

RESPIRATORY SIGNIFICANCE OF THE THORACIC AND
ABDOMINAL MORPHOLOGY OF THREE CORIXIDAE,
DIAPREPOCORIS, *MICRONECTA*, AND *HESPEROCORIXA*
(HEMIPTERA: HETEROPTERA: HYDROCORISAE)*

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A. INTRODUCTION

The Corixidae are an extremely successful and abundant family of Hydrocorisae (aquatic Heteroptera). The more than 500 living species of corixids were grouped by Hungerford (1948) into six subfamilies; more recently Popov (1971) has recognized only three subfamilies, the Diaprepocorinae, Micronectinae, and Corixinae. The Corixinae, which include four of Hungerford's subfamilies, have been extensively investigated; they consist of approximately 30 genera, occur throughout the world, and range up to 16 mm. in length. Morphological and physiological studies are almost totally lacking, however, for representatives of the other two subfamilies. The Micronectinae are nearly worldwide in distribution but members of their three genera are very small (1.5-6.0 mm.) and difficult to dissect. The Diaprepocorinae consist of a single rare genus, *Diaprepocoris*, which occurs only in Australia, Tasmania, and New Zealand.

The mode of respiration in the Corixinae has been studied by many workers, including Hagemann (1910), Ege (1918), Popham (1960) and Parsons (1970). Like most Hydrocorisae, the Corixinae use "air-bubble" respiration and depend upon atmospheric air, which they carry in air stores on their bodies. The parts of the air stores which are exposed to the water can extract dissolved oxygen from the water by acting as "physical gills" (Thorpe 1950). The stored air is not a true plastron (*sensu* Thorpe 1950) because it is of considerable volume and must be periodically renewed at the surface of the water.

The air-bubble mode of respiration is reflected in the gross morphology of *Hesperocorixa* (Corixinae; Parsons 1970, 1974). In the present study the respiratory morphology of this corixid is

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compared with that of representatives of the other two subfamilies, whose respiration has never been investigated. The fine structure of the hydrofuge hairs and of the metathoracic and first abdominal spiracles, which has not yet been studied in any of the Corixidae, is also compared in *Hesperocorixa*, *Micronecta* (Micronectinae), and *Diaprepocoris* (Diaprepocorinae).

The Corixinae differ markedly from other Hydrocorisae in many morphological features. Their unusual characteristics include the very complex mesothoracic scolopophorous organ ("Hagemann's organ" of many authors), the modified mesothoracic and metathoracic epimera, the elongation of the pronotum and the posterior margin of the head, the metathoracic "air trough", and the unusual position of the metathoracic and first abdominal spiracles (Parsons 1970, 1974). These characteristics are compared in representatives of all three subfamilies, and their phylogenetic implications are discussed, below.

B. MATERIALS AND METHODS

Observations were made on *Hesperocorixa interrupta* (Say) from Massachusetts and Ontario, *Diaprepocoris zealandiae* Hale, from New Zealand, and *Micronecta sedula* Horváth, from Fukuoka, Japan. The insects, preserved in ethanol or Bouin's fluid, were dissected in 80% ethanol under a stereoscopic microscope.

For examination under the scanning electron microscope, specimens were transferred, through decreasing concentrations of ethanol, to distilled water. They were then mounted on aluminum stubs with silver Electrodag and kept briefly in distilled water until they were freeze-dried in an Edwards Speedivac-Pearse Tissue Drier, Model 1. They were coated with 20-40 nm of gold in an Edwards Vacuum Evaporator, examined under a Cambridge Stereoscan, Model 2A, and photographed with Kodak Verichrome Pan 120 roll film.

C. AIR STORES

I. Hydrofuge hairs

The distribution of the air stores in living specimens of *Hesperocorixa* was described in an earlier study (Parsons 1970). There are, to my knowledge, no similar descriptions of the air stores of *Diaprepocoris*, and Leong (1961) mentions those of *Micronecta* only briefly. Although only preserved specimens of all three corixids

were available for the present study, the location of their air stores can be deduced from their morphology, particularly the distribution of hydrofuge hairs on the body. These hairs, which are clearly visible under the scanning electron microscope, can conveniently be divided into two categories according to their length.

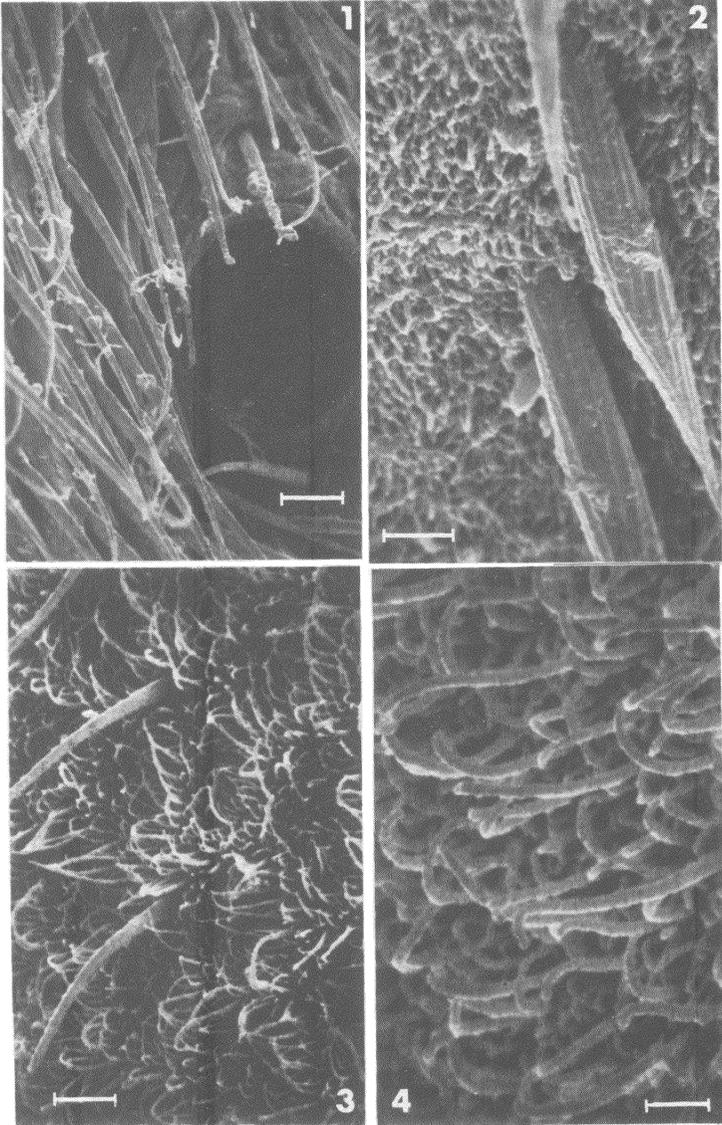
The *long hairs* (Figs. 1-3) range from 20 to 70 μm in length and are shorter in *Micronecta* (20-40 μm) than in the other two corixids. They are from one to five μm in diameter basally, and taper terminally. In *Diaprepocoris* and *Hesperocorixa* most, if not all, of the long hairs bear spiral grooves (Figs. 1 and 2); although those of *Micronecta* may have similar grooves they were not visible in any of the photomicrographs. When closely-packed, as on the abdomen of *Hesperocorixa* (Fig. 1), the long hairs are capable of holding a relatively thick air layer or "macroplastron" (term of Thorpe and Crisp 1949).

The *short hairs* (Figs. 2-4), unlike the long ones, are visible only under the scanning electron microscope and are much more densely packed. They range from two to ten μm in length and from 0.35 to 0.55 μm in diameter, and their tips are strongly curved. In many photomicrographs of *Micronecta*, and in occasional ones of *Hesperocorixa*, the short hairs have the appearance shown in Fig. 3; they resemble low arches, with several branch-like ribs, rather than separate hairs. It is not clear whether these arches are artifacts caused by the clumping of the tips of short hairs during preparation for the scanning electron microscope, or whether they represent a different type of hydrofuge structure.

II. Ventral Air Store

The ventral surfaces of the thorax and abdomen are covered with hydrofuge hairs in all three corixids. The ventral abdominal surfaces bear closely-packed long hairs which are approximately 9 to 23 μm apart in *Micronecta* and 13-18 μm apart in *Diaprepocoris* and *Hesperocorixa*. A conspicuous, thick ventral abdom-

Figs. 1-4. Hydrofuge hairs; tops of figures are anterior. Fig. 1. *Hesperocorixa interrupta*; long hairs on ventral surface of third abdominal segment in region of left third abdominal spiracle (right side of figure). Scale line = 10 μm . Fig. 2. *Diaprepocoris zealandiae*; short hairs and parts of three spirally-grooved long hairs on external surface of corium of forewing. Scale line = 5 μm . Fig. 3. *Micronecta sedula*, short hairs and parts of three long hairs on ventral surface of right prothoracic epimeron. Note arched appearance of most short hairs. Scale line = 5 μm . Fig. 4. *H. interrupta*; short hairs on ventral surface of right prothoracic epimeron. Scale line = 2 μm .



inal air layer is visible in living specimens of the latter (Parsons 1970). The third abdominal spiracles (Figs. 5-7, S3) and the spiracles posterior to them are located among the hairs in all three insects. In *Diaprepocoris* (Fig. 5) a longitudinal sulcus lies medial to these spiracles on the third through seventh abdominal segments.

Miconecta, unlike the other two insects, possesses short hairs as well as long ones on the ventral abdominal surface. The short hairs are more sparsely distributed medially than laterally, and on the fifth and more posterior abdominal segments they end approximately 10 μm from the lateral edge of the body, which is devoid of hairs. Leong (1961) mentioned the presence of "fine hairs" and a silvery ventral air layer on the abdomen of *Miconecta* sp.

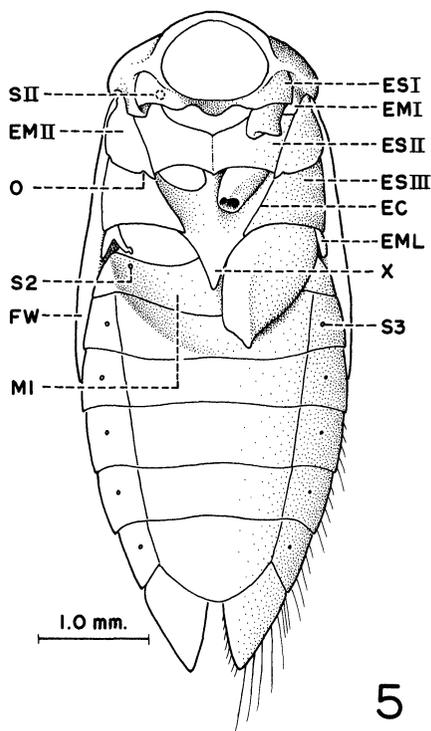


Fig. 5. *D. zealandiae*, ventral view. Head and legs removed; coxae and long setae shown only on right side of figure. Mesothoracic spiracle (S II) concealed by prothorax.

The anteroventral portion of the abdomen is concave on each side of the midline, forming a pair of *metacoxal indentations* (Figs. 5-7, MI) which accommodate the metacoxae and contain the second abdominal spiracles (S2). The metacoxae of living *Hesperocorixa* are surrounded by an air layer which extends into the metacoxal indentations (Parsons 1970). In all three corixids the ventral and posterodorsal surfaces of the metacoxae bear closely-packed long hairs, but these hairs are lacking on the anterodorsal coxal surfaces and on the metacoxal indentations in which they lie. The air in the indentations of *Hesperocorixa*, and presumably in those of the other two insects, must be retained by the close apposition between the coxae and the abdomen rather than by hydrofuge hairs.

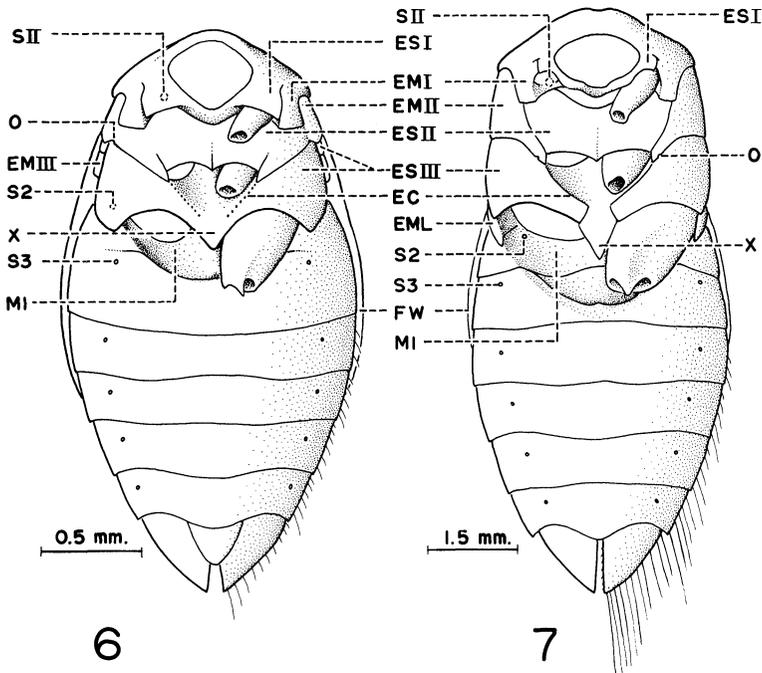


Fig. 6. *M. sedula*, ventral view, prepared as in Fig. 5. Second abdominal spiracle (S2) concealed by lobe of metathoracic episternum. Efferent channel (EC) of metathoracic scent gland, indicated by dotted lines, lies beneath exoskeleton.

