the before-mentioned nasale are the principal features on the dorsal surface. The epicranial suture is so modified that the hypothetical Y-form is not apparent. The frontal sutures (fig. 1, *A*, *fs*), the branches of the inverted Y, alone are readily seen. If the head of the hypothetical hypognathous insect were bent upward into the prognathous position with the mouth raised into the plane of the body, the stem of the Y and the sclerites which it is supposed to separate would be shoved under the anterior margin of the first thoracic tergite, the pronotum. When the larva of *Limonius canus* is greatly distended or when the head is mechanically bent ventrally, an area of semimembranous tissue with a plainly discernible dorsal suture is exposed. This may be the parietals, the sclerites in question, separated by the lost stem of the Y.

The frontal sutures depart from the hypothetical straight lines and enclose an area resembling in shape a bulbous vase with flaring top. These sutures arise from the dorsoposterior margin of the sclerotized head capsule and adjacent to the semimembranous area. Their points of origin are separated by a distance as great as the width of one of the stipites in the "lower jaw." The sutures arch laterally and approach again when slightly more than halfway to the anterior limits of the head capsule. Here the sutures are nearly parallel for a very short distance and are about as widely separated as at the point of origin. From here the sutures bend laterally and extend at right angles to the median plane to where gradual and uniform curves will take them around the outer margins of the bases of the mandibles. Each would appear to pass between the base of the mandible and that of the antenna.

The sclerite which is set off by these two sutures from the remainder of the head capsule is the "frons with nasale" of Hyslop (*10*). It is a fused plate containing the frons, clypeus, and nasal lobe without indication of points of separation. The nasal lobe or nasale owes its origin to the fusion of the plates and to the apparent disappearance of the labrum. The nasale (fig. 1, *A*, *n*) is of taxonomic importance both in placing the larva in the family Elateridae and in determining the division of the family to which it belongs. Its importance, however, is much more limited than is realized by many authors owing to the changes wrought by wear during the period between molts. The amount of wear is influenced by different types of foods. The special structures of the nasale will be discussed more fully under a separate heading.

The frons bears three pairs of bristles which are particularly noticed. Other setiferous punctures are often found nearer the nasale, but are not so outstanding. The pair situated within the neck of the vase are noticed for their location rather than their size. They are found, one on each side, near the frontal sutures and where these sutures first approach one another. Two large spines are situated on the wings of the sclerite not far from the ends and about midway between the base of the mandible and the frontal suture. These spines, one on each side, are similar in size and length to the larger of those found on the stipites. The third, and last of the pairs mentioned, are found one on each side near the frontal suture and both posterior to and outside of the longer spines just described. These latter spines are greatly reduced, and in size are approximately

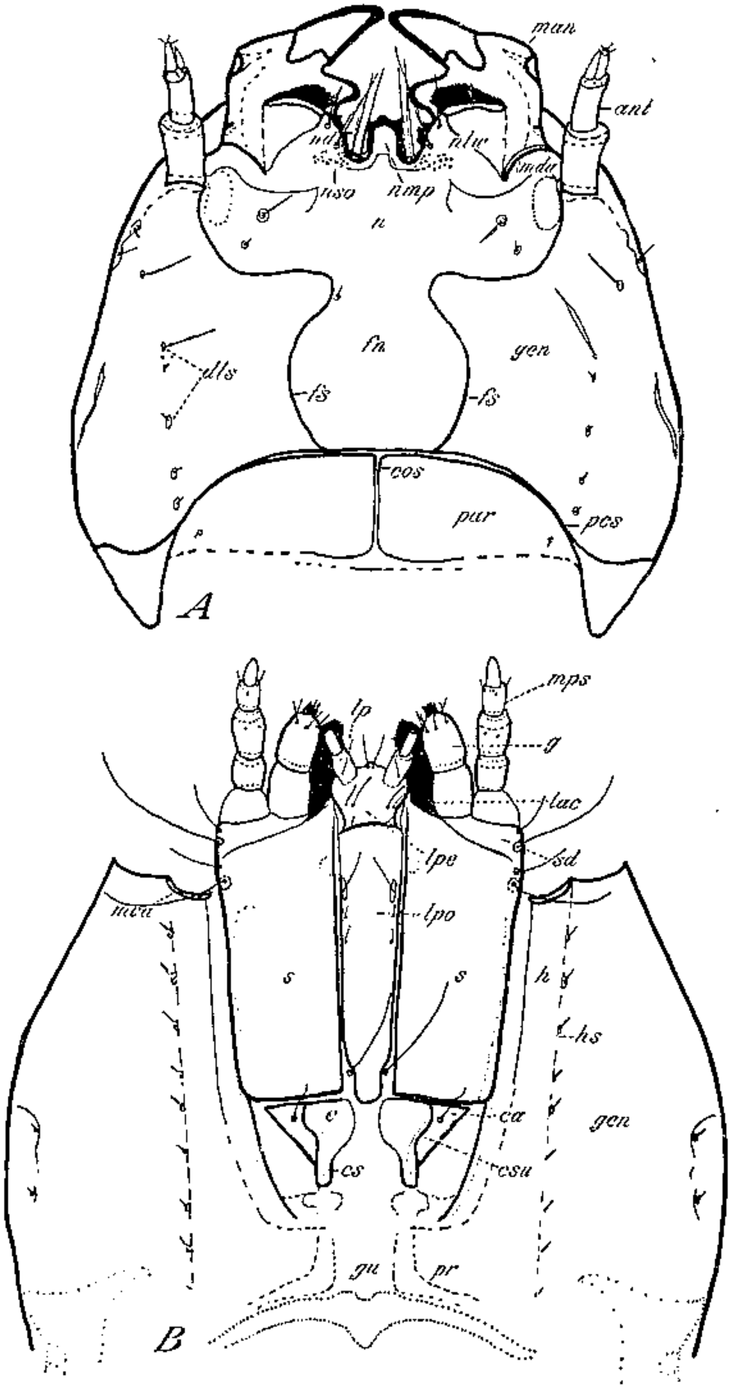

FIGURE 1.—Head capsule of larva of *Limonius canus*: *A*, With mandibles and antennae, dorsal view; *B*, without mandibles or antennae, ventral view. Both × 60.

midway between the first and second pairs. A similar comparison may be made of the alveoli from which the spines arise. The alveoli of the third pair of spines have about half the diameter of those of the second pair, but are nearly twice the diameter of the alveoli of the first pair. Spines similar in size to those of the first pair are to be found in the front center of the sclerite, and when several are present they are often arranged in an arc. Other setaceous growths appear around the nasale. These latter will be discussed in connection with that organ.

The areas of the head capsule outside the frons and nasale are very generally fused from the postoccipital suture, from which arise the frontal sutures, to the surfaces of mandibular articulation. The antennal sclerites, the less sclerotized areas surrounding the base of the antennae, are distinctly marked, while setae-bearing grooves, one on each side, extend from the ventrolateral base of the mandible to near the posterior margin of the capsule. The area thus formed surrounds the "lower jaw." Its free lateral margins are very greatly infolded and are connected to the infolded lateral margins of the stipites by a flexible membrane. The slender sclerites laterad of the "lower jaw," the hypostomata (fig. 1 *B*, *h*), bend mesally at their posterior end, where they are joined by the anteriorly-bent ventral ends of the postoccipital ridges (fig. 1, *B*, *pr*).

The lateral walls of the head capsule extend much farther posteriorly than the posterior margin of the epicranium, the dorsal part of the head. These lateral posterior extensions appear to be more important in the articulation with the thoracic segments than does the dorsal margin. Posterior to the postoccipital suture is a sclerite, or series of sclerites, which may be more cervical than cephalic. Dorsally the sclerotized part is very narrow, including little more than the posterior wall of the suture, and fades into the intersegmental membrane connecting the head to the prothorax. As the arch of the head capsule is followed laterally, and posteriorly, the width of the sclerite appears to increase until at the dorsolateral extremities it forms a triangular plate whose acute angle extends posteriorly under the exoskeleton of the prothorax. This extension of the sclerotized area is an invagination of the suture, however, for it lies under the transparent intersegmental membrane and is a part of the endoskeleton.

Between the anteriorly bent ends of the postoccipital ridges is an area, the gula (fig. 1, *B*, *gu*), whose anterior portion is very slightly colored and merges into the nonsclerotized membrane surrounding the cardines of the "lower jaw." Its posterior margin, however, is a structure usually hidden within the prothorax. In the fully expanded larva it appears as a narrow cupid's bow extending across the median part of the ventral surface and similar in color to the longitudinal sutures of the cardines. It is brown in comparison to the yellow of the part of the sclerite which is anterior to it and to the white of the intersegmental membrane by which it is usually covered.

This bow-shaped posterior margin of the gula appears to extend behind the postoccipital ridges and to strengthen the posterior margin of the head capsule. The posterior tentorial arms (fig. 2, *A*, *tp*) arise on the inner surface of the postoccipital ridges without any external indication of posterior tentorial pits. One prong of each extends dorsoposteriorly a short distance, but the longer part extends dorsoanteriorly. It passes directly over the articulation of the posterior tip of the cardo to the mesal end of the margin of the hypostoma and serves as a support for the stomodaeum, the foregut.

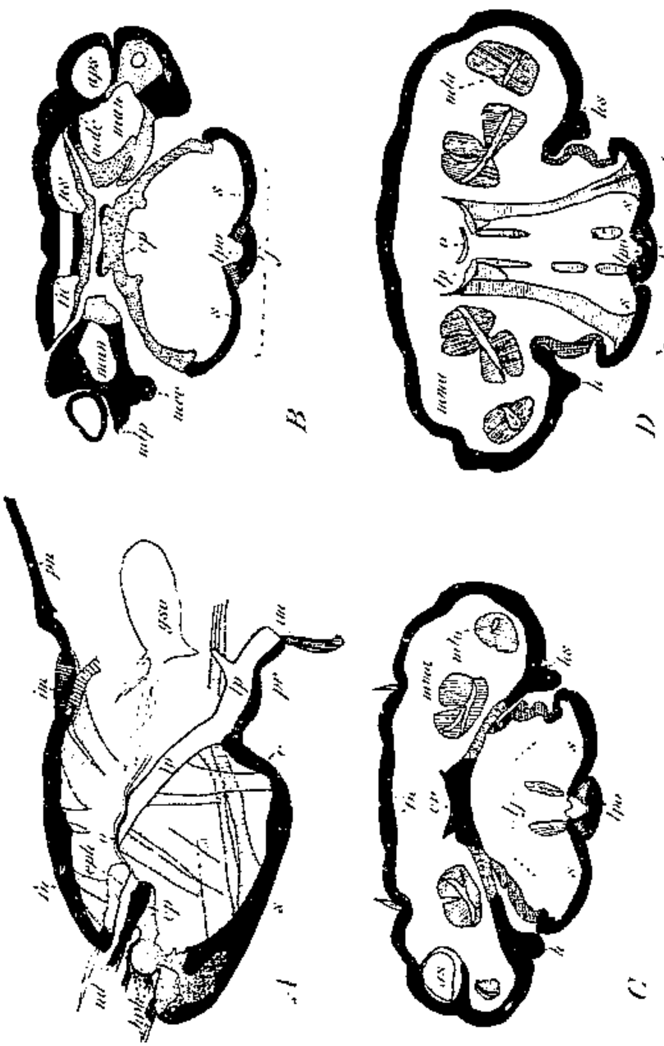

FIGURE 2. Sections through head of larva of *Limonius canus* to show arrangement of parts: *A*, Longitudinal section through head showing portions of muscles of "lower jaw" arising from posterior tentorium; *B*, cross section through posterior limit of the preoral cavity showing rear limits of subnasale and anterior margin of closing plate, one free mandible and one attached to head capsule; *C*, cross section through closing plate posterior to preoral cavity, showing mandibular apodemes with attached muscles; *D*, section near proximal ends of the stipites, showing mandibular apodemes, musculature of "lower jaw," and association of posterior tentoria and oesophagus.