Fig. 7. *H. interrupta*, ventral view, prepared as in Fig. 5.

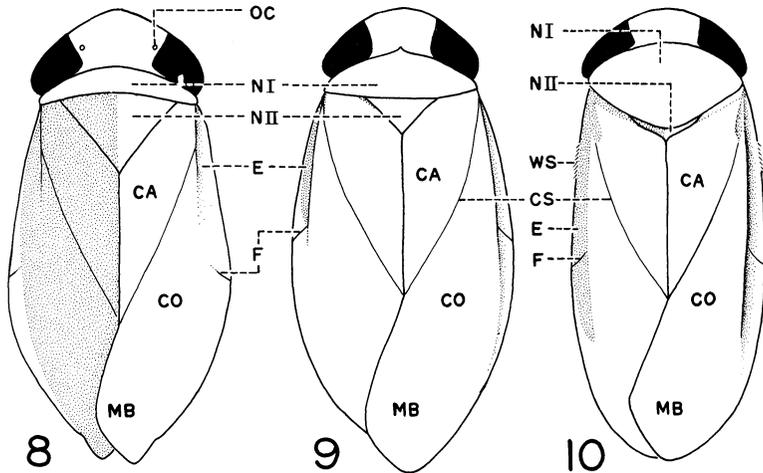
In all three corixids the exposed ventral surfaces of the prothorax and pterothorax are covered with densely distributed short hairs. Although long hairs are also present on the thorax, they are usually farther apart than on the abdomen and are entirely absent in some areas. Long hairs are rarer on the ventral thorax in *Diaprepocoris* than in the other two insects, and they are shorter than those on the abdomen. In *Corixa* (Corixinae; Thorpe 1950) and *Hesperocorixa*, however, the thoracic long hairs are longer than the abdominal ones. The ventral thoracic air layer is easily visible in living *Hesperocorixa* (Parsons 1970); the presence of hydrofuge hairs on the ventral thorax of the other two corixids indicates that they possess a similar, although perhaps thinner, air store in this region.

III. Supra-alar Air Store

In *Diaprepocoris* almost all of the exposed surface of the forewing bears hydrofuge hairs (Fig. 8, stippling on left). The clavus (CA), corium (CO) and membrane (MB) are covered with densely-packed short hairs which extend nearly to the lateral edge of the wing. The clavus and corium also bear long hairs which are 20 to 30 μm apart (Fig. 2). The extreme lateral edge of the corium lacks hairs, the bare strip being widest (approximately 0.2 mm) posterior to the nodal furrow (Fig. 8, F). The embolium (E), unlike that of the other two corixids, is not sharply differentiated from the rest of the corium and is indented only anteriorly, approximately half way to the nodal furrow.

In *Micronecta* (Fig. 9) and *Hesperocorixa* (Fig. 10) the embolium is more sharply differentiated and most of the exposed surface of the forewing lacks hydrofuge hairs. Living specimens of *Hesperocorixa* have an air layer (Fig. 10, stippling on left) on the strongly-indented embolium, on the anterior part of the claval suture (CS) and on the portion of the clavus which is overlapped by the pronotum (N I) (Parsons 1970). All these regions have a pruinose texture and are covered with short hairs and occasional long ones in *Hesperocorixa*. The hairs on the embolium extend well posterior to the nodal furrow. Anterior to the furrow they reach to the lateral edge of the wing, but posterior to the furrow they end a short distance medial to the lateral edge.

Micronecta has an even less extensive supra-alar air store (Fig. 9, stippling on left). The corium and clavus bear thick setae, up to

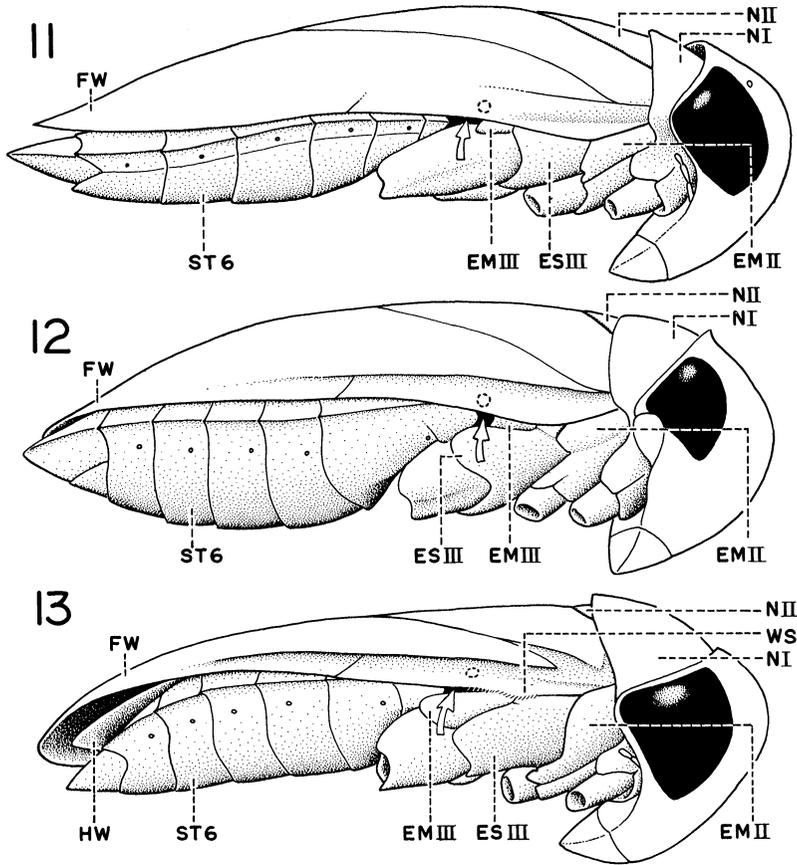


Figs. 8-10. Dorsal views; extent of exposed dorsal air stores indicated by stippling on left half. Fig. 8. *D. zealandiae*; exposed air stores on mesonotum (N II) and most of forewing. Fig. 9. *M. sedula*; exposed air store confined to anterior portion of embolium (E) and anteriormost part of claval suture (CS). Air on mesonotum is concealed by pronotum (N I). Fig. 10. *H. interrupta*; exposed air store on forewing more extensive than in Fig. 9 but much less extensive than in Fig. 8. Air on mesonotum mostly concealed by pronotum.

15 μm in length, which are spaced too far apart (500-600 μm) to retain air. Only the embolium (E), the anteriormost part of the claval suture (CS), and the part of the wing beneath the pronotum (NI) have short hydrofuge hairs. On the embolium, which is less indented than in *Hesperocorixa*, they extend only as far posteriorly as the nodal furrow. The extreme lateral edge of the embolium bears short hairs only at the level of the mesothorax. Posterior to this level the lateral edge lacks hairs; at the nodal furrow they end approximately 80 μm from the lateral edge.

IV. Cervical Air Store

In the Corixidae, unlike other Hydrocorisae, the posterior and lateral parts of the head are flattened and form flanges which overlap the prothorax (Figs. 11-13). The cervical space is filled with air which is directly continuous with the ventral air store and is exposed to the water along the posterior edges of the head (Parsons 1970).



Figs. 11-13. Lateral views. Long setae on lateral abdomen omitted; legs removed distal to coxae. Arrow indicates gap through which ventral air store communicates with subalar air store, which contains the abdominal spiracle (broken circle). Fig. 11. *D. zealandiae*. Fig. 12. *M. sedula*. Fig. 13. *H. interrupta*.

In all three corixids studied here the part of the pronotum which is overlapped by the head bears hydrofuge hairs which help to retain the air store. In *Hesperocorixa* this area, unlike the exposed part of the sclerite (Figs. 10 and 13, N I), has a pruinose texture similar to that of the embolium of the wing. The scanning electron microscope shows that in *Diaprepocoris* and *Micronecta* the exposed posterior parts of the pronota (Figs. 8, 9, 11, and 12,

N I) lack hydrofuge hairs while the anterior parts, which lie beneath the head, are covered with closely-packed short hairs. Long hairs are also present in the posteromedial part of the overlapped region in both insects. A curious feature of this region is that in both *Diaprepocoris* and *Micronecta* the localized spots at which muscle fibers attach on the pronotum are devoid of hydrofuge hairs externally.

V. I-II Air Store

Although all Hydrocorisae carry some air between the prothorax and mesothorax, this air space is greatly enlarged, in *Hesperocorixa*, by the very long pronotum (Parsons 1970). The I-II air space contains the mesothoracic spiracle (Figs. 5-7, S II). In all three corixids the spiracle is somewhat smaller than the metathoracic one and lies ventrolaterally in the intersegmental membrane, just ventromedial to the prealar bridge of the mesothorax. In *Hesperocorixa*, in which the spiracle is large enough to be examined under the stereoscopic microscope, it is covered by a "sieve-plate" similar to that of the metathoracic spiracle (see p. 161).

The I-II air store is directly continuous with the ventral thoracic and supra-alar stores. Its dorsal portion differs in the three insects. In *Hesperocorixa* (Fig. 10) the long pronotum (N I) conceals almost all of the mesonotum (N II). The latter has a pruinose texture like that of the hydrofuge parts of the forewings. The air on the mesonotum is largely concealed, although it is exposed along the posterior margins of the pronotum.

In *Diaprepocoris* (Fig. 8) the pronotum is quite short and covers only the anteriormost part of the mesonotum. The exposed part of the latter (N II), however, has long and short hydrofuge hairs like those on the dorsal surface of the forewings. It probably bears an extensive air layer which is fully exposed to the water, rather than only partly exposed as in *Hesperocorixa*.

The pronotum of *Micronecta* (Fig. 9) is longer than that of *Diaprepocoris* but shorter than that of *Hesperocorixa*, and does not cover the posteromedial tip of the mesonotum. The scanning electron microscope shows that the exposed portion of the mesonotum, unlike that of *Diaprepocoris*, lacks hydrofuge hairs. The overlapped anterior part, however, is covered with short hairs except laterally and posterolaterally, in the groove which holds the anteromedial margins of the forewings.

VI. Subalar Air Store

In all three insects the forewings are fully developed and extend to the tip of the abdomen (Figs. 11-13). All the *Hesperocorixa* examined had fully developed hindwings (Fig. 13, HW) and flight muscles. All specimens of the other two corixids, however, had vestigial indirect flight muscles and short hindwings. The latter extended to the level of the fourth and fifth abdominal tergites in *Diaprepocoris* and *Micronecta* respectively.

Hesperocorixa, like most Hydrocorisae, carries air beneath the forewings. The large subalar air store is exposed along the edges of the forewings posterior to the level of the mesothoracic epimeron, and the amount of exposure is increased when *Hesperocorixa* bends the abdomen ventrally on the thorax (Parsons 1970).

Leong (1961) reported the presence of a subalar air store in *Micronecta* sp., and *Diaprepocoris* almost certainly possesses one. The scanning electron microscope shows that in both insects the ventral surfaces of the clavus and corium bear short, densely-packed hydrofuge hairs. In these two insects the ventral margin of the forewing (Figs. 5 and 6, FW) projects laterally, beyond the edge of the body, as far posteriorly as the anterior abdominal segments. The short hydrofuge hairs extend onto the exposed, ledge-like ventral edge of the wing in both insects. In *Micronecta* they extend all the way to the lateral edge, while in *Diaprepocoris* they cover only the medial half of the exposed portion.

In *Hesperocorixa* the ventral edge of the wing does not project as far laterally as in the other two corixids. At the level of the metathorax the extreme dorsolateral edge of the embolium bears a patch of very long, curved setae (Figs. 10 and 13, WS), and immediately ventral to the posteriormost setae there is an extensive gap between the edge of the wing and the edge of the body (Fig. 13, arrow). In living specimens the subalar, supra-alar, and ventral air stores communicate with each other along this gap and for some distance posterior to it (Parsons 1970). The subalar and ventral abdominal air stores also appear to communicate with each other along the posterolateral margins of the abdomen, which bear long setae (Fig. 7, right side of figure).

The amount of communication between the subalar and supra-alar stores cannot be determined in the other two corixids without living specimens. Like *Hesperocorixa*, however, both *Diaprepocoris* and *Micronecta* possess a large space between the fore-

wing, the metathoracic epimeron, and the anterolateral part of the abdomen (Figs. 11 and 12, arrow) which allows the subalar air store to communicate with the ventral one. The two air stores probably also communicate along the posterior part of the abdomen, which bears lateral setae (Figs. 5 and 6, right sides of figures).

D. PTEROTHORAX

I. Typical Hydrocorisae

The pterothorax of typical Hydrocorisae has been described in previous publications (Parsons 1970, 1974) and will be only briefly summarized here.

The mesothoracic (Fig. 14A, EM II) and metathoracic episternum (ES III) form flat evaginated lobes laterally, posteriorly, and pos-

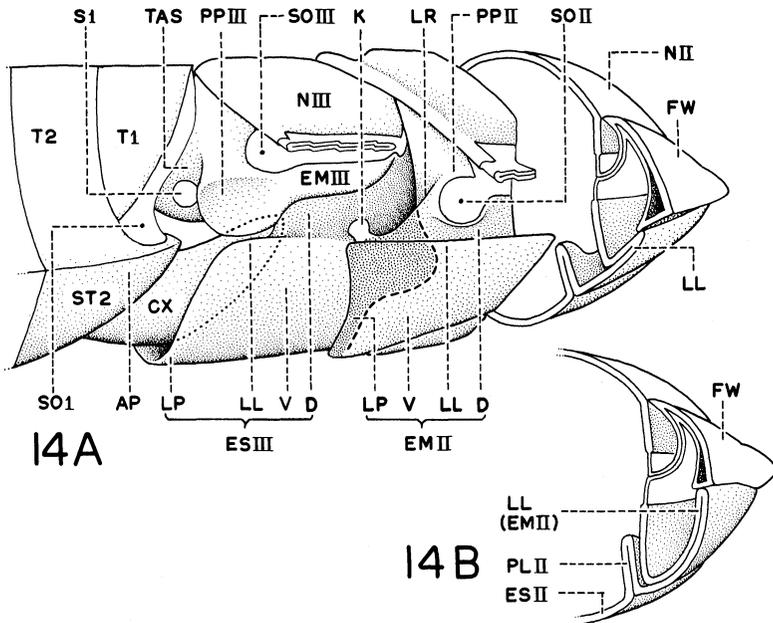


Fig. 14A and B. Diagrammatic lateral views. (A) Pterothorax and anterior abdomen of typical Hydrocorisae. Mesothorax cut transversely, wings removed posterior to transverse cut. Heavy broken line indicates position of lateral intersegmental boundary, concealed by external wall of mesothoracic epimeron (EM II); heavy stippling indicates intersegmental air store, which contains metathoracic spiracle (concealed in this view). (B) Anterior mesothorax, cut as in Fig. 14A, showing how lateral epimeral lobe (LL) is modified in *M. sedula* and *H. interrupta*.

teromedially. The *lateral lobes* (LL) subdivide each pleurite into dorsal and ventral portions. The dorsal portions (D) of the pleurites are vertical and concealed by the forewings; the ventral portions (V) are more horizontal and are exposed to the water. The *posterior lobes* (LP) of both pleurites are continuous with the lateral ones. The posterior lobe of the mesothoracic epimeron overlaps the metathoracic episternum, whose posterior lobe overlaps the metacoxa (CX).

The posterolateral corner of the mesothoracic epimeron bears a knob-like process (Fig. 14A, K) which fits into a depression on the costal margin of the forewing, anchoring it against the edge of the lateral epimeral lobe. The subalar air space between the forewing and the body is enlarged lateral to the vertical, dorsal portions of the mesothoracic epimeron and metathoracic episternum, which are indented on the body.

The mesothoracic postalar bridge projects laterally into the subalar space forming a collar-like *postalar projection* (Fig. 14A, PP II). A double-walled *lateral ridge* (LR) of the mesothoracic epimeron runs from the postalar projection to the wing-anchoring knob. The postalar projection encircles the membrane of a mesothoracic *scolopophorous organ* (SO II) either partially, as in Fig. 14A, or completely. The function of this paired sense organ, and of its homologues on the metathorax (SO III) and first abdominal segment (SO I) has been debated. Larsén (1957) believed them to be equilibrium perceptors. More recently, however, experimental evidence has indicated that the mesothoracic scolopophorous organs of *Notonecta obliqua* (Notonectidae; Arntz 1972) and *Corixa punctata* (Corixinae; Prager 1973) and the mesothoracic and metathoracic organs of *Nepa cinerea* (Nepidae; Arntz 1975) are sensitive to sound.

The boundary between the mesothorax and metathorax curves sharply anteriorly into the mesothoracic region in the lateral part of the body (Fig. 14A, heavy broken line). In some Hydrocorisae this lateral intersegmental boundary forms a prominent, flap-like invagination which grows anteriorly during postecdysial development (Parsons 1974). A lateral intersegmental air space (heavy stippling), which is posteriorly continuous with the subalar air space, is formed between the invaginated boundary and the lateral ridge of the mesothoracic epimeron. It is ventromedially continuous with a much smaller ventral intersegmental air space which lies dorsal to the posterior epimeral lobe.

The *metathoracic spiracle* (concealed in Fig. 14A) is located anterior to the intersegmental boundary in all Hydrocorisae which have been examined thus far (Parsons 1974). It lies on the mesothoracic epimeron, and usually opens onto the lateral intersegmental or ventral intersegmental air space (Positions 1 and 2, respectively, of Parsons 1974). It is thus concealed externally by the lateral ridge or posterior lobe of the mesothoracic epimeron. In *Hesperocorixa* and *Notonecta*, however, the spiracle lies immediately adjacent to the mesothoracic scolopophorous organ, on the dorsal, vertical part of the epimeron, and opens directly onto the subalar air space (Position 3 of Parsons 1974).

II. *Diaprepocoris*

Of the three corixids examined, *Diaprepocoris* shows the least modification of the typical plan diagrammed in Fig. 14A. The lateral lobe of the mesothoracic epimeron (Fig. 15, LL) is relatively narrow and projects laterally and somewhat dorsally, as in typical Hydrocorisae, rather than curving sharply dorsally, as in *Micronecta* and *Hesperocorixa* (Fig. 14B). Thus the costal margin of the wing lies farther ventrally on the body than in the latter two insects.

Posterior to the wing-anchoring knob of the mesothoracic epimeron, the margin of the forewing fits into a horizontal groove (Fig. 15, W) on the metathoracic episternum. The homologies of this groove are uncertain. Unlike the wing-holding devices on the metathoracic episterna of *Micronecta* (Fig. 16, W) and *Hesperocorixa* (Fig. 17, W), it lies far ventral to, rather than at the level of, the metathoracic coxal process (Fig. 18, PR), and appears externally as a groove rather than as a ridge. In addition, it does not form the ventral boundary of a well-developed "air trough" such as that of *Hesperocorixa* (Fig. 17, AT). In the latter, both the epimeron and the episternum of the metathorax are strongly indented in the region of the pleural sulcus (PL III). In *Diaprepocoris*, as in most other Hydrocorisae, only the dorsal portion of the episternum and a small portion of the epimeron are indented in this region (Fig. 15).

The boundary between the mesothorax and metathorax is marked dorsally by the second phragma (Fig. 18, 2PH). Ventral to the mesothoracic scolopophorous organ (SO II) the boundary bends sharply anteriorly and then curves posteromedially onto the ventral surface of the body. The portion of the boundary

which bends anteriorly forms a short projection internally (II-III); this flap, which is similar to the intersegmental projection of *Aphelocheirus* (Aphelocheiridae; Parsons 1974), partially conceals the base of the metathoracic spiracular trachea. The metathoracic spiracle (Figs. 15 and 18, S III) lies immediately below the scoloporous organ in the dorsal part of the mesothoracic epimeron, immediately anterodorsal to the intersegmental boundary. The fine structure of the spiracle and sense organ are described on pp. 161 and 164.

Unlike *Micronecta* and *Hesperocorixa*, *Diaprepocoris* possesses a lateral epimeral ridge, which runs from the wing-anchoring knob to the postalar region (Fig. 15, LR). The ridge is much less pronounced than its homologue in typical Hydrocorisae (Fig. 14A) and, unlike the latter, is not high enough to conceal the metathoracic spiracle externally or to create a lateral intersegmental air space. Thus the spiracle, like those of *Micronecta* and *Hesperocorixa*, opens directly onto the subalar air space.

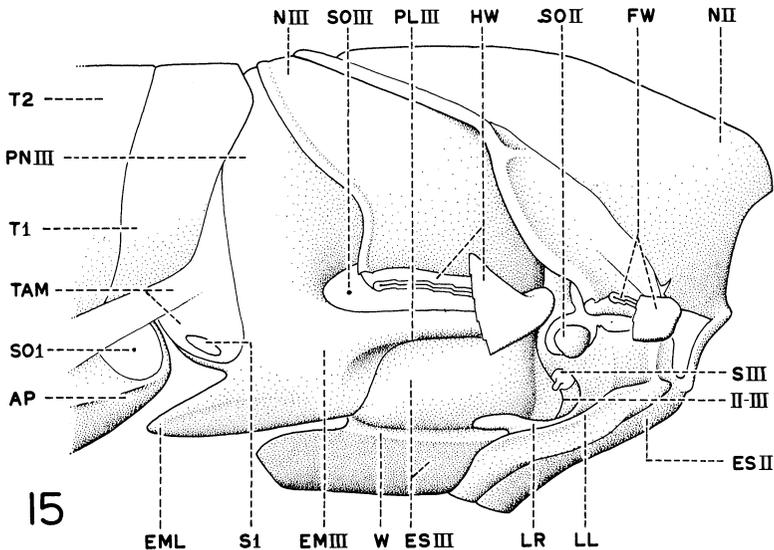


Fig. 15. *D. zealandiae*; lateral view of pterothorax and anterior abdomen. Wings and coxae removed.

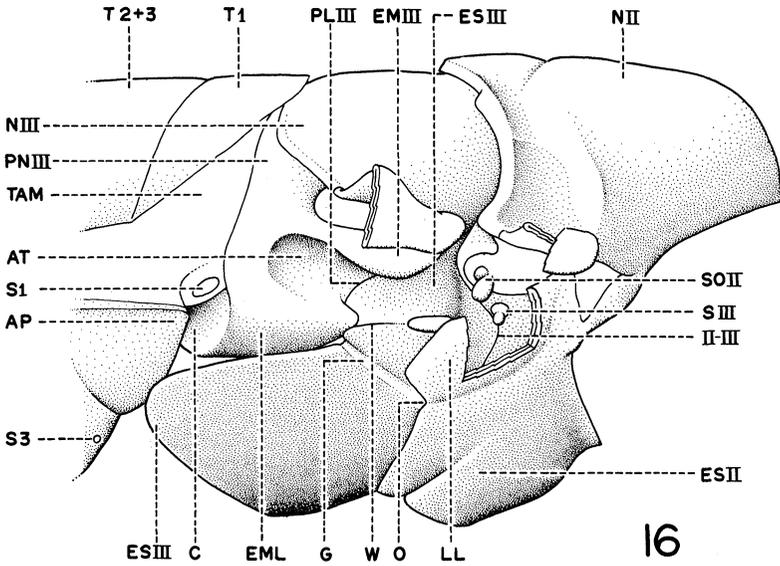


Fig. 16. *M. sedula*; lateral view of pterothorax and anterior abdomen. Wings and coxae removed; portion of lateral lobe (LL) of mesothoracic epimeron cut away to reveal structures shown in Fig. 26.

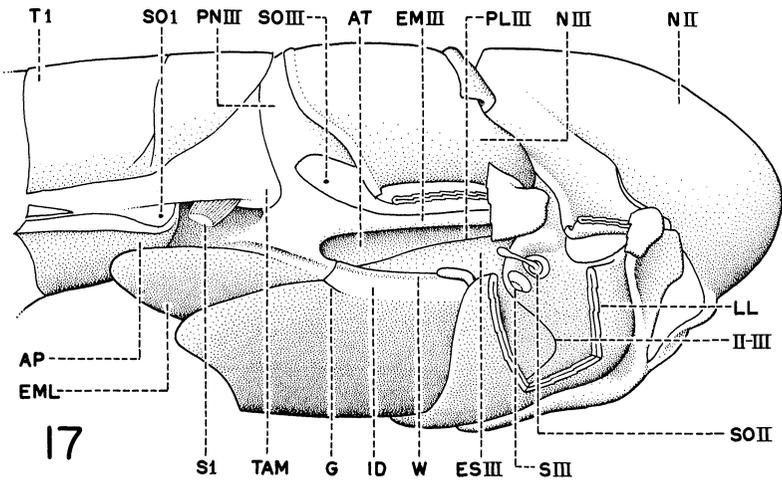


Fig. 17. *H. interrupta*; lateral view of pterothorax and anterior abdomen. Wings and coxae removed; portion of lateral lobe (LL) of mesothoracic epimeron cut away to reveal structures shown in Fig. 27.

III. *Micronecta* and *Hesperocorixa*

Two previous papers (Parsons 1970, 1974) have described the ways in which the pterothorax of *Hesperocorixa* differs from that of the typical Hydrocorisae. *Micronecta* shares these characteristics to a greater extent than does *Diaprepocoris*.

The mesothoracic epimeron of *Micronecta* and *Hesperocorixa* is considerably different from that of *Diaprepocoris* and the typical Hydrocorisae. It possesses no lateral epimeral ridge, and its lateral lobe (Fig. 14B, LL), which is greatly widened, curves strongly dorsolaterally rather than projecting laterally and only slightly dorsally (compare Figs. 14A and 14B). In both corixids the edge of the lobe (Figs. 16 and 17, LL) extends dorsal to the level of the metathoracic spiracle (S III) and reaches nearly to the level of the mesothoracic scolopophorous organ (SO II). The costal margin of the forewing (Fig. 14B, FW), which rests on the edge of the lateral lobe, lies farther dorsally on the body than in *Diaprepocoris*. Thus on the mesothorax the ventral part of the subalar air space is bounded by the lateral lobe (LL) rather than by the forewing.