THE NASALE

The nasale is defined by Böving and Craighead (*1, p. 84*) as—

> an anterior and median projection from frons, formed either by a fusion of frons, clypeus and labrum, or sometimes by frons and clypeus alone; in this latter case labrum is small and hidden below the nasal projection.

A true labrum in the sense of a movable upper lip has not been found in the larva of *Limonius canus*

The above definition of the nasale is subject to question in its reference to the larva of this species. It has a narrow median projection, while in certain subfamilies of elaterid larvae the term "anterior and median projection" would apply to much more of the anterior margin than in this larva. For example, in the larva of *Pyrophorus luminosus* Illig. (*10, p. 248, fig. 2e*) the definition of the nasale would apply to an area which would include the indentations on both sides of the "anterior and median projection" in larvae of *Limonius canus*.

While the narrow median projection of this species is the most highly sclerotized area and is the portion which is in direct apposition to the inner tooth of each mandible, the base and lateral wall of the deep indentations on each side of the median projection is observed to assist in crushing food bodies. Thus, much of the work is divided over the anterior margin. Moreover the sensory areas, which form a part of many labra, are largely situated on the lateral wings, the mandibular sclerites of Guéniat (*5, p. 108*). Further, these duties are not normally those of the clypeus. For these reasons it is best to include in the discussion of the nasale all the areas on the anterior margin of the fronto-clypeal sclerite which assist in the masticatory processes and also the adjacent sensory areas.

As stated in the discussion of the head capsule, the nasale has been considered of primary importance in the taxonomy of elaterid larvae. This plate has considerable value in the separation of groups and is perhaps as variable between species as any structure on the larvae. In the case of the various species of *Limonius* larvae reared, it has been repeatedly observed that the nasal projection, as well as the tips of the mandibles, is very subject to wear, the amount of wear being in part dependent on the type of food. The larvae of *Limonius canus* have been observed to be especially subject to variation in the form of these wearing surfaces during the period between molts. Because of the variation in the form of the nasal projection and the mandibles their value as a specific character is very questionable.

The median projection (fig. 1. *A*, *nmp*) appears when viewed from above as a nearly square extension into the space between the mandibles. It is situated much farther ventrally than can be shown in a dorsal view; it is in apposition to the mandibles, in that the inner tooth, the proximal lobe of the mandible, grinds against the under surface of the nasal projection; and it is situated almost between the mandibles as viewed from in front (fig. 3, *A*). In freshly molted specimens the anterior end of the projection is trilobed and somewhat expanded. This effect may soon disappear in larvae that feed on comparatively hard food, as wheat or corn kernels.

On each side of the median projection is the depression in the margin of the sclerite. These depressions (fig. 1, *A*, *nd*) are each nearly as wide as the projection. Their walls are nearly vertical, and in the basal wall of each is a cavity which contains two setal alveoli. From each of these alveoli arises a strong bristle which extends anteriorly over the cavity between the mandibles for a distance fully twice the length of the median projection, and these bristles attain the tips of the closed mandibles. While the mesal walls of the depressions are nearly straight and parallel, the lateral walls extend anteriorly in a smooth arc to a point near the base of the proximal lobe of the closed mandible. A farther extension of this sclerite bends laterally over the mandible. The outer half of the lateral margin, and most of the portion above the mandible, is provided with a dense growth of bristles. This heavy brush of hairs is directed mesally and somewhat anteriorly. It brushes the upper surface of the mandible and probably sweeps back any food particles that might cling to the mandible as it is being opened.

The lateral wings (fig. 1, *A*, *nlw*), the mandibular sclerites of Guéniat, in addition to the dorsal mandibular brushes on their mar-

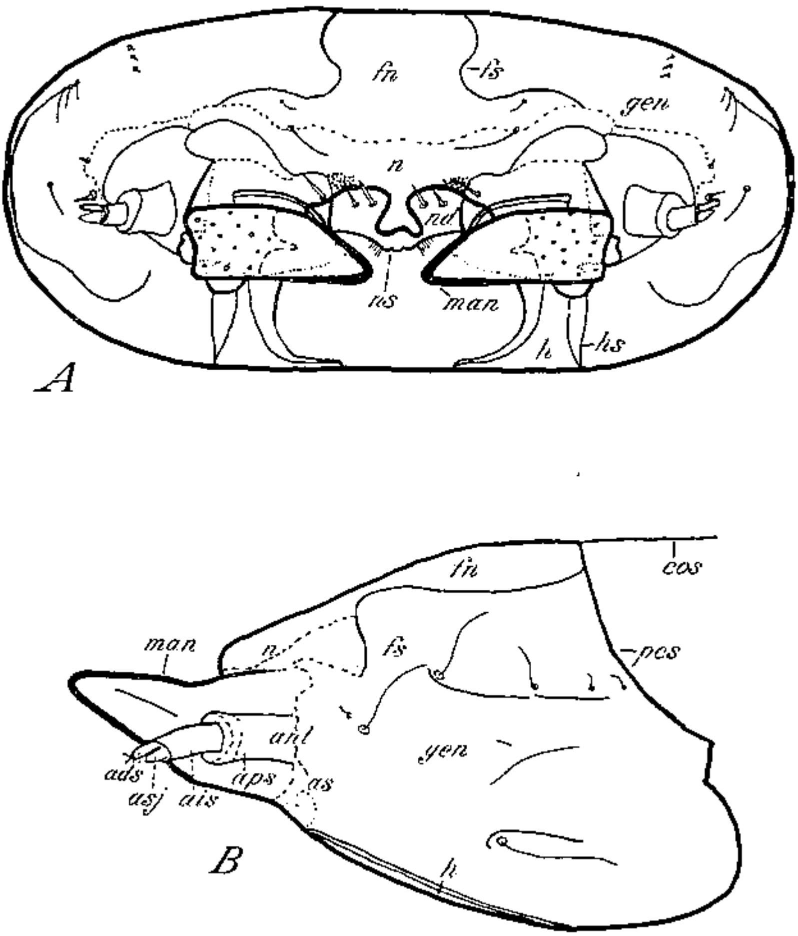

FIGURE 3.—Head capsule of larva of *Limonius canus*: *A*, Anterior view, with mandibles and antennae; *B*, lateral view of left side. Both × 55.

gins, each bear two short but comparatively heavy spines. These are similar in diameter to the largest ones on the fronto-clypeal sclerite, but appear to be both shorter and more stiffly fixed in their sockets. With the more lateral one of each pair of spines in the nasale depressions they form lines extending diagonally forward and over half the distance across the lateral wings. Near the base of the nasal area and extending from the base of each depression laterally, fully as far as the terminal spine in each row, is a narrow area quite uniformly supplied with sensory organs which appear to be different from any others found on the larva.

Superficially these sensory organs (fig. 1, *A*, *nso*) appear similar to setal alveoli of average size, but without setae except for a minute dark speck in the center. Sections through the nasal area, however, show them to be globular bodies nearly flush with the surface of the plate. They completely fill their cavities in the sclerotized plate. Each organ is nearly spherical, slightly flattened on top and with a minute elevation, a little point, in the center of this flattened exterior surface. The farther from the nasal depressions the organs are situated the deeper they are in their sockets and the longer the median spike. Within, the organs each show a channel leading through the sclerotized portions of the cuticula. The channel is bent posteriorly and disappears in the tissue on the inner surface of the cuticula.

The walls of the individual sensory organs are thin while the interior appears to be hollow. The stains being used on the prepared slides do not differentiate nerve tissue, and further studies will be necessary to determine the type and amount of innervation. The general appearance of the organs is similar to that described for the sensilla campaniformia of Snodgrass (*17, p. 521*) and Eltringham (*3, p. 98*).

Laterally from these sensory areas and connecting the brush-bearing margin of the lateral wing with the fronto-clypeal sclerite is a nearly transparent, uncolored area which further covers the dorsal surface of the mandible.

These regions described collectively under the name "nasale" are a part of the head capsule in that they are immovable, and with the other areas described under the head capsule form the only immovable portions of the exoskeleton of the head. The endoskeleton will be mentioned only as it influences the external portions.

THE PREORAL CAVITY

The preoral cavity of the larva of *Limonius canus* presents some interesting adaptations from the hypothetical primitive coleopterous larva. A development of considerable importance in the feeding habits of the larva is the presence of extensive hair brushes and sieves in and around the preoral cavity. The amount of hair appears to be much greater in this species than in many of those that have been studied at the laboratory at Walla Walla, Wash., and is much greater than that figured by Guéniat (*5, fig. 16, B, p. 112*) for *Agriotes obscurus* (L).

Mention is made under other headings of the hair growth on the laciniae, at the base of the mandibles, on the inner anterior angles of the lateral wings of the nasale, on the tips of the labial palps and the galeae, and on the dorsal surface of the labium. In addition to these, other dense growths of hair are to be found on the hypopharynx and the "closing plate" (fig. 4, *B*).

The hair growth within the preoral cavity and along the lateral margins of the hypopharynx is a continuation of the rows of hairs formed by the brushes on the laciniae. These rows along the margins of the hypopharynx are composed of very many hairs and nearly fill the preoral cavity, while the individual hairs appear to be longer than those of the laciniae. Like those of the laciniae these hypopharangeal hairs point forward and inward. These hairs of the two organs form long lines which assume much the form of a funnel for the passage of food. The direction of the hairs, however, would very efficiently prevent the passage of any large particles of food.

A further obstruction to the funnellike food passage is the tuft of hair, the labial brush (fig. 4, *B*, *lb*), described as on the dorsal

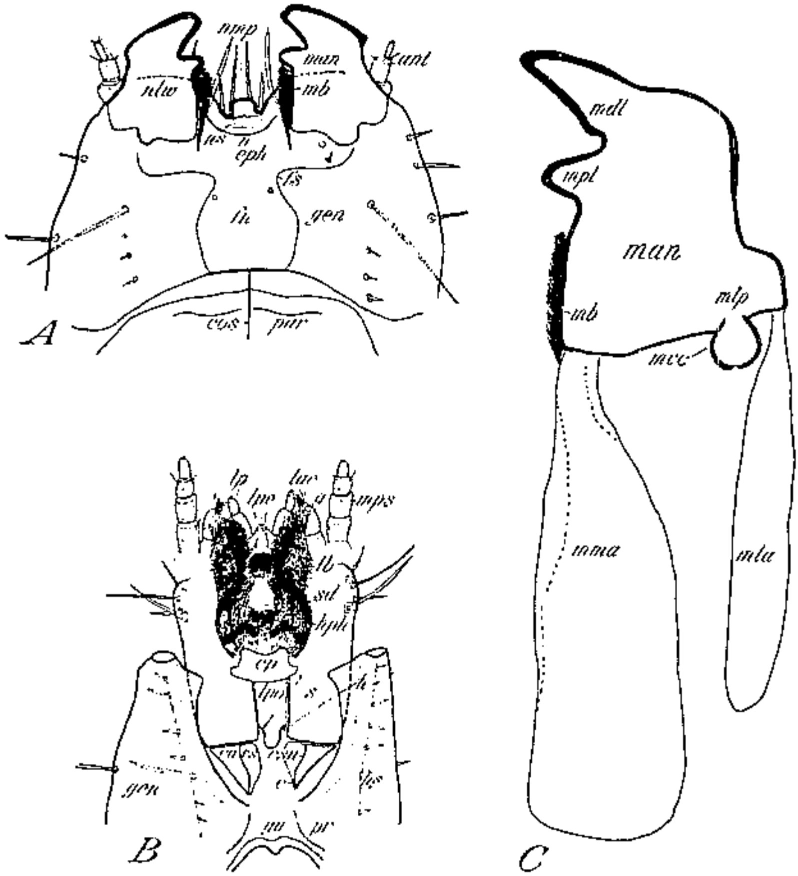

FIGURE 4.—Head parts of larva of *Limonius canus*: *A*, Preoral cavity, dorsal surface, × 37; *B*, preoral cavity, ventral surface, × 37; *C*, mandible, with apodemes, × 90.

surface of the labium, specifically the prelabium. These hairs are erect in growth and form an obstruction across the food passage about one-third of the distance from the anterior tip of the labium to the closing plate when the parts are in an extended condition. Since these hairs closely brush the upper surface of the preoral cavity, the epipharynx, they divide the passage into two parts.