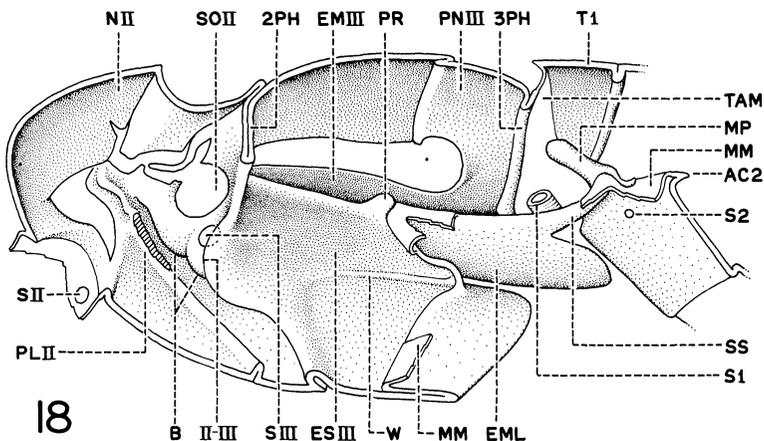


Fig. 18. *D. zealandiae*; internal view of pterothorax and anterior abdomen, cut parasagittally lateral to mesocoxa. Cross-hatched cut edge of mesothoracic pleural ridge (PL II) indicates base of pleural apophysis (removed). Metacoxa and soft tissues removed; part of metacoxal membrane (MM) cut away to show sclerotized strip (SS) and inner wall of metathoracic epimeral lobe (EML). First abdominal spiracular trachea (S I) emerges from spiracle lying in thoraco-abdominal membrane lateral to sclerotized strip.

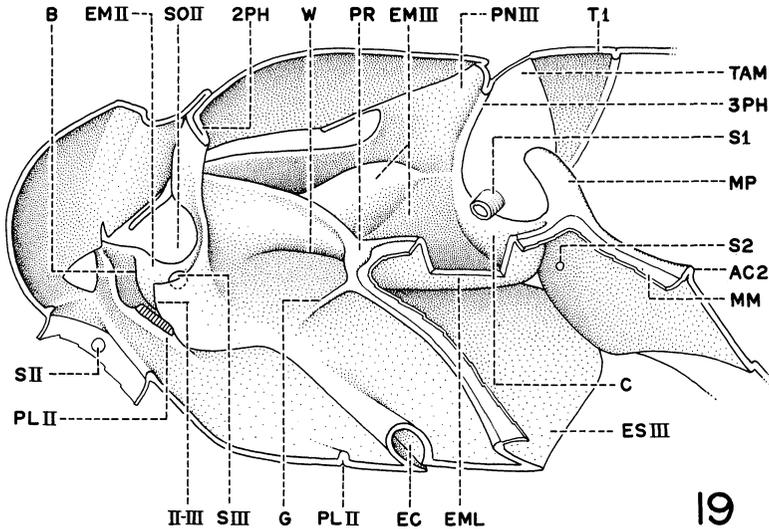


Fig. 19. *M. sedula*; internal view of pterothorax and anterior abdomen, cut parasagittally lateral to mesocoxa. Cross-hatched cut edge of mesothoracic pleural ridge (PL II) indicates base of pleural apophysis (removed). Metacoxa and soft tissues removed; part of inner wall of metathoracic epimeral lobe (EML) cut away to show indented portion (C) of outer wall of lobe.

The lateral lobe is so wide that its base (Figs. 19 and 20, B) lies immediately lateral to the mesothoracic pleural apophysis (Fig. 14B, PL II; Figs. 19 and 20, cross-hatched part of PL II). In mature specimens of both corixids the base of the lobe adheres closely to the pleural apophysis and can be dissected away from it only with difficulty. In *Micronecta* the base of the lateral lobe is marked by a groove, on the external surface of the epimeron, which extends posteriorly as far as the ostiole of the metathoracic scent gland (Fig. 16, O). The mesothoracic pleural sulcus of *Hesperocorixa*, like that of *Diaprepocoris*, is complete and extends from the mesothoracic coxal process to the pleural wing process. In *Micronecta*, however, the sulcus is incomplete and can be clearly distinguished only in the region of the pleural apophysis (Fig. 19, cross-hatched portion of PL II).

All three corixids possess a metathoracic scent gland and a paired efferent system which carries the secretion from the dorsal surface of the metasternal xiphus (Figs. 5-7, X) to an ostiole at the posterior

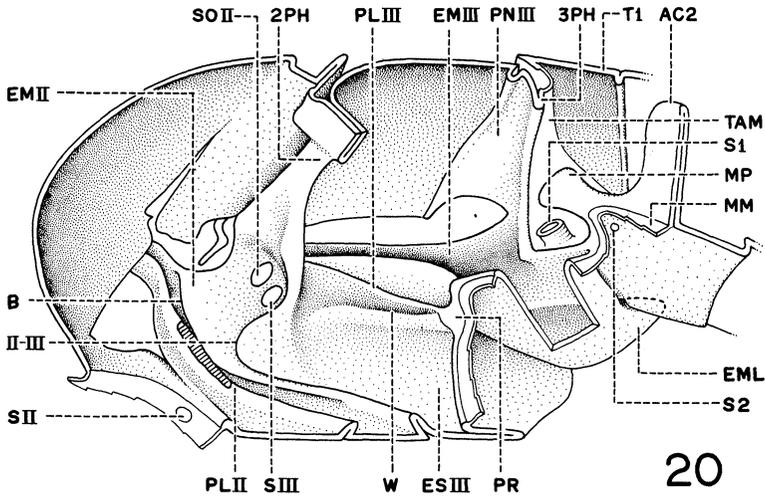


Fig. 20. *H. interrupta*; internal view of pterothorax and anterior abdomen, cut parasagittally lateral to mesocoxa. Cross-hatched cut edge of mesothoracic pleural ridge (PL II) indicates base of pleural apophysis (removed). Metacoxa and soft tissues removed; part of inner wall of metathoracic epimeral lobe (EML) removed to show outer wall of lobe.

edge of each mesothoracic epimeron. In *Hesperocorixa* and *Diaprepocoris* the ostiole (Figs. 5 and 7, O) lies posteromedially on this sclerite. The edge of the epimeron which is immediately lateral to it lacks hydrofuge hairs and resembles the "evaporating surface" of *Gelastocoris* (Gelastocoridae; Parsons 1960). In *Micronecta* the ostiole occurs far more laterally on the epimeron, at the posterior end of the lateral epimeral lobe (Figs. 6 and 16, O). The edge of the epimeron which lies lateral to it possesses hydrofuge hairs and is triangular, its apex pointing posteriorly.

The efferent canals leading to the ostioles also differ in the three corixids. In *Hesperocorixa* and *Diaprepocoris* the canals are deep, open channels which extend anteromedially on each metathoracic episternum (Figs. 5 and 7, EC). They have a similar form in such other Hydrocorisae as *Gelastocoris* (Parsons 1960), *Ilyocoris* (Naucoridae; Staddon and Thorne 1973) and *Notonecta* (Notonectidae; Staddon and Thorne 1974). In *Micronecta*, however, the canals are not externally visible on the metathoracic episternum; they are closed ducts which lie immediately beneath the surface of

the exoskeleton. These ducts (indicated by dotted lines, Fig. 6) open onto the intersegmental groove (Fig. 19, EC), between the metathoracic episternum and the mesothoracic epimeron, which leads to the lateral ostiole.

In *Hesperocorixa* the subalar space external to the metathoracic pleural sulcus (Fig. 17, PL III) is enlarged by a pronounced, horizontal, trough-like indentation (AT) which extends from the intersegmental boundary to a level posterior to the metathoracic coxal process. This "air trough" is formed by both the dorsal portion of the metathoracic episternum and the ventral portion of the metathoracic epimeron. It is bounded ventrally by a pronounced ridge (W) which appears to represent the anterior part of the episternal lateral lobe. The costal margin of the forewing fits closely against this ridge, closing off the air trough ventrally. The raised episternal ridge performs the same wing-holding function as does the horizontal episternal groove of *Diaprepocoris* (Fig. 15, W) but, unlike the latter, extends anteriorly from the coxal process (Fig. 20, PR) rather than lying far ventral to it (Fig. 18). In *Hesperocorixa* a possible homologue of the episternal groove of *Diaprepocoris* is a short groove (Fig. 17, G) which lies posteroventral to the wing-anchoring ridge, at the posteroventral edge of an indented region (ID) of the episternum. On this indentation the ventral thoracic air layer is greatly thickened. Unlike the rest of the exposed episternum, the indentation lacks long hydrofuge hairs and is covered only with short ones.

In *Micronecta* the metathoracic air trough is less well-developed. Anteriorly it is formed only by the recessed dorsal portion of the metathoracic episternum (Fig. 16, ES III). The anterior part of the epimeron (EM III) is entirely convex, like that of *Diaprepocoris* and typical Hydrocorisae, rather than partially concave as in *Hesperocorixa*. Only the portion of the epimeron which lies at the level of the coxal process is concave, forming the posterior part of the air trough (AT).

The episternal wing-holding mechanism of *Micronecta* consists of a low horizontal ridge (Fig. 16, W) which, like its more pronounced homologue in *Hesperocorixa*, forms the ventral boundary of the air trough. Ventral to this ridge is a deep groove (G) which runs obliquely anteromedially and ends at the ostiole of the metathoracic gland (O). This groove may be homologous with the wing-holding groove of *Diaprepocoris*. Its function is difficult

to determine. It may serve as an "evaporating area"¹ for the secretion which emerges from the ostiole; unlike the smooth "evaporating surfaces" on the mesothoracic epimera of *Hesperocorixa* and *Diaprepocoris*, however, the groove of *Micronecta* bears short hydrofuge hairs similar to those on the rest of the ventral portion of the episternum.

In both *Hesperocorixa* and *Micronecta* the lateral boundary between the mesothorax and metathorax projects anteriorly, as in *Diaprepocoris*. In *Micronecta* it forms a flap-like internal projection (Fig. 19, II-III) which overlaps the trachea of the metathoracic spiracle (S III); the flap is similar to, but longer than, that of *Diaprepocoris*. Externally the lateral intersegmental boundary of *Micronecta*, like that of *Diaprepocoris*, forms a faint line (Fig. 16, II-III) which reaches anteriorly only as far as the level of the spiracle S III). In *Hesperocorixa* the boundary projects farther anteriorly, beyond the level of the spiracle (Fig. 17) and forms only a low ridge, rather than a flap, internally (Fig. 20, II-III).

The metathoracic spiracles of both *Hesperocorixa* and *Micronecta* lie on the mesothoracic epimeron, anterodorsal to the intersegmental boundary and ventral to the mesothoracic scolopophorous organ. The fine structure of the spiracle and sense organ are described on pp. 161 and 164.

E. THORACICO-ABDOMINAL REGION

I. Typical Hydrocorisae

The typical structure of the lateral thoracico-abdominal region of Hydrocorisae is diagrammed in Figs. 14A and 21. The metathoracic epimeron (EM III) is relatively smaller than the mesothoracic one and has a quite different shape. Anteriorly, beneath the hindwing, it is narrow; in the postalar region it broadens and joins the metathoracic postnotum forming a large, lateral postalar projecton (PP III). The metathoracic scolopophorous organ (SO III) lies anterodorsal to the projection.

Posteromedial to the postalar projection, and separated from it by a pronounced fold, is a roughly triangular structure (TAS) which has been termed the "thoracico-abdominal sclerite" (Parsons

¹Although this term is not appropriate when applied to underwater insects, it is retained here because of its general use in the literature on terrestrial Heteroptera.

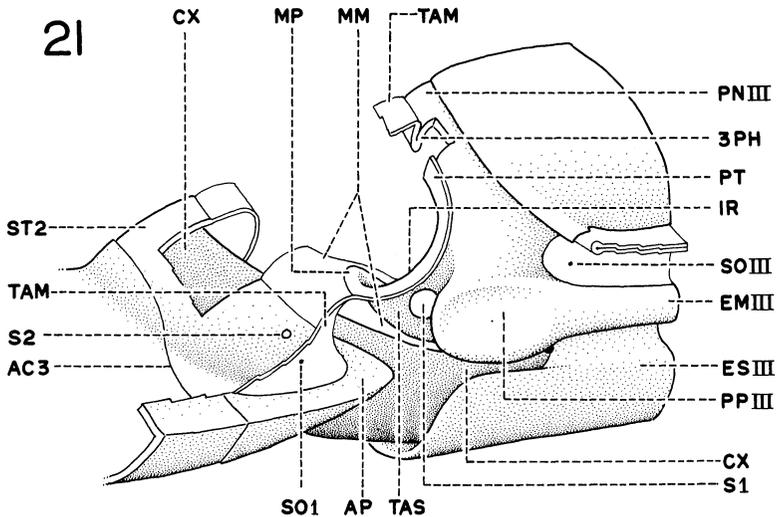


Fig. 21. Diagrammatic lateral view of thoraco-abdominal region of typical *Hydrocorisae*. Hindwing, soft tissues, and abdominal tergites removed; thoraco-abdominal membrane (TAM), which attaches to posttergite (PT) and lateral wall of intersegmental ridge (IR), mostly removed.

1970). The sclerite is recessed on the body and usually contains the *first abdominal spiracle* (S 1) which thus opens onto an enlargement ("first abdominal spiracular chamber", Parsons 1970) of the subalar air space.