These two parts of the preoral cavity are evidently divisions of the cibarium. There is no indication of a salivarium, nor has any structure been found which might be considered as either salivary gland or salivary meatus, and while digestive fluids are commonly found in the preoral cavity they have been seen to be discharged from the stomodaeum.

The anterior portion of the cavity is widely open in front and affords a ready passage for food. The palpi and mandibles bring the food into position while the hairs of the many brushes prevent its escape laterally. The secondary or posterior portion is more heavily clothed with hairs; even the ventral surface, the upper surface of the hypopharynx, is clothed with short, anteriorly directed hairs. Microscopic sections through this region show small, anteriorly directed hairs on the ventral surface of the epipharynx, the roof of this portion of the cavity, which gross dissections had failed to show. The hypopharynx is restricted to this secondary portion of the cavity; for the floor of the anterior portion is the labium and the lateral margins of the laciniae, the mandibles are its walls, while the roof is formed by the subnasale and the space anterior to the nasale in which the proximal lobes of the mandibles move.

The hypopharynx (fig. 4, *B*, *hph*), understood to be the ventral surface of the portion of the preoral cavity posterior to the labium-borne tuft of hairs, extends posteriorly to the closing plate, the structural mouth. The hypopharynx is very subject to being extended until the surface is smooth, or shortened until it forms one or more extensive pockets or folds. Longitudinal muscles are so attached to its under surface as to make the primary pocket immediately behind the labial tuft and the secondary pocket just anterior to the closing plate. Its form is subject to the movements of the sundry parts of the "lower jaw" and somewhat to the movement of the closing plate. Observations of the feeding larva and of the larva when dissected in Ringer's solution and electrically stimulated indicate that every possible movement of these areas appears to be participated in quite frequently. The sundry palpi, the labium, and the "lower jaw" as a unit are thrust forward and withdrawn; the anterior end, or the posterior end, of the "lower jaw" is raised or lowered, while a similar motion may be noted between the two sides of the same area which gives to it a lateral rocking motion in addition to the linear one.

The transverse sclerotized plate (fig. 4, *B*, *cp*) at the posterior end of the hypopharynx is termed the "closing plate," since it provides a means of closing the opening into the alimentary canal. Properly it is a portion of the digestive tract, of the mouth proper, and not of the preoral cavity. It does, however, bear brushes of hairs and affords a posterior limit to the cavity. The posterior margin of the hypopharynx is attached to the plate, while the ventral portion of the anterior end of the stomodaeum is likewise attached to it. The lateral wings are attached to the anterior portion of the head capsule by strong muscles, and in gross dissections the plate has been found tightly pressed against the roof of the food meatus just posterior to the thickened plate which is the subnasale and epipharynx. The plate is readily detached from the ventral portion of the head and it is moderately difficult to dissect open the preoral cavity so as to retain the structure in the ventral half.

The closing plate is twice as wide as long and the anterior and posterior faces are approximately parallel, though the latter is rounded posteriorly in the middle. The four corners of the plate are extended laterally and provide attachments for muscles. The hair growths are attached to the yellowish plate by a brief, but transparent, membrane. They extend in a continuous row from near the posterior angles, along the lateral ends, and across the anterior face of the plate. The hairs are greatly reduced in length and in number for approximately the middle one-third of the anterior margin. The remainder of the hair growth supplements the lateral rows of the hypopharyngeal brushes. Under certain conditions the brushes of the posterior portion of the preoral cavity are pushed forward and fill the space between the nasale and the bases of the mandibles and extend as far as the tip of the nasal projection.

The subnasale (fig. 3, *A*, *ns*), the posterior surface of the nasal projection, is difficult to study satisfactorily. If seen with transmitted light it may show little more than the pattern of the less densely sclerotized areas of the nasale. In this instance it would be a bluntly three-lobed figure somewhat similar in shape to the nasal projection but considerably reduced. When viewed from the anterior end of the nasal projection it is seen that the subnasale slopes ventro-posteriorly and an impression is obtained of a serrate margin. In well cleared specimens, or when viewed by reflected light, and under magnifications of at least 80 diameters, the subnasale is seen to be provided with conical projections or points over much of its surface. The arrangement is more comparable to that of the cells in a honeycomb than to a system of rows. The length of the points appears to increase posteriorly though their bases are not greatly increased in size. This condition continues posterior to the bases of the depressions on each side of the nasal projection. These points have been noted to be sharper in recently molted larvae than in those which have fed for a time. This would indicate that the projections are subject to considerable wear. The posterior margin of the subnasale is abrupt, the edge appearing right-angled with the posterior surface extending dorsally. Transversely the posterior margin is smooth and arcuately bent anteriorly near the ends. Flexible tissue forming the remainder of the roof of the preoral cavity and of the anterior portion of the stomodaeum is attached to this margin of the subnasale.

THE ANTENNAE

The movable parts of the head are the antennae, the mandibles, and the "lower jaw." The last is the plate combining the maxillae and labium. The antennae are the least of the organs in size, but are morphologically considered to be the most anterior in point of origin, and will be described first.

The larval antennae are situated laterad of the mandibles. The antennal socket (fig. 3, *B*, *as*), from which the antenna arises, occupies the space provided by the lateral end of the anterior tip of the dorsoventrally flattened head capsule and the concavity on the lateral margin of the mandible. The antenna as it arises from the antennal socket is partially protected by the lateral surface of the mandible. It is attached to the antennal socket by a flexible transparent membrane which permits of considerable retraction of the antenna, as well as free movement in any direction. This membrane may include an antennal sclerite. No articulatory point has been observed on the larval antenna.

The antenna contains three sclerotized segments. The basal or proximal segment (fig. 3, *B, aps*) is one-half the length of the entire antenna, while it is correspondingly greater in diameter than either of the more distal segments. This segment is larger than any of those to be found in the maxillary palpus and is longer than either of the segments of the galea of the same larva. Its form is cylindrical, but a slight lateral bend in the segment is accentuated by an enlargement at the distal end on the side away from the mandible. A few minute spines are near the distal end of the segment.

The intermediate segment (fig. 3, *B, ais*) is also intermediate in size. It is slightly more than half as long, or as wide, as the proximal one. On the other hand, it is longer than the distal segment and much greater in diameter. Cylindrical in form, the segment increases slightly and uniformly in diameter toward the distal end, where it bears a few small spines. It is attached to the truncate distal end of the proximal segment by a transparent membrane.

The distal segment (fig. 3, *B, ads*) is a slender sclerotized cylinder. Its distal end is rounded and membranous. This tip bears three, perhaps four, short but comparatively heavy spines with very thin walls. Very minute papillae are also present on the membranous tip. Sections through these delicate parts have not been studied.

A transparent, unsclerotized, cone-shaped structure is associated with the distal segment on the truncate tip of the intermediate segment. This is termed the "supplementary joint of antenna" by Böving and Craighead (*1, p. 85*), the "tactile papilla" in referring to the drawings made by Hyslop in the same publication (pl. 86), the "sense process" which Hyslop (*10, p. 258*) refers to Böving (1910), and the "accessory process of the antennae" by Whitehead (*22, p. 220*) in his list of abbreviations used on the plates. It is generally found on the antennae of the larvae of the family Elateridae, and in certain genera the number of tactile papillae acquires importance as a taxonomic character. Similar structures were noted in the illustrations of the larvae of 45 coleopterous families. Its purpose is sensory, but further study will be necessary to make certain as to the type of cells present. In this species the supplementary joint (fig. 3, *B, asj*) arises from the end of the intermediate segment, and is mesad of the distal segment.

THE MANDIBLES

The mandibles are the outstanding features of the larval head of *Limonius canus* (fig. 1, *A, man*). They are rugged, heavily sclerotized, and brown, becoming black toward the tips. To judge from their appearance their functions are those of grasping, piercing, and tearing rather than of grinding and pulverizing.

Each mandible bears two teeth. The distal lobe (fig. 4, *C, mdl*) is the primary portion of the mandible. It is bent mesally, and in the newly molted larva the distal lobe meets and overlaps that of the other mandible when the inner or mesal margin of the mandible approaches the plane parallel to the median line of the larval body. This overlapping of the distal lobes is characteristic of the closed position of the mandibles. These lobes are subject to wear, however, and specimens of this species are frequently found in reared material the lobes of whose mandibles will not meet. Normally the closed mandibles provide the larva with a highly sclerotized edge to the wedge formed by the anterior portion of its body. The narrowing of the mandible inwardly is partially compensated for by the overlapping of the tips, and a nearly transverse edge is provided this anterior tip of the wireworm.

Approximately three-fifths of the distance from the base to the anterior surface of the mandible, and on its inner surface, is the proximal lobe (fig. 4, *C*, *mpl*). This is variously termed the retinaculum, the proxidentis, and, perhaps, even the molar lobe. It is somewhat similar in shape and direction to the distal lobe, but is smaller, is not over half as long, and is directed posteriorly instead of slightly anteriorly as is the distal lobe. It appears subject to heavy wear and is as apt to be worn down or broken as the more prominent distal lobe. Evidently it has more of a molar duty than its pointed shape would indicate. It is apposed to the nasal projection and to the surface of the subnasal.

Each mandible consists of the highly modified stub of a segmental appendage. It has developed an articulatory union with the dorsal surface of the head in addition to the one on the ventral surface, has modified its musculature to permit of the opening and the powerful closing action in a single plane, and has developed the rigidity of structure to withstand normal wear.

The base of the mandible is roughly triangular with the angles at the two points of articulation and at the base of the inner or blade edge. The dorsal articulation surface, dorsal condyle, preartis, or epicondyle, is a distinct socket (fig. 2, *E*, *mdc*). This socket is rather deeply sunken into the basal angle of the mandible and articulates on an arched thickening of the anterior margin of the frons (fig. 1, *A*, *mda*). The appearance of this articulatory surface precludes any movement other than in the one plane—any other would be over irregular surfaces. It is a heavily sclerotized projection of the cranial margin which is rounded only in the line of the plane through which the mandible moves. The union is very definitely a ginglymoidal joint.

The ventral articulation, on the contrary, consists of a ball-shaped projection of the ventral lateral angle of the base of the mandible (fig. 1, *B*, *mva*). This ventral condyle (postartis) articulates in a socket in the anterior margin of the pleurostoma just outside the hypostomal suture (fig. 4, *C*, *mvc*). These ventral articulation surfaces are of a type that would permit movement in any plane. This is to be expected, since the primitive insect forms show the ventral condyle as the only articulatory surface and since the primitive mandible is provided with a wider range of movement.

On the lateral base of the mandible appears a lateral projection which is strengthened by a ridge extending anteriorly along the lateral surface of the organ (fig. 4, *C*, *mlp*). This projection arises from near the ventral condyle, and its lateral end serves as the point of attachment for the smaller of the two apodemes which extend posteriorly into the cranial cavity (fig. 4, *C*, *mla*). This apodeme is transparent in strong contrast to the darkly colored mandibular structure. The abductor muscles are attached to its margins.

The angle at the base of the cutting edge of the mandible is quite acute. The mesal apodeme (fig. 4, *C, mma*) arises from this basal angle. This apodeme is larger than the lateral one but is, like it, a thin, chitinous, nearly transparent plate. The greater part of this plate lies in nearly the same plane as the ventral surface of the mandible, but the mesal linear margin is bent dorsally. This provides a small dorsoventral plane and greatly strengthens the apodeme.

The muscles which are attached to these apodemes arise from invaginations along the hypostomal suture (fig. 1, *B, hs*) where it parallels the cardines and from a similar invagination (fig. 1, *A, dls*) shown externally by the groove and series of spines on the dorsal surface of the head and almost directly dorsad of the hypostomal suture. All the head capsule, with the exception of a median band narrower than the distance between the bases of the mandibles, is devoted to the musculature of the mandibles. The location of ganglia of the brain in the prothorax has been mentioned (p. 5). The food meatus is to be found passing through the head capsule, the anterior ganglia of the sympathetic nervous system is there, and at times the anterior tips of the superoesophageal ganglia; the remainder is almost entirely the musculature devoted to the feeding process, and most of it has to do with the opening and closing of the mandibles. These mandibular muscles arise from the head capsule considerably posterior to their points of attachment to the apodemes. Thus the spontaneous and equal contraction of dorsal and ventral muscles will exert a posterior pull, and since these muscles arise from points in a plane between the two apodemes their action will also exert a lateral force. The force the adductor muscles apply to the mesal apodeme will draw the tip of that organ backward and to the side and in this manner cause the mandible to rotate on its axis and the tip of the mandible to describe an arc ending in the closed position. Similarly the force exerted by the abductor muscles upon the lateral apodeme will cause the mandible to swing outward into the open position. The relative power needed in the two movements of the mandible is well illustrated by the comparison of the distances of the respective points of attachment of the two apodemes from the plane of the axis and also the respective amounts of musculature. It is very evident that many times as much power can be applied in closing the mandibles as is necessary to open them.

The inner base of the mandible is provided with a brush of hairs, termed by some authors the penicillus (fig. 4, *C, mb*), which points anteriorly into the preoral cavity. Nearly a fourth of the inner edge of the mandible is sheathed by these hairs. The hair-bearing surface extends posteriorly past the base of the mandible as though to protect the connective membrane of the mandible at this point.

Much of the dorsal and ventral surfaces of the mandibles is cleaned by scrubbing hair growths on the lateral wings of the nasal region and the various organs of the "lower jaw." The lateral margin of the mandible serves as a protection for the antenna, and its surface appears smooth. The anterior surface, however, except the highly sclerotized distal lobe, is sparsely clothed with extremely fine hairs which arise from minute, but distinct, alveoli. These hairs are probably sensory, those of the brushes having other primary purposes.

THE "LOWER JAW"

The movable plate on the ventral surface of the head of a wireworm consists of a union of the various parts of the maxillae and the labium to provide a unit for movement. The various movements in which this plate acts as a unit, together with its unified appearance and taxonomic importance, lead to the need of some term which can be used for the unit. Böving and Craighead (*1, pls. 84, 85*) illustrate the "ventral mouthparts," Hyslop (*10*) repeatedly speaks of "labium and maxillae," Guéniat (*5, p. 112*) terms this plate the maxillolabial apparatus (appareil maxillo-labial), Horst (*8, pl. I, fig. 4, and in text*) uses the term "lower jaw," while Glen (*4, p. 233*) calls it the "hypostome." The first two terms are not specific enough to describe a plate as unified in action and appearance as that found in the wireworm. The use of the term "hypostome" may be a misinterpretation. The term is applied to the labrum of trilobites and other Crustacea (Webster's dictionary), and to the lower portion of the face of Diptera and Hemiptera by Smith (*16*). Snodgrass (*17, p. 127*), however, defines the term as applying to a portion of the lateroventral surface of the head capsule, and in this description the hypostomata are considered the narrow sclerites of the head capsule bordering the opening on the ventral surface of the head capsule. Of the terms "maxillolabial apparatus" and "lower jaw" the latter has the advantage of both brevity and an indication of unity, and the part called "lower jaw" is to be understood as the unified movable plate on the ventral surface of the larval head which is made up of the parts of the maxillae and the labium. This is the plate McDougall (*12*) used for measurements instead of the head capsule when studying instars and larval growth.

The "lower jaw" (fig. 2, *B*, *lj*) is a nearly square area, its length doubled by the addition of the palpuslike structures at the anterior end and the two small and roughly triangular sclerites at the posterior end. The plate itself is made up of three linear and parallel sclerites. The form of the lateroposterior angles of the lateral sclerites and the width of the posterior end of the middle sclerite are factors influencing the form of the "lower jaw" and are of taxonomic importance. In the "lower jaw" of the larva of *Limonius canus* the posterior angles of the lateral sclerites are nearly 90° angles, and the medial sclerite is very slightly narrowed posteriorly. The middle sclerite, with its anterior appendages, is the labium. The lateral ones, with their anterior attachments, and the smaller posterior plates are the maxillae.

THE MAXILLA

The individual maxilla represents the least modified of the segmented appendages serving the insect mouth. In the wireworm of this species the posterior, or proximal, sclerite, the cardo (fig. 1, *B*, *c*), is small and roughly triangular in shape. The large lateral sclerite distal to the cardo is the stipes (*s*). At its anterior or distal end are the two endite lobes normally found in the maxilla. The mesal lobe is the lacinia (*lac*), while the lateral lobe is the galea (*g*). Slightly posterior to these terminal organs and at the lateral angle of the stipes is the maxillary palpus (*mps*). Each structure will be described under a separate heading.

THE CARDO

The cardo (fig. 1, *B, c*) is the proximal segment of the maxilla and is nearly right triangular in shape. The distal end, the base of the triangle, fits directly against the proximal end of the stipes and is connected to it by a brief but very flexible membrane. The mesal margin, the perpendicular of the triangle, is somewhat irregular and merges into the membranous tissue connecting the two cardines. The lateral margin, the hypotenuse, is more regular and, because of its infolding, much darker in color. This infolded margin greatly increases the rigidity of the cardo, which is further strengthened by the invagination of the suture which passes longitudinally through the sclerite. The cardinal suture (*csu*) approximately bisects the distal margin of the cardo and passes longitudinally through the sclerite in an undulatory course to near the proximal end of the lateral margin. The suture firmly unites the two parts of the cardo, the mesal or subcardo (*cs*), and the lateral or alacardo (*ca*).

The proximal end of the cardo is strengthened by the fusion of the infolded lateral margin and the cardinal suture. This end articulates with the posterior end of the margin of the hypostoma. The joints at the two ends of the cardo permit the backward and forward movement of the "lower jaw." When the "lower jaw" is retracted the cardo is in a nearly perpendicular position, but when the muscles that arise from the under surface of the tentorium and are attached to the inner surface of the cardo near its distal end contract, the cardo is pulled into a horizontal position and the "lower jaw" is shoved anteriorly the length of the cardinal sclerites. This illustrates the limits of movement of the "lower jaw" and the importance of the cardines in its movements.

A single seta is located in the alacardo midway between its lateral margins and toward the distal end. This seta is similar in size to the smaller ones of the group of four at the distal end of the stipes. The alveolus shows white in contrast to the brownish yellow of the surrounding plate.

THE STIPES

The stipes (fig. 1, *B, s*) is the largest part of the maxilla, and the two stipites, together with the postlabium which is between them, form the larger part of the "lower jaw." Each stipes is a nearly rectangular plate. The inner, or mesal, margin is straight and connected to the postlabium by a narrow membrane. The inner proximal angle is practically a right angle or very slightly obtuse, whereas the outer proximal one closely approaches a right angle but differs from the inner in being rounded. The lateral margin of the sclerite is very nearly straight, and very nearly parallel to the inner margin. The distal end of the stipes is not so smoothly rectangular. It serves as the base for the attachment of the maxillary palpus, the galea, and the lacinia in that order from the lateral to the mesal angles.

The mesal margin of the stipes is slightly bent inward. The amount of the inward bend gradually increases distally. The outer margin, however, is bent inward a distance approximately one-half the breadth of the ventral surface of the sclerite. This infolded lateral margin of the stipes is again bent, this time mesally. The result is a flange of the sclerite which is parallel to the ventral surface. Similarly the infolded margin of the hypostoma (p. 8) is doubly bent, but the flange thus formed extends under the stipes rather than back under the hypostoma. Thus the inward, or mesal, bent flange of the stipes rests upon the extended, or mesally bent, flange of the hypostoma. The width of the flange of the stipes is reduced distally, while the depth of the depression in, and the width of the opening between, the hypostomae is reduced proximally. The very flexible membrane connecting the stipes to the hypostoma arises from the edges of these flange-like margins.

A group of spines, usually four in number, form an irregular row along the margin near the distal angle of the visible portion of the stipes. The most proximal of these is perhaps half as long as the sclerite, if viewed from the same angle, and arises from a comparatively large, circular, nonsclerotized pit. The second spine of the series is not over a third as long as the first and arises from a small alveolus situated near the margin of the stipes. The third spine is similar in size to the first. Its alveolus is so far on to the slope of the margin that from the normal viewpoint it does not appear as large as that of the first. The last spine in the row is similar in size to the second, and its alveolus is farther from the margin than that of the third.

The lateral margin of the stipes bends slightly outward from a point proximal to the first spine of the group, and the infolding of the margin is greatly diminished from approximately this same place. Directly across the plate from the second spine of the series and on the inner margin of the stipes is an area which in cleared material is apt to appear to be a large alveolus. The structure is not on the ventral surface of the stipes, however, and appears to have some relation to the proximal end of the anterior-mesal face of the lacinia.

The distal end of the stipes shows one, and sometimes two, distinct sutures on the ventral surface in some species of elaterid larvae. In Hyslop's figure of the larval mouth parts of *Monocrepidius auritus* (Hbst.) (Böving and Craighead, *1, pl. 87, C, dis*) the area thus set off is termed the dististipes. These sutures are not present on the stipes of the larva of *Limonius canus*. A rather distinct line is formed, however, by the limits of sclerotization. The nonsclerotized area may be termed the dististipes (fig. 1, *B*, *sd*).

THE MAXILLARY PALPUS

The maxillary palpus (fig. 1, *B*, *mps*) of the larva of *Limonius canus* apparently consists of only four segments. These have their tubular sides heavily sclerotized while the ends of the segments are colorless. When the palpus is artificially extended, as in the illustration, there develops an evagination of the membrane surrounding the base of the proximal segment which may assume much the appearance of a distinct segment. On the other hand the palpus may be withdrawn into the distal end of the stipes nearly the length of the proximal segment. This flexible membrane does not appear to have any of the characteristics of a palpal segment, but is only the connective membrane.