In an earlier study (Parsons 1970) I could not determine whether this sclerite is thoracic, abdominal, or a combination of both. Further investigation of a wider variety of *Hydrocorisae* has strongly indicated that the "thoraco-abdominal sclerite is a recessed, posterior part of the metathoracic epimeron, and that in most *Hydrocorisae* the first abdominal spiracle, like the metathoracic one, has moved from the intersegmental region into the more anterior segment (Parsons 1972a).

The ventral portion of the sclerite, to which the metacoxal membrane attaches (Fig. 21, MM), is weakly evaginated in such *Hydrocorisae* as *Belostoma* (Belostomatidae), *Nepa* (Nepidae), *Ambrysus* (Naucoridae) and *Pelocoris* (Naucoridae). The evagination is much larger and more prominent in the *Corixidae* examined here (Figs. 22-24, EML). This suggests that the evaginated portion is a

supracoxal lobe, homologous with the supracoxal lobe of the mesothoracic epimeron which was described in a previous paper (Parsons 1974).

The boundary between the thorax and abdomen is less clearly marked than that between the mesothorax and metathorax. The low third phragma (Fig. 21, 3PH) is anteriorly continuous with the metathoracic postnotum (PN III) and possesses a short posterior wall, the posttergite (PT; *sensu* Snodgrass 1935). The phragma represents the first abdominal antecosta, while the posttergite represents, according to Snodgrass, the anterior part of the first abdominal segment. Thus the membrane which attaches to the posttergite is the *functional thoracico-abdominal membrane* (TAM) rather than the morphological one (Parsons 1970).

The lateral part of the phragma is continuous with a low internal ridge (Fig. 21, IR) which runs along the posteroventral edge of the thoracico-abdominal sclerite. The ridge, which is here interpreted as the thoracico-abdominal boundary, becomes indistinct posteromedially. It can be traced as far as a process (MP), of variable size and shape, from which one or more dorsoventral muscles arise. The muscles attach dorsally on the first abdominal tergite, suggesting that the process is a part of the abdomen which is fused with the posteriormost part of the metathoracic epimeron. The process may be separated from the rest of the abdomen by the functional thoracico-abdominal membrane (Fig. 21), as in *Ambrysus* (Parsons 1970), *Belostoma* (Parsons 1972a) and *Diaprepocoris* (Fig. 22), or it may be fused with the abdomen, as in *Notonecta* (Parsons 1971), *Micronecta* (Fig. 23) and *Hesperocorixa* (Fig. 24). When fused with the abdomen its crest is medially continuous with the second abdominal antecosta (Figs. 23 and 24, AC2).

The first abdominal segment, unlike the more posterior ones, is incomplete laterally. Its tergite (Fig. 14A, T1) is separated from its sternal portion by the functional thoracico-abdominal membrane, which usually contains the first abdominal scolopophorous organ dorsolaterally (Figs. 14A and 21, SO 1). The lateral portion of the reduced first abdominal sternite is represented by at least part of the process MP (Fig. 21). The medial portion of the sternite may be entirely membranous and incorporated into the metacoxal membrane (Fig. 21), as in *Belostoma* and *Ambrysus*, or may be represented by a narrow sclerotized region anterior to the crest of the second abdominal antecosta, as in *Notonecta* (Parsons 1971),

Ranatra (Nepidae; Parsons 1972a), and the Corixidae examined here.

The sternite and tergite of the second abdominal segment are joined laterally (Fig. 14A). The anterolateral part of the segment projects anteriorly forming an *abdominal projection* (Figs. 14A and 21, AP) upon which the edge of the forewing rests. The second abdominal spiracle, like the more posterior ones, is much smaller than the first abdominal one and lies in the ventrolateral part of the segment (Fig. 21, S2).

All three of the corixids examined here differ from the typical plan in three major respects: (1) the evaginated lobe of the metathoracic epimeron is much larger than in other Hydrocorisae, (2) the metathoracic postalar region does not form a strong lateral projection, and (3) the first abdominal spiracle lies in the functional thoracico-abdominal membrane rather than in the metathoracic epimeron. The three insects differ mainly in the shape of the metathoracic epimeron and in the way in which it is joined to the anteroventral part of the abdomen.

II. *Diaprepocoris*

The posterior part of the metathoracic epimeron of *Diaprepocoris* is diagrammed in Fig. 22. Unlike the thoracico-abdominal sclerite of typical Hydrocorisae (Fig. 21, TAS) it is not recessed on the body; its external wall is directly continuous with the postalar bridge, which does not project strongly laterally. The posterior part of the subalar membrane contains a small sclerite (SO III) which probably forms an attachment for the scolophore of a metathoracic scolopophorous organ.

The epimeron forms a large, two-walled ventral lobe (Figs. 18 and 22, EML) which extends posteroventrally from the metacoxal process (Fig. 18, PR; Fig. 22, heavy black dot). The metacoxal membrane (MM) attaches along the free dorsal edge of the inner wall of the lobe. The inner (medial) and outer (lateral) walls are joined anteriorly, ventrally, and posterodorsally; their apposed surfaces adhere closely to each other and are difficult to separate. The dorsal opening into the lobe extends from the coxal process to a point (Fig. 22, P) approximately midway between the level of the third phragma (3PH) and the anterior edge of the abdominal projection (Figs. 15 and 22, AP). Posterior to Point P the lobe projects posteroventrally, as a blind sac, ending just ventral to the anterior edge of the abdominal projection.

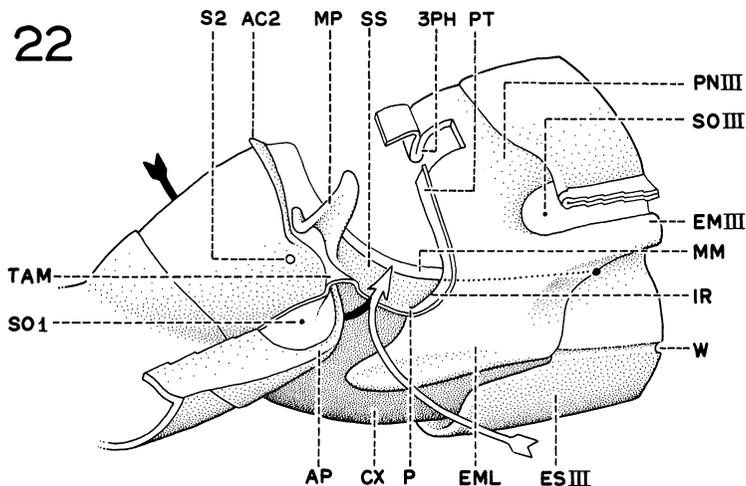


Fig. 22. *D. zealandiae*; semi-diagrammatic lateral view of thoraco-abdominal region, prepared as in Fig. 21. Thoraco-abdominal membrane (TAM, mostly removed) attaches along posttergite (PT) and lateral edges of intersegmental ridge (IR) and sclerotized strip (SS). Heavy black dot indicates position of coxal process; heavy dotted line indicates dorsal edge of inner wall of metathoracic epimeral lobe (EML). Head of arrows indicates position of first abdominal spiracle (removed) in thoraco-abdominal membrane; spiracle communicates with ventral air store (white arrow) and with air store surrounding metacoxa (black arrow).

The intersegmental boundary (Fig. 22, 3PH) is transverse in the dorsolateral part of the body. At the level of the opening into the epimeral lobe the boundary bends abruptly posteroventrally, forming a low internal ridge (IR). The ridge adheres to the inner wall of the lobe, obscuring the posterior part of the opening. Only mature specimens were available for this investigation; quite possibly the opening is not obscured in newly-moulted individuals.

At Point P the epimeral lobe becomes continuous with a narrow sclerotized strip (Fig. 22, SS) which runs posteromedially and ends in a muscle process (MP). All but the most ventral, posterolateral edge of this strip is concealed externally by the functional thoraco-abdominal membrane (Fig. 15, TAM; membrane mostly removed in Fig. 22), which attaches along this edge. The first abdominal spiracle (Figs. 15 and 18, S1) lies in the thoraco-abdominal membrane immediately lateral to the sclerotized strip. The anteromedial edge of the strip is more dorsal than the posterolateral edge and

provides an attachment for the metacoxal membrane (Figs. 18 and 22, MM). Although the intersegmental boundary is not indicated by any definite landmark on the sclerotized strip, comparison of *Diaprepocoris* with *Micronecta* (Fig. 23, IR) and *Hesperocorixa* (Fig. 24, IR) strongly suggests that the boundary runs lengthwise along the structure, paralleling the attachment of the thoracico-abdominal membrane.

The muscle process (Figs. 18 and 22, MP) which lies at the posteromedial end of the sclerotized strip projects anterodorsally. A large muscle attaches to its anterior face and extends dorso-medially to the medial portion of the first abdominal tergite. This suggests that at least the anterior portion of the process represents the first abdominal segment, and that the thoracico-abdominal boundary passes anteromedial to its base.

The muscle process, unlike that of *Micronecta* (Fig. 23) or *Hesperocorixa* (Fig. 24) is separated, by a membrane, from the anteroventral portion of the abdomen. An irregularly shaped medial arm of the process articulates flexibly with the anterior wall of a low second abdominal antecosta (Fig. 22, AC2); this narrow anterior wall appears to represent a reduced first abdominal sternite. The rest of the muscle process is separated, by a narrow strip of the thoracico-abdominal membrane, from the part of the abdomen containing the second abdominal spiracle (S2). The latter region lacks a second abdominal antecosta and appears to consist only of the second abdominal segment. Laterally it forms the abdominal projection (AP). The dorsal portion of the thoracico-abdominal membrane, which attaches to the abdominal projection, contains the sensory membrane of the first abdominal scolopophorous organ (SO 1). This sense organ, like the metathoracic one (SO III), was not examined here; the small sclerite to which its scolophore probably attaches does not appear to be unusually modified.

III. *Micronecta*

The metathoracic epimeral lobe and the second abdominal spiracle of *Micronecta*, unlike those of *Diaprepocoris* and *Hesperocorixa*, are concealed ventrally by the metathoracic episternum (Fig. 6, ES III), whose posterior lobe is longer than in the other two insects. As in *Diaprepocoris*, the epimeral lobe (Figs. 19 and 23, EML) is a two-walled structure lying posteroventral to the metathoracic coxal process (Figs. 19, PR; Fig. 23, heavy black dot). The lobe differs from that of *Diaprepocoris*, however, in the shape of the

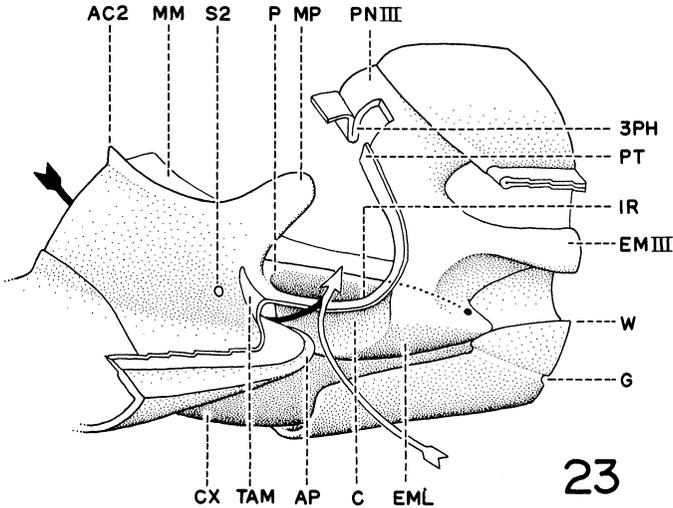


Fig. 23. *M. sedula*; semi-diagrammatic lateral view of thoraco-abdominal region, prepared as in Fig. 21. Heavy black dot indicates position of coxal process; heavy dotted line indicates dorsal edge of inner wall of metathoracic epimeral lobe (EML). Head of arrows indicates position of first abdominal spiracle (removed) in thoraco-abdominal membrane (TAM); spiracle communicates with ventral air store (white arrow) and with air store surrounding metacoxa (black arrow).

outer wall and in the extent of the dorsal opening between the inner and outer walls.

The anterior portion of the outer wall of the lobe is dilated on the body (Fig. 23, EML) and resembles a weakly-developed postalar projection. Immediately anterolateral to the metacoxal process it forms a short anterior extension which fits against the wing-anchoring ridge (W) of the episternum. The posterior portion of the outer wall (C) is strongly indented on the body. The convex internal surface of this indented portion adheres to the inner wall of the lobe but elsewhere the two walls, like those of *Diaprepocoris*, are separated by a distinct lumen. The dorsal opening into the epimeral lobe extends all the way to the base of the muscle process (MP) rather than ending anterior to the process as in *Diaprepocoris* (compare Point P, Figs. 22 and 23). Thus the posterior part of the lobe lies much closer to the abdominal process (AP) than in *Diaprepocoris*.

The thoracico-abdominal boundary is marked dorsally by the third phragma (Fig. 23, 3PH). The lateral part of the phragma becomes continuous with a low ridge (IR) which bends postero-medially. The bending is less abrupt than in *Diaprepocoris* and the intersegmental ridge does not adhere to the inner wall of the epimeral lobe like that of *Diaprepocoris*. It extends along the dorsal edge of the outer wall of the lobe as far as Point P. The narrow, flange-like external wall of the ridge is continuous with the posttergite of the third phragma and forms, like the latter, an attachment for the thoracico-abdominal membrane (TAM). The first abdominal spiracle (Figs. 16 and 19, S 1) lies in the thoracico-abdominal membrane immediately dorsal to the narrow flange. Although the spiracle is clearly visible under the stereoscopic and scanning electron microscopes, neither of these techniques revealed whether *Micronecta* possesses metathoracic or first abdominal scolopophorous organs.