The third, or next to last, segment of the palpus bears two spines near the distal margin of the sclerotized area. The proximal segment frequently bears a similar spine. The tip of the distal segment is provided with short, minute, transparent sensory spines.

These are distinctly different from those on the tip of the galea. Occasional circular areas similar in appearance to the alveoli of the spines are found on the sclerotized surfaces, but are not seen to carry spines. These may also be sensory.

THE GALEA

The galea (fig. 1, *B*, *g*) is a distinct, robust lobe consisting of two nearly equal segments. It is situated between the maxillary palpus and the lacinia at the mid portion of the distal end of the stipes. The distal segment of the galea bears a large number of short, coarse spines at its tip. This dense clump of sensory spines causes the tip of the segment to appear reduced and drawn out. Several longer spines form a ring around the sensory tip and are large enough to provide it with considerable protection. Normally the tip of the galea is directed forward and toward the median line. No particular activity has been noted for the organ.

THE LACINIA

The lacinia (fig. 1, *B*, *lac*) is normally the mesal endite of the maxilla. In the undisturbed larval mouth-parts it is hidden by the immense growth of hairs with which it is clothed. This hair growth, the lacinarastra, is located on the ventral and mesal surfaces of the lacinia. The hairs form a dense brush and are directed slightly forward but mostly toward the median line and reach past the labial palpus when it is in its normal position. This dense mass of hairs very thoroughly closes the opening between the maxilla and the labium.

When the lacinia is dissected out it proves to be a chitinous plate which is strongly concave to allow its close approach to the mesal side of the galea. Its mesal surface is a vertical wall set at right angles to the horizontal plane of the stipes, and this elongated side is attached to the infolded surface of the inner margin of the stipes (see p. 21). By virtue of its right-angle position the lacinia forms the wall of a channel in which the tubular labium is permitted a dorsoventral movement.

THE LABIUM

The labium does not show any signs of the paired condition of the second maxillae of primitive insect forms except the paired labial palpi. The slender labium, the middle portion of the "lower jaw" which separates the two maxillae, is readily divided into two parts. The distal portion, the prelabium (fig. 1, *B*, *lpe*), is freely movable and bears the labial palpi (*lp*), whereas the proximal portion of the organ, the postlabium (*lpo*), is closely attached throughout most of its length to the mesal margins of the stipites. Considerable confusion has developed over the use of terms for the various parts of the insect labium, and the terms used here appear least subject to misinterpretation.

THE POSTLABIUM

The proximal portion of the labium in insects is frequently divided into two parts or sclerites, the proximal sclerite being termed the submentum and the distal one the mentum. These terms are also used for the proximal and distal portions of the labium, respectively. The elongate, flattened, sclerotized, proximal plate of the labium of the larva of *Limonius canus* might be termed the submentum and the nonsclerotized portion at its distal end the mentum. There is no distinct division between the two parts except the rather gradual reduction in sclerotization. It seems unnecessary to treat the parts separately.

The postlabium (fig. 1, *B*, *lpo*) tapers proximally, and near the proximal end is suddenly reduced in width. The end is rounded. The reduction of the plate is formed by, or is to provide room for, the alveoli from which arise spines similar in size to the largest of those borne by the stipites. The spines are slightly distad of the proximal corners of the stipites, and the end of the sclerite extends slightly into the area between the cardines. The distal half of the sclerotized plate bears along the lateral margins occasional regularly spaced spines. These are all small with the exception of the most distal one on each margin. This distal spine is approximately as long as the postlabium is wide at this point. The alveolus from which it arises is larger than the others in the row. The pits in which the alveoli of the distal pair of spines are found mark the distal end of the uniformly sclerotized plate.

The membraneous area at the distal part of the postlabium is less closely united to the mesal margins of the stipites and partakes more of the cylindrical form of the prelabium. The sides round in more gradually and the ventral surface is not so flat as that of the more heavily sclerotized proximal area. The distal end of the postlabium is little more than an extensive connective membrane. It is possible for the prelabium to be retracted into the distal end of the organ until over half of its sclerotized plate is covered by the semitransparent membrane of the postlabium.

THE PRELABIUM

The distal portion of the labium, the prelabium (fig. 1, *B*, *lpe*), forms the mesal part of the lower lip of the opening of the preoral cavity. It is not fixed like the nasale above, but is subject to extensive movement backward and forward in the horizontal plane. This movement is due to two sources. The entire "lower jaw" moves as has been mentioned, and in addition the prelabium may be retracted into the distal end of the postlabium independently of the movement of other mouth parts. A dorsoventral movement is also apparent.

The prelabium as viewed from the ventral surface is a pear-shaped sclerotized structure attached to the postlabium by its smaller end and with the palpi attached to the ventrolateral angles near the distal end. The organ becomes less sclerotized distally and the tip from the bases of the palpi is membranous.

The glossae and paraglossae of the generalized insect labium have disappeared except for the sensory area of the prelabial tip. The labial palpigers and the labiostipes have fused without any indication of the union.

Two spines arise near the distal tip and close to the median line. Six spines are on the ventral surface of the sclerotized area. The two largest are somewhat smaller than those at the proximal end of the postlabium. The pits which contain their alveoli are farther from the median line than are the inner margins of the bases of the palpi while they mark the approximate point where the organ increases in width. Near each of these large spines and toward the lateral margin arises a spine less than half as long. The last two of these six spines are near the proximal margin and in the plane of the largest. The last two are much the smallest.

The membranous tip is provided with short, blunt, transparent sensory organs which appear different from those on any of the other mouth parts. They are somewhat scattered over the surface surrounding the tip, especially on the dorsal surface. Very little has been learned of their cellular structure.

The prelabium, when dissected out, proves to be cylindrical in form with the dorsal surface forming a portion of the floor of the anterior part of the preoral cavity. This surface is membranous, but posterior to it and on the more proximal part of the prelabium is a sclerotized area from which arises a large, dense tuft of slender but stiff bristles, the labial brush (fig. 4, *B*, *lb*). These bristles slant forward at the points of origin, but bend gradually upward until their tips are directed dorsally. They appear to be somewhat bent away from the mesal line further to outline the food meatus.

The sclerotized plate from which the brush arises is readily separable from the remainder of the labium and is frequently left in the preoral cavity when the "lower jaw" is dissected away. The plate is the dorsal portion of the sclerotized tube which forms the proximal part of the prelabium.

The labial brush separates the preoral cavity, as has been mentioned, into two parts, and the plate from which it arises serves for the attachment of the anterior margin of the hypopharynx.

THE LABIAL PALPI

The labial palpi (fig. 1, *B*, *lp*) arise from the distal end of the prelabium near the lateral edges, but on the ventral surface. Each consists of two segments. The segments are similar in structure to those of the maxillary palpi. The proximal segment is more slender than those of the maxillary palpi, but the distal segments are very similar in size. Each proximal or basal segment bears a spine on its ventral surface. The spine is similar in size to those near the distal tip of the prelabium.

The distal portion of each segment, as with the other palpi and the antennae, is covered with a semitransparent membrane in sharp distinction to the strongly sclerotized tubular walls of the body of the segment. The tip of the distal segment bears numerous sensory papillae which are similar in appearance to the smaller ones on the tips of the galeae.

THE THORAX

When one of these wireworms is killed with hot water, or examined alive after having been submerged in water for a day or two, the body back of the head is seen to be nearly cylindrical while the three thoracic segments are each provided with a pair of legs which are extended ventrally from this cylinder. The skin is seen to contain a definite number of harder brownish areas. These are seen in cross section to be somewhat thinner than the intermediate membrane and prove to be relatively inflexible. Under normal conditions the greater part of the thick, flexible membrane is not visible, since it is folded under the sclerites, which may even overlap when the larva is in extreme contraction. The larvae of *Limonius canus* are observed to maintain themselves in a nearly cylindrical form, somewhat flattened beneath, when crawling. The legs are held close to the flattened under surface.

THE PROTHORAX

The sclerites of the prothorax differ markedly from those of the other two thoracic segments, the latter being much more like those of the abdomen, but all are alike in having a large tergite covering nearly the whole upper half. The sternite beneath is next in size, and there are two or three pleurites on each side that are much smaller and vary in the successive segments.

THE PRONOTUM

Since most of the dorsal muscles are attached to the posterior margin of the head capsule and to the antecosta of the mesonotum, they pass completely through the prothorax. For this reason the pronotum (fig. 5, *A*, *pn*) bears folded connective membrane (*im*) at the anterior as well as the posterior margin. This folded intersegmental membrane permits of the telescoping of the adjacent segments and is found on the posterior margin of the dorsal surface of the thoracic and first eight abdominal segments. The prothorax is the only segment which bears this type of membrane on the anterior margin. This is because the head capsule telescopes into the prothorax rather than over it.

The dorsal surface of the prothorax is a distinctly sclerotized, yellowish plate longitudinally divided by the median suture. The term "notum" is used to distinguish more readily between this area of the thoracic segments and the similar areas, the terga, of the abdominal segments. This sclerotized area is greater than in the other thoracic segments. The length of the plate is as great as the greatest length of the head capsule and a half longer than the notum of either of the other thoracic segments. The sclerotization is intermediate between that of the head capsule and that of the other thoracic and the abdominal segments. The punctation is minute, scattered, and irregular. The punctures are for the greater part nearly uniform in size, the distance between them averaging about 10 times their diameters.

Six spines are on each side of the pronotum near the posterior margin. These arise two each from depressions in a line parallel to this margin. The depressions are rounding and of greater diameter than their distance in from the edge of the sclerotized area. Two alveoli, or spine sockets, are found in each depression, one being directly anterior to the other. These alveoli show as round white areas surrounding the bases of the spines. The spines are brown, normally erect, and vary somewhat in length, averaging about one-third the length of the pronotum. They are comparable to the longer of the spines found on the stipites. A similar arrangement of spines is found on each of the succeeding segments to and including the eighth abdominal.