Posteromedial to Point P the intersegmental boundary appears to lie anterior to the base of the muscle process. The process (Fig. 23, MP) is larger and flatter than that of *Diaprepocorix* and is separated from the second abdominal segment only laterally. Medially its crest is directly continuous with the second abdominal antecosta (AC2), and its anterior and posterior surfaces thus appear to represent the first and second abdominal segments respectively. As in *Diaprepocoris* a muscle arises on its anterior surface and attaches dorsomedially on the first abdominal tergite.

IV. *Hesperocorixa*

The metathoracic epimeral lobe of *Hesperocorixa* was described and termed the "thoracico-abdominal sclerite" in a previous paper (Parsons 1970), but its homologies were not clear until the present investigation.

The lobe (Fig. 24, EML) is relatively larger, both dorsoventrally and anteroposteriorly, than its homologues in *Diaprepocoris* and *Micronecta*. Its outer wall is anteriorly dilated and has a short anterior extension which fits against the wing-anchoring ridge of the episternum (W), as in *Micronecta*. From this extension a horizontal groove extends posteriorly along the outer wall; the edge of the forewing fits into this groove, which divides the outer wall of the lobe into dorsal and ventral portions. The ventral portion (EML; "thoracico-abdominal lobe" of Parsons 1970) is convex

along its entire length; the dorsal portion, which is concealed by the wing, is convex anteriorly but deeply recessed posteriorly (C). The recessed portion lies closely against the inner wall of the lobe, and the apposed surfaces of the two walls ("vertical plate" of Parsons 1970) become secondarily fused in mature specimens.

Because of the close apposition of the two walls, the full extent of the dorsal opening into the lobe is visible only in newly-moulted insects. As in *Micronecta*, the opening extends posteriorly as far as the base of the abdominal muscle process (Fig. 24, MP). An earlier publication (Parsons 1970) has described how the posterior part of the opening becomes secondarily closed off in mature specimens.

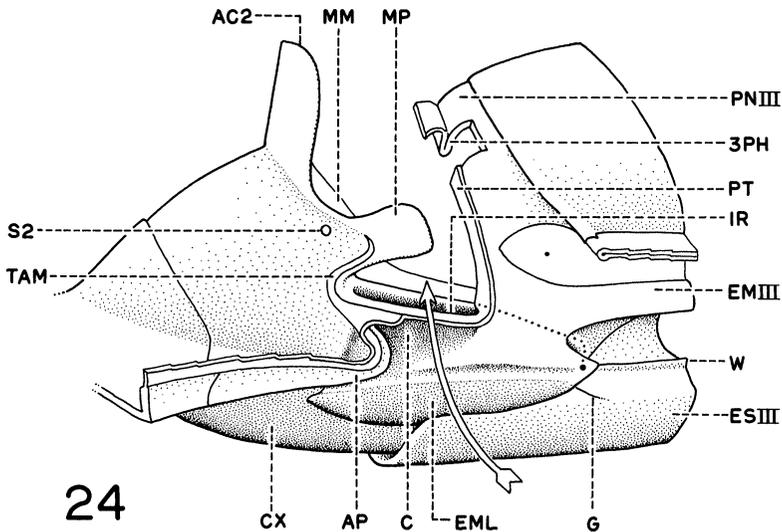


Fig. 24. *H. interrupta*; semi-diagrammatic lateral view of thoraco-abdominal region, prepared as in Fig. 21. Heavy black dot indicates position of coxal process; heavy dotted line indicates dorsal edge of inner wall of metathoracic epimeral lobe (EML). Head of arrow indicates position of first abdominal spiracle (removed) in thoraco-abdominal membrane (TAM); spiracle communicates with ventral air store (white arrow) and with supra-alar air store.

The thoraco-abdominal boundary follows the same course as in *Micronecta*. The transverse third phragma (Fig. 24, 3PH) extends as far as the level of the dorsal opening into the epimeral lobe (heavy dotted line). The boundary then bends abruptly posteriorly, forming a right angle, rather than a gradual curve as in *Micronecta*, and runs along the dorsal edge of the outer wall of the lobe in the form of a low ridge (IR). The thoraco-abdominal membrane (TAM) attaches along the narrow external wall of the ridge and contains the first abdominal spiracle (Figs. 17 and 20, S 1).

The intersegmental ridge extends as far as the base of the muscle process (Fig. 24, MP). The process is larger and more rectangular than its homologue in *Micronecta* but resembles it otherwise and bears a similar muscle attaching dorsomedially on the first abdominal tergite. As in *Micronecta* it is incompletely separated from the second abdominal segment and its crest is laterally continuous with the second abdominal antecosta (AC2). The antecosta, unlike that of *Micronecta* and *Diaprepocoris*, forms a large, raised apodeme just lateral to the muscle process; the anterior face of the apodeme provides an extensive surface for the attachment of the very large ventral longitudinal muscle of the first abdominal segment.

Although the relationship of the epimeral lobe to the abdomen is very similar in *Micronecta* and *Hesperocorixa*, the two insects differ in one major respect. In *Micronecta*, as in *Diaprepocoris*, the posterior part of the lobe does not contact the abdominal process; the two structures are separated by a narrow space in *Micronecta* and by a much larger gap in *Diaprepocoris* (Figs. 22 and 23, black arrows). In *Hesperocorixa*, however, the vertical posterior edge of the lobe fits into a groove on the ventral surface of the abdominal process (Fig. 24). The two structures fit so closely together that there is little, if any, space between them. This close fit creates a barrier between the first abdominal spiracle of *Hesperocorixa* and the air layer which surrounds the metacoxa (see p. 172).

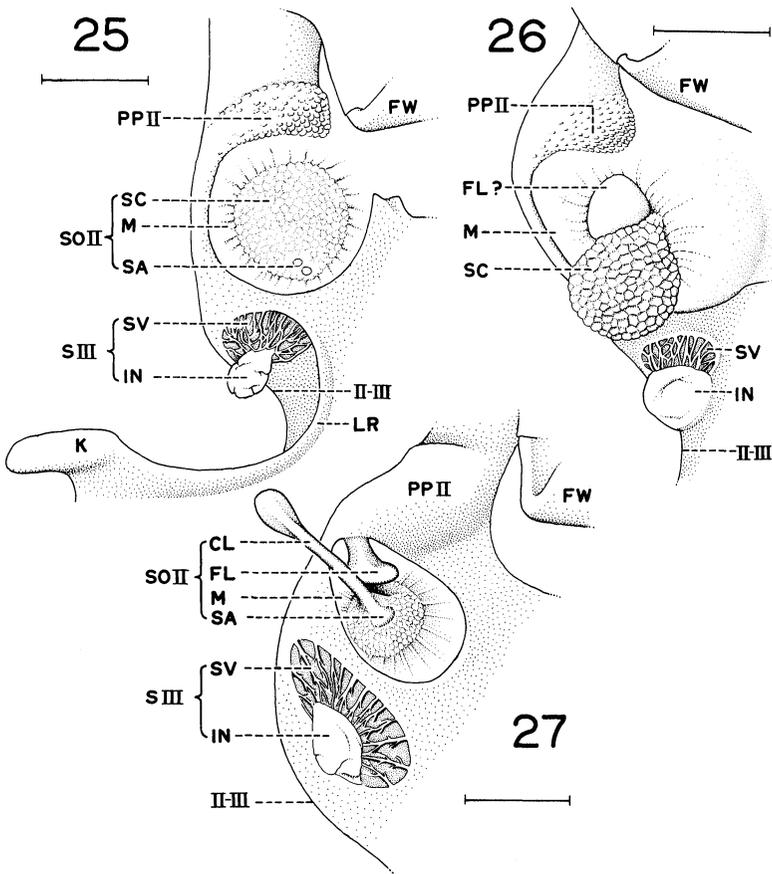
F. METATHORACIC AND FIRST ABDOMINAL SPIRACLES

I. Metathoracic spiracle

In all three corixids the orifice of the metathoracic spiracular trachea is covered by a *sieve-plate* and an *integumental region*

(terms of Parsons 1972b). In the metathoracic spiracles of *Belostoma* and *Ranatra*, which also have these two components, the integumental region bears the ecdysial opening and is lined by epidermis, while the sieve-plate lacks an underlying cellular layer (Parsons 1972b).

The sieve-plate (Figs. 25-27, SV) is composed of branching and anastomosing trabeculae (Figs. 28 and 29) which are connected, by short struts, to an internal membrane. The fine structure of



Figs. 25-27. Mesothoracic scolopophorous organs (SO II) and metathoracic spiracles (S III), oriented as in Figs. 15-17. Fig. 25. *D. zealandiae*; scale line = 100 μ m. Fig. 26. *M. sedula*; scale line = 50 μ m. Fig. 27. *H. interrupta*; scale line = 150 μ m.

the latter was clearly observed only in *Hesperocorixa* (Fig. 28); it bears very narrow, slit-like openings which are pinnately arranged on an otherwise solid surface. The arrangement of the openings is similar to that on the inner membranes of the mesothoracic, metathoracic, and eighth abdominal spiracles of *Belostoma* (Parsons 1972b, 1973). The openings appear, however, to be considerably narrower, and the metathoracic sieve-plate less porous, in *Hesperocorixa* than in *Belostoma*.

The integumental region (Figs. 25-27, IN) lies ventral to the sieve-plate. It is definitely at the margin of the plate in *Hesperocorixa* and *Micronecta* and is either marginal or very acentric within the plate in *Diaprepocoris*. Its size, relative to that of the sieve-plate, is largest in *Micronecta* (Fig. 26) and smallest in *Hesperocorixa* (Fig. 27). It forms a prominent knob in *Micronecta* and *Diaprepocoris* (Fig. 25) but is flatter in *Hesperocorixa*. In all three corixids the integumental region is covered with irregular folds (Fig. 29) which conceal the position of the ecdysial opening.

II. First Abdominal Spiracle

The first abdominal spiracle of all three genera is larger and much more permeable than the metathoracic one. Its longest dimension, compared with that of the metathoracic spiracle, is approximately 135 μm : 90 μm in *Diaprepocoris*, 45 μm : 35 μm in *Micronecta*, and 320 μm : 275 μm in *Hesperocorixa*. In *Diaprepocoris* and *Micronecta* it lacks a sieve-plate and integumental region; the spiracular trachea attaches directly to a round or oval opening in the thoracio-abdominal membrane (Figs. 15 and 16, S 1) and its orifice is not modified in any way.

In *Hesperocorixa* (Fig. 30) the orifice of the spiracular trachea lacks an integumental region and is encircled by a collar-like network of trabeculae which branch and anastomose like those on the sieve-plate of the metathoracic spiracle. Unlike the latter, however, the trabeculae lack an inner membrane and surround the tracheal orifice rather than cover it. The spiracle is thus as widely open as its less elaborate homologues in *Diaprepocoris* and *Micronecta*. The first abdominal spiracle of *Hesperocorixa* is similar to those of *Belostoma* and *Ranatra* (Parsons 1972b) except that in those two Hydrocorisae the trabeculae cover, rather than surround, the tracheal orifice.

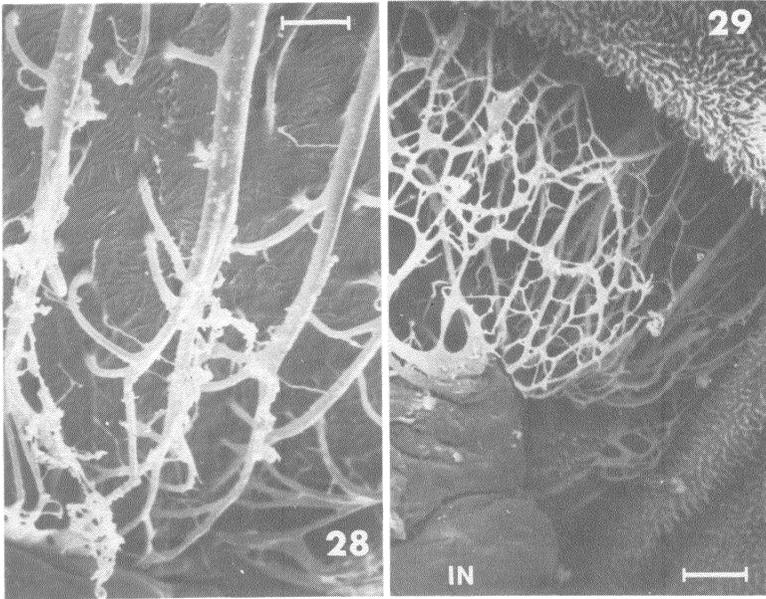


Fig. 28. *H. interrupta*; detail of external surface of sieve-plate on right metathoracic spiracle. Branching trabeculae are connected by short struts to an inner membrane which bears pinnately-arranged narrow slits. Dorsal margin of integumental region appears at extreme lower left. Top of figure is dorsal, right side is anterior. Scale line = 10 μ m.

Fig. 29. *D. zealandiae*; external surface of anterodorsal part of metathoracic spiracle, oriented as in Fig. 25. Sieve-plate bears branching trabeculae; inner membrane is too deep to be visible. Surface of mesothoracic epimeron (upper and lower right) is covered with short hydrofuge hairs. IN = integumental region of spiracle, with irregular folds. Top of figure is dorsal, right side is anterior. Scale line = 10 μ m.

G. MESOTHORACIC SCOLOPOPHOROUS ORGAN

The mesothoracic, metathoracic, and first abdominal scolopophorous organs of most Hydrocorisae consist of a sensory membrane which bears a very small sclerite for the attachment of a two-celled scolophore (Larsén 1957). In the Corixidae, however, the mesothoracic scolopophorous organ, unlike the metathoracic and first abdominal ones, bears a large sclerite, which is modified in different ways in the three forms here examined.

All three corixids possess mesothoracic sensory membranes with radially arranged low folds (Figs. 25-27, M). In *Hesperocorixa* (Fig. 27) the membrane is oval and completely surrounded by sclerotized areas; in the other two corixids it is round and anteriorly continuous with the subalar membrane. The postalar bridge dorsal to it (Figs. 25-27, PP II), which forms only a weak lateral projection, is covered with flattened, scale-like structures in *Micronecta* (Fig. 31) and *Diaprepocoris* (Fig. 32); similar scales were not observed in this region in *Hesperocorixa*.

The sclerite of the scolopophorous organ is most elaborate in *Hesperocorixa*. The "Hagemann's organ" of Corixinae has been described by many authors including Popham (1961), who believed it to be a pressure receptor, and Prager (1973), who found it to be sensitive to sound. Both these authors studied *Corixa punctata*, whose mesothoracic scolopophorous organ closely resembles that of *Hesperocorixa interrupta*. In both these Corixinae the sensory membrane bears a flask-shaped body (Fig. 27, FL) and a larger club-shaped structure (CL) whose base is considerably larger than its apex. The flask-shaped body ("B¹" of Popham 1961; "flaschenförmiger Körper" of Prager 1973) lies in the posterodorsal part of the sensory membrane and appears to contact the sclerotized rim of the scolopophorous organ. Immediately anteroventral to it lies the base ("B²" of Popham; "Basis" of Prager) of the club-shaped structure. Popham, who studied the sense organ histologically, stated that the flask-shaped and club-shaped bodies are joined; the scanning electron microscope shows that they are at least in very close contact.

The base of the club-shaped structure bears a pronounced knob (Figs. 27 and 33, SA) to which the scolophore attaches internally (Popham 1961). A narrow shaft joins the base to the dilated tip ("Kolben" of Prager 1973) of the club-shaped body, which extends, posteriorly and somewhat dorsally, beyond the rim of the sensory membrane and lies lateral to the metathorax. Popham (1961) believed that accidental flooding of the lateral subalar air space causes the club-shaped body to rotate until its tip touches the postalar projection (Fig. 27, PP II), thus warning the insect against tracheal flooding. Prager (1973) did not comment upon this hypothesis.

Popham (1961) described the club-shaped structure of *Corixa* as being covered with hydrofuge cuticle. The scanning electron microscope shows that in *Hesperocorixa* both the club-shaped and the flask-shaped bodies are covered with short, densely-packed projections with rounded tips. The projections are approximately 0.2 to 0.5 μm in diameter and give the surfaces of these structures a granular appearance. The base of the club-shaped body has a distinctive pattern; its granular surface is subdivided, by low grooves, into hexagonal facets (Fig. 33). This pattern was not observed elsewhere on the scolopophorous organ.

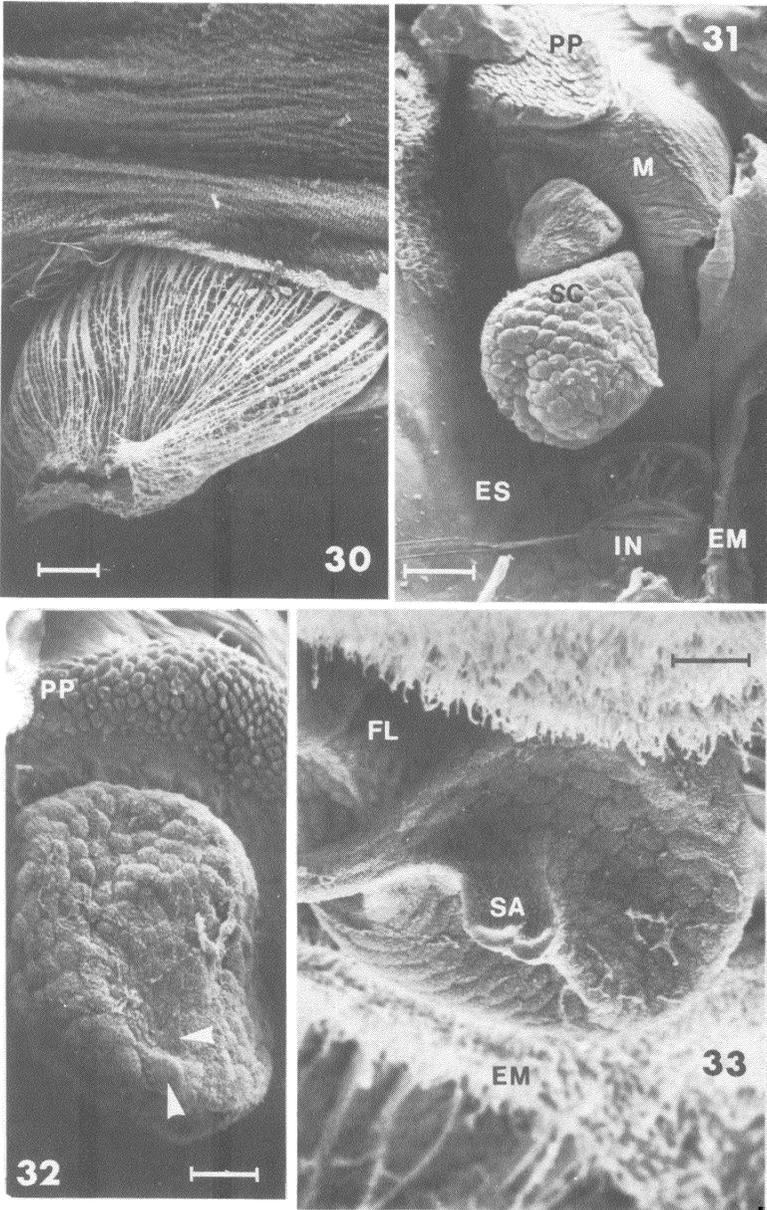
The mesothoracic scolopophorous organ of *Diaprepocoris* is considerably simpler than that of *Hesperocorixa*. The sensory membrane bears a central, roughly spherical sclerite (Figs. 25, SC; Fig. 32), which is darkly pigmented and approximately 100 μm in diameter. It projects laterally and somewhat ventrally from the

Fig. 30. *H. interrupta*; collar-like network of trabeculae surrounding orifice of right first abdominal spiracle, located in thoraco-abdominal membrane (top of figure). Spiracle lacks an inner membrane and is widely open. Top of figure is dorsal, right side is anterior. Scale line = 50 μm .

Fig. 31. *M. sedula*; right mesothoracic scolopophorous organ and metathoracic spiracle, oriented as in Fig. 26. Sensory membrane (M) of scolopophorous organ and wall of mesothoracic epimeron (EM) have been damaged at right side of figure. Bulb-shaped sclerite (SC) of sense organ bears hexagonal pattern; possible homologue of flask-shaped body of *Hesperocorixa* lies immediately dorsal to it. Spiracle possesses prominent integumental region (IN); sieve-plate lies immediately dorsal to it. Mesothoracic postalar projection (PP) bears flattened scales. ES = metathoracic episternum. Top of figure is dorsal, right side is anterior. Scale line = 20 μm .

Fig. 32. *D. zealandiae*; sclerite of right mesothoracic scolopophorous organ, oriented as in Fig. 25. A small portion of the sensory membrane is visible between the sclerite and the mesothoracic postalar projection (PP), which bears flattened scales. Note granular appearance of sclerite and pentagonal or hexagonal arrangement of grooves on its surface. Arrowheads indicate probable sites at which two cells of scolophore attach internally. Top of figure is dorsal, right side is anterior. Scale line = 20 μm .

Fig. 33. *H. interrupta*; base of club-shaped sclerite of right mesothoracic scolopophorous organ, showing granular appearance and hexagonal pattern of grooves. Scolophore attaches on internal surface of knob (SA) on base; shaft of club-shaped sclerite extends posteriorly (left side of figure) from site of scolophore attachment. Specimen has been tilted ventromedially, concealing sensory membrane. FL = part of flask-shaped body. EM = mesothoracic epimeron. Sieve-plate of metathoracic spiracle appears at lower left. Top of figure is dorsal, right side is anterior. Scale line = 20 μm .



membrane and bears, on its ventrolateral surface, two small smooth areas (Fig. 25, SA; Fig. 32, arrows) which probably represent the points at which the cells of the scolophore attach internally. The rest of its surface is covered with small rounded projections, similar to those observed in *Hesperocorixa*, which give it a granular appearance, and it has a pattern of pentagonally or hexagonally arranged grooves (Fig. 32). This pattern, along with the attachment of the scolophore, suggests that the entire structure is homologous with the base of the club-shaped body of *Hesperocorixa*. *Diaprepocoris* appears to possess no counterpart of the flask-shaped body or of the shaft and tip of the club-shaped body of *Hesperocorixa*.

Micronecta, however, shows a possible homologue of the flask-shaped body. In the posterodorsal part of the sensory membrane lies a roughly spherical structure (Fig. 26, FL?; Fig. 31) whose surface has a granular appearance but no hexagonal pattern. Its position suggests that it is the counterpart of the flask-shaped body of *Hesperocorixa*. Posteroventral to it lies a larger, bulb-shaped body (SC) which attaches to the sensory membrane by means of a narrow neck. The bulb-shaped body has a hexagonal pattern, and is probably homologous with the spherical body of *Diaprepocoris* (Fig. 25, SC) and with the base of the club-shaped body of *Hesperocorixa*. The grooves between the hexagons are deeper than those on the apparently homologous structures, and the surface of the bulb-shaped body is smooth rather than covered with granular projections. There is no distinctive feature to mark the attachment of the scolophore.

H. DISCUSSION

I. Mode of Respiration

The presence of air-bubble respiration in the subfamily Corixinae has been demonstrated by numerous physiological and behavioral studies which were mentioned in a previous publication (Parsons 1970). Similar data are lacking, however, for the Diaprepocorinae and Micronectinae except for a brief note concerning *Micronecta* sp. (Leong 1961). The following discussion of respiration in *Diaprepocoris* and *Micronecta* is therefore based almost entirely upon the morphology of preserved specimens and has yet to be confirmed or disproved by experimental evidence.

The air stores in *Diaprepocoris* and *Micronecta* appear to be at least as substantial as those of *Hesperocorixa*. All three insects possess large concealed air stores (subalar, cervical, and I-II) as well as an extensive ventral air layer which, being exposed to the water, is presumably able to obtain dissolved oxygen. *Diaprepocoris* is smaller than *Hesperocorixa* and has additional exposed air layers on the mesonotum and on most of the forewing, rather than only on the emboliar region. *Micronecta* has the advantage of very small size and, consequently, a large surface in proportion to its volume. *Diaprepocoris* and *Micronecta* thus appear to be at least as capable as *Hesperocorixa* of utilizing dissolved oxygen.

Thorpe and Crisp (1949) grouped aquatic insects with hydrofuge hairs into four categories, ranging from Group I (those with true plastral hairs) to Group IV (those with hairs which merely protect them against accidental wetting). Thorpe (1950) placed *Corixa* (Corixinae) in Group III, members of which must come to the surface at intervals to obtain atmospheric air and which are buoyant rather than heavier than water. Insects of Group III often possess a double hair pile, with a "macroplastron" of long hairs and a much thinner "microplastron" of short hairs (Thorpe and Crisp 1949). *Hesperocorixa*, like *Corixa*, clearly belongs in this category.

The similarity of the long and short hairs of *Hesperocorixa* to those of *Diaprepocoris* and *Micronecta* strongly suggests that all three insects have a similar mode of respiration. Leong (1961) and Wróblewski (personal communication) note that *Micronecta* periodically comes to the surface of the water for air although, according to Wróblewski, it can remain submerged during times of strong wave action, presumably utilizing dissolved oxygen during these occasions. Wróblewski also points out that *Micronecta* requires well-aerated aquaria. Although I could obtain no behavioral information on *Diaprepocoris*, the presence of a macroplastron of long hairs on its ventral abdominal surface would indicate that it is an air-bubble insect rather than a true plastral insect.