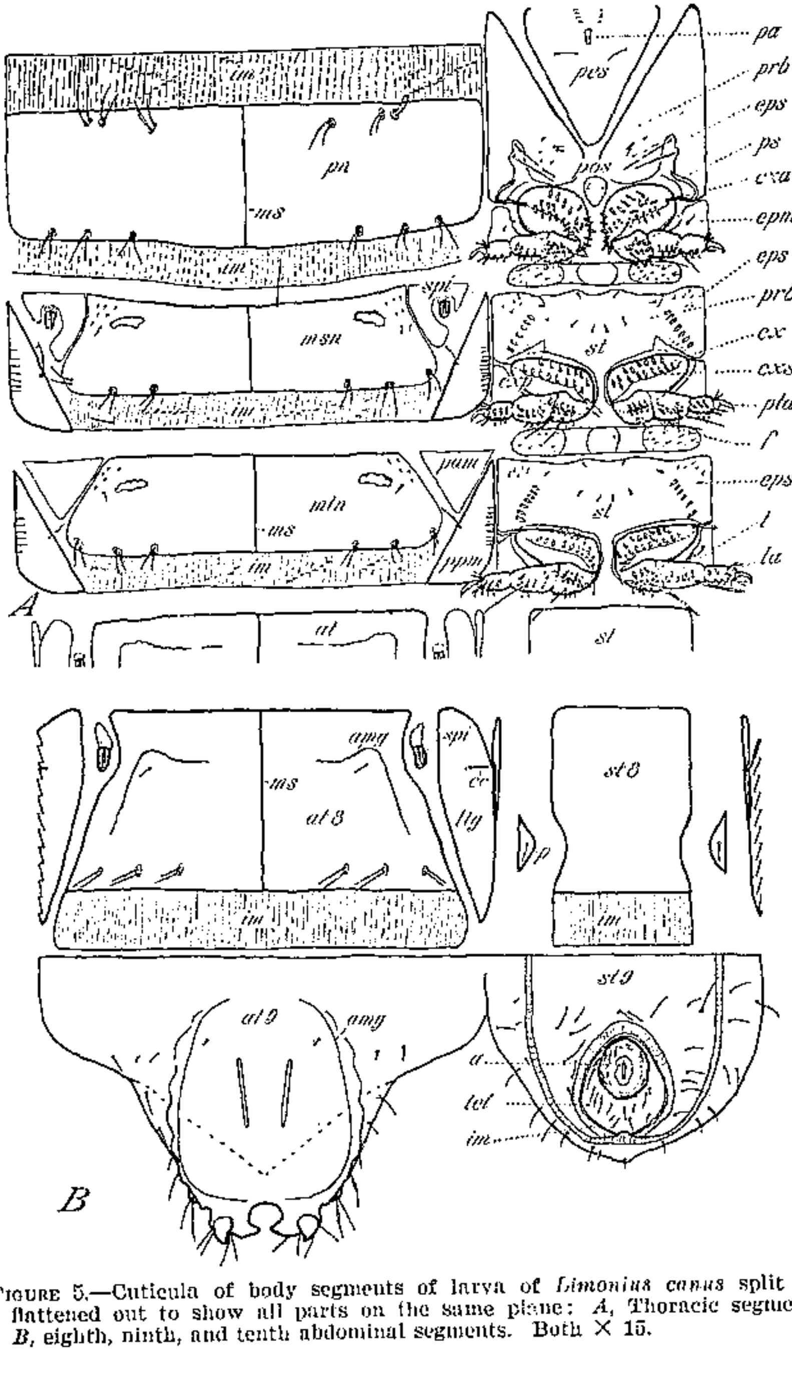

FIGURE 5.—Cuticula of body segments of larva of *Limonius canus* split and flattened out to show all parts on the same plane: *A*, Thoracic segments; *B*, eighth, ninth, and tenth abdominal segments. Both × 15.

The pronotum, however, bears on each side near the anterior margin six spines, very rarely more, which are not found on the dorsal surface of the other segments. This peculiarity may result from the fact that this is the only segment whose anterior margin is not at times telescoped into the segment ahead. These spines are like those just described in size and like them arise two from a depression, very rarely three. Each depression contains separate alveoli similarly placed, but the depressions are more irregular in arrangement. The lateral two are close together and equally near the anterior margin. They are located nearer the median suture than the middle one of the three on the posterior margin. The innermost of the group is approximately twice as far from the margin. This depression is nearer the median suture than the innermost of those near the posterior margin. A single smaller spine is sometimes found between this last pair and the more lateral two pairs.

The pronotum extends farther down over the sides than does this sclerite on any of the other body segments. The sclerotization weakens laterally from a line just outside of the lateralmost pair of anterior spines, and gradually fades into the pleural membrane. The anterior and lateral margins are nearly straight, whereas the posterior margin is slightly arcuate, the plate being gradually lengthened posteriorly near the middle.

The Propleura

A portion of the propleura may be fused to the pronotum. A comparison with the abdominal segments would indicate that the outermost pair of posterior spines should be borne by the pleurites, though it may be that these abdominal sclerites are laterotergites. On the other thoracic segments similar pleurites, or laterotergites, are found as in the abdominal segments. Their absence from the prothorax may be a result of the heavier sclerotization which may have spread across the membranes connecting the sclerites and fused them into a common plate.

The pleural plates adjacent to the insertion of the legs are similar to those in the other thoracic segments. The lateral margin of the coxa shows a definite articulation with the coxapleurite. The pleural suture (fig. 5, *A*, *ps*), which gives strength to the coxapleurite, extends laterally a short distance, then bends forward into the episternum. The anterior extension of the suture is nearly as long as its basal portion. The suture is a very distinct, dark-brown line. The internal pleural ridge is visible in cleared material.

The episternum (fig. 5, *A*, *eps*) extends anteriorly from the basal portion of the pleural suture and parallels the margin of the pronotum. Anteriorly it fuses with the prosternum (*pos*) by means of the precoxal bridge (*prb*).

The epimeron (fig. 5, *A*, *epm*) is separated from the pleural suture by a very narrow semimembranous area. It extends posteriorly along the margin of the pronotum and bends around behind the coxa to form the gradually less sclerotized postcoxal bridge. It bears a very small spine nearly in line with the posterior margin of the coxa.

The amount of pigment and the degree of opaqueness of these sclerites is difficult to express. The epimeron blends into the surrounding membrane on all its margins, least at the anterior end. The episternum is distinctly margined along the inner edge until it joins the precoxal bridge. Two large spines mark this edge, the anterior one marking the point where the episternum joins the precoxal bridge. The fused area of episternum, precoxal bridge, and sternum fade out anteriorly, while the inner leg of the inverted V formed by this fusion fades out along all its margins.

The Prosternum

The outstanding sclerite of the prosternal area is the presternum, the acrosternite of Horst (*8, p. 34*). Korschelt (*11, vol. 2, p. 533 and fig. 37*) in describing the *Dytiscus* larva states that Berlese calls this plate the acrosternite and uses the term in his illustration, but in his discussion he terms it the "brustschild," while Weber (*21, fig. 3*) illustrates the presternum as a portion of the head capsule in elaterid larvae. This plate (fig. 5, *A*, *pes*) appears as an isosceles triangle with its base forming the anterior margin of the ventral surface of the prothorax and closely attached to the posterior surface of the head. This sclerite is as intimately connected to the head as it is to the other parts of the prothorax. The slightly blunted apex of the triangle reaches two-thirds of the distance from the anterior margin of the segment to a line between the centers of the coxae. The roughly diamond-shaped area with one corner at the posterior tip of the triangle and the opposite corner at the midpoint of its base is the most heavily sclerotized portion of the prosternum. The presternum, together with the pronotum, forms a strong sclerotized ring around the body as a support and shield for the head.

A sclerotized invagination of the body wall, the prosternal apophysis (fig. 5, *A*, *pa*), which appears on the ventral surface as a small, dark-brown, elongate portion of the endoskeleton, is on the midline and about one-fourth of the distance from the base to the tip of the triangle. It is situated at the apex of a small isoscles triangle whose equal sides arise from the anterior margin of the presternum and are marked by rows of extremely fine bristles. Each side line is more distinct in the basal portion than near the tip, perhaps owing to the infolding of the surface to form the apophysis. Since the triangle is indistinct, the bristles and their alveoli minute, the apophysis is the only feature generally noted.

Midway between the anterior margins of the coxae is a small sclerite lightly fused with those portions of the sternum which are united to the episternum by means of the precoaxal bridge. A similar but less sclerotized plate is at the midpoint of the posterior margin.

The arrangement of the spines on the sternum is quite definite. In addition to the minute ones mentioned in connection with the apophysis there are two spines on the presternum. They mark the approximate lateral angles of the more heavily sclerotized diamond-shaped area. Between the two spines which mark the margin of the episternum and the tip of the presternum and within the sclerotized area are found spines. One large and one smaller are usually found on each side, their arrangement paralleling the margin of the presternum. Associated with them are smaller, minute spines. A minute spine is found on each lateral margin of the plate between the coxae.

THE MESOTHORAX AND METATHORAX

The mesothorax and metathorax are similar. A general description will be given with the variations noted as they are encountered. These segments are intermediate in form as well as in position between the prothorax and the abdominal segments. The mesothorax bears a spiracle (fig. 5, *A*, *spi*) on each lateral wall near the anterior margin, whereas the metathorax, like the prothorax, bears none. The middle thoracic segment also differs from the posterior one, the metathorax, in the anterior margin of the notum being arcuate to coincide with the posterior margin of the pronotum, which is gradually bent posteriorly in the vicinity of the medial suture. The anterior margin of the metanotum, like the posterior margins of the nota of both segments, is straight.

The Nota

These sclerotized plates cover the dorsal surface and extend at each side onto the lateral surfaces. While not occupying as much of the larval length as the pronotum, the mesonotum (fig. 5, *A*, *msn*) and the metanotum (*mtn*) are each very similar to it. Like the pronotum, they do not show any differentiation into sclerites, the only suture being the medial one (*ms*) marking the median line of the dorsal surface, which is the line of the splitting of the cuticula at ecdysis. The punctation is more variable in size than on the pronotum and with the larger punctures somewhat denser toward the anterior margin. The folded portion of the intersegmental membrane (*im*) is found only on the posterior margins of these segments.

The two inner pair of spines on each posterior corner are similar in location to those on the pronotum. The third and outer pair of spines has migrated anteriorly and is located almost midway along the side of each notum. The three pairs of spines on the anterior corners of the pronotum have been replaced in each case by a single spine and a groove. The single spine rises from a smaller depression and is slightly farther from the median suture than is the middle pair of spines on the posterior margin of the same segment or the lateralmost pair of spines on the anterior margin of the pronotum. It is situated well back from the anterior margin, as far as the innermost of the anterior pairs on the pronotum. Inward from this spine a groove develops which extends mesally in a slight arc nearly parallel to the anterior margin of the notum. It is as though made by a very small fingernail pushed into the chitin of the plate and toward the front. Thus the ends of the arc bend posteriorly and the anterior margin is thickened as though the surface had been shoved into itself, while the posterior margin is gradually thinned toward the bottom of the groove.

Single small spines are sometimes found near each end of this groove. They arise, when present, from alveoli which are similar in appearance to many of the punctures of the notum. In the anterior corners of the nota usually are found two or more, frequently several, minute hairs arising from apparently normal punctures. The mesonotum often shows more of these minute hairs than does the metanotum. Individual larvae may show variation in arrangement and number on the two sides of the body. While some of the hairs may be lost through handling of the larvae, even the arrangement of the punctures which contain the alveoli is not uniform in the species or the individual.

The Pleura

Two sclerites on each lateral surface appear to be portions of the pleura. The anterior sclerite in the mesothorax bears the spiracle which in larvae is frequently a characteristic of the pleuron. The posterior sclerite is the larger and is right-triangular in form. It is separated from the notum and the anterior sclerite by a wide band of nonsclerotized tissue which extends from the posterior margin diagonally forward and downward to the anterior margin of the segment. The anterior pleurite is separated from the notum by a narrow band of conective tissue. This band is directed downward and backward from the anterior margin to its interception with the other diagonal. Thus the lateral margin of the notum extends ventrally between the two pleurites. This condition is noted only in these two segments, for the lateral margins of the pronotum and of the terga of the abdominal segments are nearly straight. The two pleurites are separated from the sclerites beneath them by a line parallel to the body axis. The membrane along this line varies in width but forms an open band of nonsclerotized tissue longitudinally across each segment and continuing the line formed by the pleural membrane of the prothorax.

These two lateral sclerites may be portions of the episternum and epimeron, they may be laterotergites, or they may be extrapleural plates, but for purposes of distinction they can be termed the anterior and posterior mesopleurites and metapleurites (fig. 5, *A*, *pam* and *ppm*).

The episternum (fig. 5, *A*, *eps*) and epimeron (*epm*) of these thoracic segments are similar to those of the propleura. The coxapleurite is on the lateral margin of the coxa and is determined by the pleural suture (*ps*) and the pleural ridge. The pleural suture extends directly from the coxa to the pleural membrane; it does not bend anteriorly as in the prothorax.

The episternum is shorter than in the prothorax owing to the greatly reduced lengths of these segments. It appears to be fused with the precoxal bridge (*prb*), but the sternal sclerites are so slightly colored as to be impossible to trace without special treatment. The sclerotized area, which is the episternum and probably some portion of the sternum, very likely the precoxal bridge, is distinct from the area located on the ventral surface. Its inner margin throughout most of its length is marked by a row of conical projections. These projections are heavily sclerotized, darkly colored, quite rigidly attached to the chitinous tissue. These short, heavy spines arise from alveoli which show as very narrow white rings around the bases of some of the spines. In prepared sections through the body wall of the larva the individual alveolus shows as a deep, close-fitting cup into which the tapering base of the spine fits rigidly. From six to eight spines are normally found along this diagonal margin of the episternum. The arrangement is usually in a row, but may become somewhat irregular toward the front end. It gives much the appearance of a ctenidium. On the episternum, especially toward the front margin, are a number of minute spines arising from similarly minute and rather evenly distributed punctures.

The epimeron is not separated from the pleural suture as in the propleura. The lateral margin is distinct, but the portion toward the coxae and the postcoxal bridge fade into the connective tissue with little line of demarcation. The sclerite bears a spine in line with the coxae. Those on the metathorax are somewhat farther back than the spine on each epimeron of the mesothorax.

The Sterna

The sternal area (fig. 5, *A*, *st*) is membranous in appearance and free from sclerotized plates except for small and but slightly colored areas close to the intersegmental line at the anterior margin of each segment. There are three of these on each segment in a line across the body. The lateral ones are more distinct than the one on the midline of the ventral surface. The lateral ones, moreover, resemble in appearance, and in the presence of rather evenly distributed minute spines, the anterior portion of the episternum. Since these plates each lie anterior to the episternum and precoxal bridge they may be portions of this fused plate separated from it only by the transverse infolding of the ventral surface. The sclerite on the midline shows more of the structure of the sternal area.

The membranous-appearing areas are of varying intensity of structure. A wedge-shaped area, with its elongated tip extending backward between the coxae and with its base including the three slightly sclerotized areas just described, is a sternal plate. It shows under magnification and in certain lights to have a roughened surface and to be connected with adjacent portions of the body surface by connective tissue. Lack of sclerotization, or more probably lack of pigmentation, has tended to make the plate indistinguishable. It bears eight moderately small spines arranged in an elongate oval paralleling the base of the wedge.

THE SPIRACLES

The presence of a pair of spiracles on the mesothoracic segment has been noted. These are similar in appearance to the eight pairs to be found on the first eight abdominal segments. They give the appearance of each being two rather slender parallel openings in the cuticula. The slits are directed anteroposteriorly, and they increase slightly in size toward the anterior end. Closer examination indicates that the openings are only cross-striated grooves which increase in depth anteriorly, and that much of the spiracle is in the area immediately anterior to the grooves. The center of the anterior area is scarred, and in sections through the cuticula this scar is seen to close an opening into a chamber forming the outer end of the trachea. The parallel grooves serve to bring the air in contact with a wall of the tracheal chamber, and the gases diffuse through this wall.

The spiracles of the larva of *Limonius canus* (fig. 6) are very similar in form and function to those of *Alaus oculatus* described and illustrated by Snodgrass (*17, p. 445, fig. 234, A, B, C, D*). The grooves (the secondary atrial chambers of Snodgrass) are more nearly parallel in the spiracles of the larva of *L. canus* than in *A. oculatus*. The V-shaped form of the latter is similar to that observed in larvae of *A. melanops* Lec. The scarred area is not so distinct in the larva of *L. canus* as it is shown in the illustration of *A. oculatus* or observed on the larva of *A. melanops*, and the color of the spiracular sclerite in *L. canus* does not contrast so strongly with the rest of the body surface as in *A. melanops*. This is due to the heavy pigmentation of most of the sclerites of the larva of *L. canus*. In both instances the larval spiracles are brown, but the nearby sclerites of *L. canus* are brownish yellow whereas those of *A. melanops* are nearly white.

THE LEGS

The six legs of the larva of *Limonius canus* are simple in structure, if not in appearance, and are little modified from the typical larval pattern. They each consist of coxa, trochanter, femur, tibia, a one-segmented tarsus, and pretarsus with a single claw. The pairs of the three thoracic segments show little difference in size or structure, though they increase slightly in length from front to back. They are short, compactly folded against the sterna, and entirely hidden by the body when it is viewed from above. Their appearance is made noteworthy by the large number of very heavy spines with which the various segments of each leg are armed.

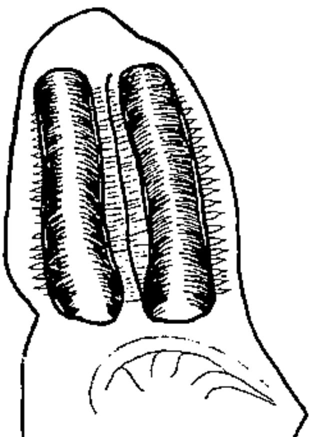

FIGURE 6.—Abdominal spiracle of *Limonius canus*, right side of larva. × 290.

THE COXA

The coxa (fig. 5, *A*, *cx*) is much the largest segment of the leg. It is oval in form with its longer axis lying crosswise of the larval body and protruding farther and farther from the level of the sterna as it approaches the median line of the body. The single external articulation (*cxa*) is slightly in front of the midpoint of the end nearest the pleural line. The articulatory surface is dark and extends as a slender pointed projection into the body cavity.

From the base of this point of articulation two sutures arise with the corresponding thickening and strengthening of the coxal wall. One, the anterior and perhaps the coxal suture (fig. 5, *A*, *cxs*), continues the line of the pleural suture and extends over the top of the coxa arching slightly anteriorly and reaching nearly to the inner end of the coxa and including the articulation of the trochanter. This suture or ridge forms the ventral margin of the anterior face of the coxa. The posterior suture (fig. 5, *A*, *cxp*), which has some of the characteristics of the basicostal suture, follows the posterior surface around to the inner end and joins the anterior suture. The area inclosed by the two sutures forms a depression in which the femur, tibia, and a portion of the tarsus rest when the leg is depressed.

The spines with which the coxa is armed are similar in color and structure to those of the episternal margin in the mesothorax and metathorax, while in size they are as large or larger, there being considerable variation between those on the individual coxa. The more rounding procoxae carry a few more of these spines on the anterior surface than the more elongate mesocoxae and metacoxae. The number of spines ranges in the neighborhood of 20 to 24. The posterior surfaces of the several coxae are very narrow, somewhat subject to the rubbing of the leg segments, and are generally free from spines of this kind.

The Trochanter

The trochanter is a small sclerite fused to the proximal end of the femur and is triangular in form when the leg is viewed from the side. In position, however, it is buried in the coxa, for the suture connecting it with the femur is the line of connection with the coxa. The trochanter forms a heavily sclerotized prolongation of the femur extending into the coxa and providing attachment for the various muscles which move the trochanter and the attached femur.

The Femur

The upper surface of the femur (fig. 5, *A*, *f*) is for the major portion not sclerotized; even the distal part is very lightly constructed, as this surface is in contact with the surface of the coxal depression. The lateral and ventral surfaces are similar in appearance to the sclerotized surfaces of the coxae. They bear spines like those of the coxae on the distal two-thirds. The portion nearest the trochanter is bare owing to its contact with the coxa when the leg is extended. The spines number about 8 or 10 on each side, leaving a strip lengthwise of the ventral surface of this and the following segments bare. The position of the spines serves to increase the width of the traction surface as well as provide against slipping. These spines on the anterior margin are the heavier, less pointed, and tend to be in two distinct and parallel rows. Those on the posterior margin, as the leg lies in its normal transverse position, are less regularly placed. Two long hairs arise from the opposite ends and near the posterior margin of the open strip between the two groups of spines. They are several times as long as the spines.

The Tibia

This intermediate segment (fig. 5, *A*, *t*) has little to distinguish it except that it is the first to provide a complete cylinder. The margins of the ventral surface are similarly spined as in the femur. The number of spines is slightly reduced, six or seven being the usual number. Only one long hair is noted and it is toward the distal end of the segment.

The Tarsus

This single segment (fig. 5, *A*, *ta*) has the dorsal portion nearly straight, whereas the ventral surface is roundingly curved upward toward the distal end to the comparatively small union with the pretarsus. The spines are arranged in single rows along the margins of the ventral surface and the sides of the union with the pretarsus. There are generally five on each side. As in the other segments, the spines on the anterior margin are much the heavier.

THE PRETARSUS

This dactylopoditelike terminal segment (fig. 5, *A*, *pta*) consists primarily of a more heavily sclerotized structure. The reduction in the size of the cylinder which formed the leg is rapidly continued and the tip is drawn out into a single, slightly curved, clawlike point.

THE ABDOMEN

The third body section of the larva of *Limonius canus*, the abdomen, continues the form shown by the thoracic segments when the larva is killed in hot water or left in water for several hours. The body becomes distended and cylindrical; the membranous areas between the various sclerites are exposed, and the relationships of the sclerites and conjunctivae are more apparent. In the contracted condition little, if any, of the connective membrane may be seen, and the relationships of the sclerites to one another are not entirely clear, for they may even overlap. The living larva appears cylindrical above, widened and flattened beneath.

The abdomen of this wireworm consists of 10 visible segments. The first 8 are very uniform in size and structure. The ninth, the terminal segment, carries the terminal armature and is of considerable importance in the determination of species. The tenth segment forms a portion of the ventral surface of the ninth segment and contains the anal opening. Since the tenth segment is not generally noticed, the wireworm may be considered as consisting of 12 body segments in addition to the head, 3 thoracic and 9 abdominal segments.

FIRST TO EIGHTH SEGMENTS

Each of the first eight abdominal segments has the following six distinct sclerites: The tergum, sternum, two laterotergites, and two pleurites. A very limited area around each spiracle might be considered as a distinct sclerite, but since it consists primarily of the sclerotization of the spiracle walls it will be spoken of as the spiracle.

THE TERGUM

The dorsal surface of each segment in *Limonius canus* is protected by a single sclerite, the tergum (fig. 5, *B*, *at*), which is divided longitudinally into two equal parts by the median suture (*ms*). The sclerotization of the terga is very similar to that of the nota of the two preceding thoracic segments. The principal difference is to be found in the greater length of the groove (fig. 5, *B*, *amg*) found on each side and near the anterior margin, in comparison with those of the mesothorax and metathorax. Whereas in these thoracic segments the groove is compared to the print of a minute fingernail and appears to have developed from two depressions, each for a pair of spines, as seen in the prothorax, on the abdominal terga the groove parallels much of the anterior margin of the sclerite and laterally bends posteriorly and roughly parallels the lateral margin for nearly half its length. On the first abdominal tergite the anterior portion of the groove is moderately short; it is longest on the second to fifth tergites and somewhat shorter in the more posterior segments. It decreases in intensity mesally and does not attain the median suture. The inner margin gradually fades from the darker sclerotized surface to the nearly white bottom of the groove. The outside or anterior and lateral margins, respectively, of the groove are dark and sharply outlined. This margin is scalloped from one punctation of the tergite to the next. These punctations, like the most of those which are sparsely and somewhat irregularly scattered over the surface of each tergum, are similar in appearance to those depressions which bear spines. Under magnification of over 100 diameters and in certain lights most of these depressions appear to contain spines, but under low powers the spines cannot be seen.

Certain spines are very readily seen. One arises in the angle made by each groove. Another is near the lateral margin of the tergum, opposite the midpoint of the spiracle, and slightly posterior to the spine just mentioned. Near the posterior margin and paralleling it are three depressions each of which bears two spines. These depressions are elongate, contain two alveoli, and extend at right angles to the margin. The lateral depression bears the longest spines and is in line with the single spine near the spiracle. The continuation of the lateral portion of the groove would pass between this lateral depression and the middle one, while the inner depression is about midway between the lateral margin and the median suture.

The Sternum

The sternum (fig. 5, *B*, *st*) is the second largest sclerite of the abdominal segment. It covers most of the ventral side, and though it is made of several plates there is little indication of any division throughout the sclerite. The width of the plate is sharply reduced in the posterior half to provide space for the two pleurites. From a point about one-third of the way back along the side of the sternum the lateral margins bend from a line parallel with that of the body and extend diagonally backward toward a point near the middle of the posterior margin of the sternum. At slightly more than three-fourths the length of the plate the marginal line turns slightly outward and continues in that direction to the posterior end of the plate. The form of the pleurites is such as to fit into this indentation in the sternum. The measurements are variable, since the size of the pleurites decreases from segment to segment posteriorly, until in the eighth segment the pleurite interferes but slightly with the parallel margins of the sternum.

The number and position of the spines vary from segment to segment. In general the segments farthest back have the most spines. The number along the lateral margin ranges from four to seven spines comparable to those of the tergum. Smaller hairs may be found in many of the punctures if the magnification is sufficiently high.

The Laterotergites

Next largest in size are the laterotergites (fig. 5, *B*, *ltg*), the slender sclerites paralleling the lateral margins of the tergum. These appear to have a narrow splinter of sclerotized plate split off from the ventral margin. The separation is broad at the anterior end, but gradually narrows posteriorly and the splinter usually appears to fuse with the larger plate shortly posterior to the tip of the spiracle. In a few instances, however, it has been possible to mount sections of the body wall so as to show a complete separation between the splinter and the larger sclerite. When separated it is seen that the small sclerite is two-thirds the length of the larger one. The anterior half of the smaller plate is much wider than the posterior half; the change in width occurs rather suddenly and on the margin next to the larger plate, whose margin shows a corresponding bulge. At this point of the change of width a curious structure may be noted within the cuticula. What appears to be a hollow tube (fig. 5, *B*, *cr*) extends from a darkened point on the margin of the larger sclerite across the sclerite to about its middle, the general direction being toward the posterior tip of the spiracle. This may be seen in most cleared larval mounts under the dissecting microscope, and with the compound microscope when the transmitted light is cut to a minimum. From the cross section of the larval body the structure appears to be a sclerotized rod within a definite tubular cavity, and this is also the interpretation of the structure as viewed from the inner surface of the body wall.

Each of the larger laterotergites bears on its dorsal margin a pair of spines similar to the ones found near the posterior margin of the tergum. This pair of spines is situated somewhat farther forward than the posterior tergal ones. Scattered punctation is to be noted on the surface of the plates, especially toward the anterior end.

The margins are, except for short distances near the ends, very distinct, and appear to turn inward to serve as points of muscle attachment. Cross sections of the larval body show lateral muscles attached to these margins, especially the ventral.

The Pleura

The small sclerites intimately associated with the sternum, and becoming smaller progressively from segment to segment toward the posterior of the larva, are the pleura. The shape is roughly that of a shoe with the flat of the sole directed obliquely forward and toward the sternum, the toe pointing forward. Two spines are present on each pleuron, except on the eighth segment. The larger is found near the midpoint of the margin farthest from the sternum, the smaller spine being somewhat farther from the margin and posterior to the one just mentioned. Like the laterotergites these sclerites are sparsely punctate, more densely toward the anterior end. The margin nearest the sternum, the shoe sole, is the most distinctly outlined.

NINTH AND TENTH SEGMENTS

The ninth abdominal segment forms the posterior tip of the body. The segment is longer than those immediately preceding it, roundingly narrows the body width, and does not bear spiracles but carries the heavily sclerotized terminal armature. On the ventral surface between the sternum of the ninth abdominal segment and the under surface of the terminal armature is the tenth abdominal segment.

THE NINTH TERGUM

The ninth tergum (fig. 5, *B*, *at9*) has been expanded and modified to fit a special condition. The lateral portions of the grooves characteristic of the terga of the preceding abdominal segments have their outer margins raised and intensified with increasing sclerotization posteriorly. The posterior portion of the tergum is bent downward and under to enclose the terminal portion of the segment. The size

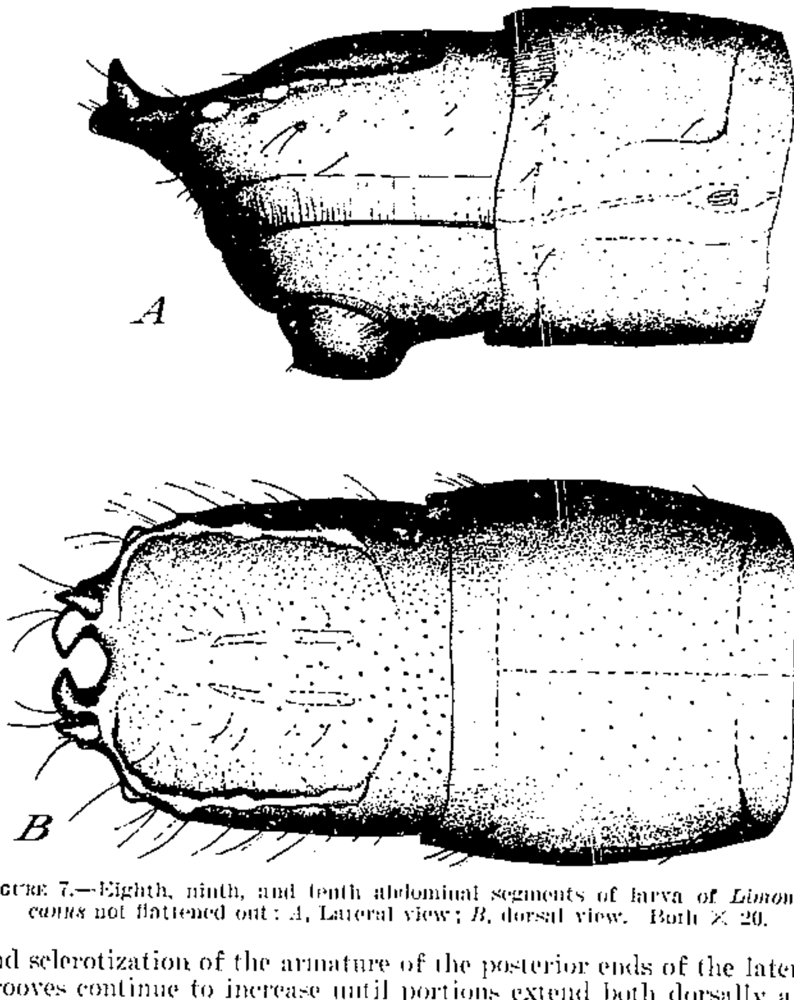

FIGURE 7.—Eighth, ninth, and tenth abdominal segments of larva of *Limonius canus* not flattened out: *A*, Lateral view; *B*, dorsal view. Both × 20.

and sclerotization of the armature of the posterior ends of the lateral grooves continue to increase until portions extend both dorsally and posteriorly considerably beyond the plate of the tergum.

This terminal armature, the urogomphi (fig. 7, *A* and *B*), is of taxonomic importance among the larvae in the portion of the elaterid family termed the Pyrophorinae, of which *Limonius* is one of the genera. In the larvae of *Limonius canus* the urogomphi are paired, each urogomphus consisting of a prolongation extending posteriorly and divided at the tip into two prongs. One of these prongs is bent dorsally and narrowed to a blunt point. The mesal surface of this prong is nearly perpendicular. The other prong is bent inward toward the median line of the dorsal surface of the body. The tip of this horizontal prong points toward that of the horizontal prong of the other urogomphus and slightly posteriorly. The two horizontal prongs form at least two-thirds of the posterior wall that encloses the space whose anterior wall is the downward-bent surface of the urotergum and whose lateral walls are the basal portions of the urogomphi. This enclosed space, the "keyhole," is to be found in those species of *Limonius* and *Athous* whose larvae have been examined. In larvae of *Limonius canus* the tips of the horizontal prongs never approach close enough to arouse any question as to whether they touch. The plane of these prongs is higher than that of the ninth tergum, and the direction of the keyhole is backward as well as downward, enough so that when the point of a No. 1 insect pin is inserted gently into the keyhole from above and allowed to come to rest it will form an angle of approximately 45° with the dorsal surface of the larval body—the larva being held straight.

The sclerotization of the ninth tergum is little if any heavier than that of the preceding terga, and the punctation is very similar. Many of the punctures of the ninth tergum, especially those of the lateral and posterior surfaces of the segment, bear single spines comparable in size with the paired ones of the preceding terga. The dorsal surface does not bear the median suture characteristic of the thoracic and first eight abdominal segments. It does bear, however, in the median area of the dorsal surface, two irregular longitudinal wrinkles which appear as though the surface had been folded in to accommodate an excess of material. These wrinkles are approximately half the length of the disk, slightly closer together posteriorly than anteriorly, and may be connected posteriorly. Two rows of heavy perpendicular muscles arise on the under surface of this plate and are attached to the tenth segment.

The laterotergites as distinct sclerites have disappeared, their lateral positions being taken by the margins of the tergum. The pleural suture has given place to a very wide connective tissue which has much the appearance of a connective membrane.

The Ninth Sternum

The sternum of the ninth segment (fig. 5, *B*, *st9*) is a consolidated plate occupying the anterior and lateral portions of the ventral surface of the segment. It is more convex than the sterna of the preceding abdominal segments, and when gross mounts are made is subject to splitting along the median line. The sclerotization is also heavier than that of the other sterna, though little darker in color. The punctures are more distinct and many of them carry heavy spines; about 18 or 20 are of average size and tend to be gathered about the margins of the tenth segment. The outer posterior angles of the sternum are bent backward and nearly enfold the tenth segment, leaving only a very short space where the connective membrane of the tergum and the intersegmental membrane are in contact.

THE TENTH SEGMENT

The tenth segment (fig. 5, *B*), which has migrated from a terminal position forward into the sternum of the ninth and turned the ninth tergum downward and under as it drew it along, consists of a small sclerotized plate, the telson (fig. *5 B*, *tel*), with a ring of intersegmental folded membrane around it and the anal opening, the anus, occupying the major portion of its area. The anus (fig. *5*, *B*, *a*) is not only the posterior opening of the digestive tract, but in the wireworm has assumed considerable importance as an organ of locomotion. The opening appears to have somewhat the action of a vacuum cup, and the organ may be moved a considerable distance along an anterior-posterior line without changing the direction of the face of the cup. Another direction of movement of this organ which is very apparent in the living larvae is its vertical movement. The purpose of the movement is not so apparent as that which pushes the larva ahead or assists it in withdrawing, but it may bring the prongs of the urogomphi into contact with the soil when burrowing. Horst (*8, p. 29*) in discussing the larvae of *Agriotes* spp., refers to the work of Brass (*2*) and gives to the organ the name "Nachschieber," or back-pusher.

About 30 spines are distributed over the tenth segment and provide the surface with sensory structures.

The walls of the anus are another ring of folded membrane and the external valve as seen is a longitudinal slit.

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U. S. GOVERNMENT PRINTING OFFICE: 1939

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