The Corixinae, unlike other Hydrocorisae, renew their air stores by contacting the surface of the water anterodorsally and taking in the atmospheric air beneath the long pronotum and the flange-like posterior edge of the head. To my knowledge it is not known whether the Deaprepocorinae and Micronectinae share this method of obtaining air or whether they contact the surface of the water with the tip of the abdomen, like most Hydrocorisae. Although the

latter method is possible it is, in my opinion, more probable that they contact the surface anterodorsally. *Diaprepocoris* and *Micronecta* resemble *Hesperocorixa*, and differ from other Hydrocorisae, in the presence of an air store beneath the posterodorsal margin of the head. All three insects also possess an air store on the mesonotum. Both air stores would tend to increase the buoyancy of the anterodorsal part of the body in *Diaprepocoris* and *Micronecta*, and if this region contacted the water surface the air could pass directly into these two air stores. Wróblewski (personal communication) has pointed out that the posterior margin of the head of *Micronecta* is raised at the midline (Figs. 9 and 12), forming a funnel-like space through which atmospheric air might enter. It is possible that *Diaprepocoris* can contact the water surface anywhere along its dorsal surface, owing to the buoyancy of its extensive supra-alar air store. *Notonecta* (Notonectidae), which also has a large supra-alar air store, contacts the water surface posteroventrally rather than dorsally. However its ventral air store, unlike that of *Diaprepocoris*, is held by hydrofuge hairs which are much longer than those on the forewing, and its ventral surface is thus more buoyant than its dorsal surface.

In *Hesperocorixa* the atmospheric air which enters the cervical and I-II air spaces is moved posteriorly, along the emboliar and ventral air stores, by the middle and posterior legs (Parsons 1970). Both these air stores are exposed to the water and can obtain dissolved oxygen. The ventral and supra-alar air stores communicate with the subalar one along the lateral edges of the abdomen and at a gap (Fig. 13, arrow) between the forewing and the metathoracic epimeral lobe (Parsons 1970). Thus the subalar air store, in which the metathoracic and first abdominal spiracles lie, can receive both atmospheric oxygen and dissolved oxygen. The subalar spaces of both *Diaprepocoris* and *Micronecta* could receive oxygen in a similar manner. In both insects this air store communicates with the exposed ones at least along the gap in the region of the metathoracic epimeron (Figs. 11 and 12, arrow) and quite probably along the abdomen as well. It is also possible, however, that either or both of these insects contact the atmosphere posteroventrally and take air directly into the subalar air store, as does *Ambrysus* (Naucoridae; Parsons 1970).

Popham (1960) believed that oxygen enters the tracheal system of *Corixa* chiefly through the first abdominal spiracles. This also

appears to be the case in *Hesperocorixa*, *Diaprepocoris*, and *Micronecta*. The capacity of a spiracle to inhale oxygen depends upon its porosity and size and its degree of communication with a well-oxygenated air store. In all three corixids the first abdominal spiracle is larger than the other spiracles, faces onto an enlarged part of the subalar space, and is widely open, lacking any sort of modification (*Diaprepocoris* and *Micronecta*) or bearing only a highly porous collar (*Hesperocorixa*, Fig. 30).

The more posterior abdominal spiracles, although they face directly onto the well-oxygenated ventral abdominal air layer, are much smaller than the first abdominal one and lie in a region of less metabolic activity. The mesothoracic spiracle communicates broadly with both the I-II and ventral thoracic air stores, and Parsons (1970) believed it to be a major inhalant spiracle in *Hesperocorixa*. This now appears to be unlikely. In *Hesperocorixa* it possesses a sieve-plate with an inner membrane, and in all three corixids it is considerably smaller than the first abdominal spiracle. The fine structure and porosity of the mesothoracic spiracles of the three corixids, however, has yet to be investigated by means of the scanning electron microscope. The metathoracic spiracle is smaller and much less porous than the first abdominal one in all three insects. It is covered by a sieve-plate which, at least in *Hesperocorixa*, limits its porosity (Fig. 28).

The inhalant function of the first abdominal spiracle is reflected not only in its fine structure but in the gross morphology of the region surrounding it. It lies in an enlarged part ("first abdominal spiracular chamber", Parsons 1970) of the subalar air space. When the spiracle lies within the metathoracic epimeron, as in most Hydrocorisae (Fig. 21), the relatively small portion of the epimeron which surrounds it is recessed on the body, forming the spiracular chamber. In the Corixidae, however, the spiracle lies in the thoraco-abdominal membrane and its spiracular chamber is formed by the modification of the greatly enlarged metathoracic epimeral lobe which lies ventral to it.

All three corixids possess a gap, between the forewing and the body, which leads directly into the spiracular chamber (Figs. 11-13 and 22-24, white arrows). Through this gap the spiracle can receive oxygen from the ventral air layer on the exposed parts of the epimeral lobe (Figs. 22-24, EML) and abdominal projection (AP); in *Hesperocorixa*, and quite probably in the other two insects as

well, the exposed supra-alar air store also communicates, at the gap, with the spiracular chamber.

The way in which the epimeral lobe is modified to form the spiracular chamber differs in the three corixids. In *Diaprepocoris* (Fig. 22) the dorsal part of the lobe does not extend as far posteriorly as in the other two insects. The spiracular chamber is thus formed by the large space between the abdominal projection and the posterodorsal wall of the lobe. This space can receive oxygen not only through the gap beneath the forewing (white arrow) but from the air store surrounding the metacoxa (black arrow). In *Micronecta* (Fig. 23) and *Hesperocorixa* (Fig. 24) the dorsal part of the lobe extends posterior to the level of the spiracle (position of spiracle indicated by heads of arrows in Figs. 23 and 24). If the outer wall of the lobe were dilated, as in *Diaprepocoris*, the spiracular chamber would be reduced in size. In both *Micronecta* and *Hesperocorixa*, however, the outer wall of the lobe is recessed (Figs. 23 and 24, C) immediately ventral to the spiracle, forming an enlargement of the subalar space. The spiracular chamber of *Micronecta* communicates, albeit narrowly, with the air which surrounds the metacoxa (Fig. 23, black arrow). In *Hesperocorixa*, however, the posterior edge of the epimeral lobe lies closely against the ventral surface of the abdominal projection, creating a barrier between the spiracular chamber and the metacoxa (Parsons 1970). In this respect *Hesperocorixa* differs from the other two corixids.

II. Phylogenetic Implications

According to Popov (1971) the ancestral stem of the Corixidae gave rise to six subfamilies, three of which survive at the present time. The Diaprepocorinae arose somewhere near the boundary between the Triassic and Jurassic, the Micronectinae during the Jurassic, and the Corixinae during the second half of the Cretaceous. Popov (1971) placed considerable emphasis on three plesiomorphic features of the Diaprepocorinae, the presence of ocelli, the short pronotum, and the relatively undeveloped embolium of the forewing.

The condition of the pronotum and embolium appear to have respiratory as well as phylogenetic significance. In *Hesperocorixa* and, to a lesser extent, in *Micronecta*, the lengthened pronotum increases the size of the I-II air store and the buoyancy of the anterodorsal part of the body. In *Diaprepocoris* these functions are

performed by the hydrofuge hairs on the mesonotum rather than by lengthening of the pronotum. The presence of a long, strongly indented embolium appears to be related to the size of the partial supra-alar air store on that region. The embolium is longer and more sharply indented in *Hesperocorixa* (Fig. 10), in which the air layer extends beyond the nodal furrow, than in *Micronecta* (Fig. 9), in which the air extends only to the furrow. In *Diaprepocoris* the supra-alar air store covers nearly all of the forewing rather than being confined mainly to the embolium, and the latter is only weakly indented (Fig. 8).

Two previous works (Parsons 1970, 1974) have discussed the ways in which the pterothorax of *Hesperocorixa* differs from that of most other Hydrocorisae. Popov's (1971) views on the phylogeny of the three living subfamilies are supported by the fact that *Micronecta* shares more of these pterothoracic characteristics than does *Diaprepocoris*. In all three corixids the metathoracic spiracle faces directly onto the subalar air store rather than being concealed by a high lateral epimeral ridge (Fig. 14A, LR) as in most other Hydrocorisae. *Diaprepocoris*, however, possesses a low epimeral ridge (Fig. 15, LR) while the other two corixids lack the ridge entirely. All three insects possess a weakly developed, rather than a prominent, mesothoracic postalar projection and a modified mesothoracic scolopophorous organ. The latter is simplest in *Diaprepocoris* (Fig. 25) and most complex in *Hesperocorixa* (Fig. 27). *Diaprepocoris* differs markedly from the other two corixids in the shape of its mesothoracic lateral epimeral lobe, which resembles that of most other Hydrocorisae (Fig. 14A) rather than being widened and strongly curved dorsally (Fig. 14B). The metathoracic air trough is also poorly developed in *Diaprepocoris*; it is more pronounced in *Micronecta* (Fig. 16, AT) and is most highly developed in *Hesperocorixa* (Fig. 17, AT).

The thoracico-abdominal region of all three corixids differs from that of typical Hydrocorisae in the large size of the metathoracic epimeral lobe and in the location of the first abdominal spiracle in the thoracico-abdominal membrane rather than in a recessed part of the epimeron. The three insects differ, however, in the shape of the metathoracic epimeral lobe (Figs. 22-24, EML), in the length of its dorsal opening, and in the way in which the first abdominal spiracular chamber is formed. In the latter two features *Micronecta* bears more resemblance to *Hesperocorixa* than to

Diaprepocoris. The degree of continuity between the first abdominal spiracular chamber and the air layer surrounding the metacoxa also differs in the three insects; it is greatest in *Diaprepocoris* (Fig. 22, black arrow), more limited in *Micronecta* (Fig. 23, black arrow) and very limited or absent in *Hesperocorixa* (Fig. 25).

Finally, the anterolateral part of the abdomen shows variation. All three corixids possess well-developed muscle processes (Figs. 22-24, MP), but that of *Diaprepocoris* is separated from, rather than fused with, the rest of the abdomen. Both *Diaprepocoris* and *Micronecta* lack the strongly developed condition of the second abdominal antecosta which is present in *Hesperocorixa* (Fig. 24, AC2).

Summary. 1. Representatives of the three subfamilies of Corixidae were examined. Although data on the respiration of *Diaprepocoris* (Diaprepocorinae) and *Micronecta* (Micronectinae) are lacking, the morphology of preserved specimens suggests that they use air-bubble respiration like *Hesperocorixa* (Corixinae). The structure of the forewings and intersegmental regions and the distribution of the hydrofuge hairs indicate that all three insects possess air stores on the ventral surfaces of the abdomen and thorax, beneath the forewings, between the head and prothorax, between the prothorax and mesothorax, and on the forewings. *Diaprepocoris*, unlike the other two insects, has an exposed air layer on the mesonotum and a supra-alar air layer covering nearly all of the forewing.

2. *Hesperocorixa* obtains atmospheric oxygen by periodically contacting the water surface anterodorsally, taking air into the air spaces beneath the head and pronotum. It appears likely that *Diaprepocoris* and *Micronecta* share this mode of behavior. All three insects can also obtain dissolved oxygen by means of the "physical gill" effect of their exposed air stores.

3. Of the three corixids examined, *Diaprepocoris* shows the fewest pterothoracic modifications and *Hesperocorixa* shows the most. The mesothoracic epimeron of *Diaprepocoris* is not widened like that of the other two insects, and *Diaprepocoris* lacks a specialized metathoracic "air trough". The mesothoracic scolopophorous organs of all three corixids differ from those of other Hydrocorisae. Those of *Diaprepocoris* and *Micronecta* possess one and two large sclerites respectively while that of *Hesperocorixa* has two sclerites

which form an elaborate "Hagemann's organ". The efferent system which leads from the metathoracic scent gland is different in *Micronecta* than in the other two corixids.

4. In typical Hydrocorisae the first abdominal spiracle lies in the posterior part of the metathoracic epimeron. In the three corixids, however, it lies in the thoracico-abdominal membrane, and the posterior part of the metathoracic epimeron is enlarged into a lobe ventral to it. The shape of the lobe differs in the three insects and affects the communication between the spiracles and the air stores. The lobe is least complex in *Diaprepocoris* and most complex in *Hesperocorixa*.

5. In all three corixids the metathoracic spiracle lies in the mesothoracic epimeron and faces directly onto the subalar air store. It is smaller than the first abdominal one and, unlike the latter, is covered by a "sieve-plate" which appears to limit its porosity. The large first abdominal spiracle lacks a sieve-plate and appears to be the main site of inhalation in all three insects. It is unmodified in *Diaprepocoris* and *Micronecta* and is encircled by a trabecular collar in *Hesperocorixa*.

6. The present investigation supports the views of Popov (1971) on the phylogenetic relationships among the three living subfamilies of Corixidae.

EXPLANATION OF ABBREVIATIONS

The Roman numerals I, II, or III after an abbreviation indicate prothoracic, mesothoracic, or metathoracic structures respectively; an Arabic number following an abbreviation indicates the abdominal segment to which the structure belongs. The following abbreviations are used:

AC	Antecosta
AP	Abdominal projection
AT	Air trough of metapleuron
B	Base of mesothoracic lateral epimeral lobe
C	Indented portion of metathoracic epimeral lobe
CA	Clavus of forewing
CL	Club-shaped sclerite
CO	Corium of forewing

CS	Claval suture of forewing
CX	Metacoxa
D	Dorsal region of mesothoracic epimeron or metathoracic episternum
E	Embolium of forewing
EC	Efferent channel of metathoracic scent gland
EM	Epimeron
EML	Lobe of metathoracic epimeron
ES	Episternum
F	Nodal furrow of forewing
FL	Flask-shaped sclerite
FW	Forewing
G	Groove on metathoracic episternum
HW	Hindwing
ID	Indented region on exposed part of metathoracic episternum
IN	Integumental region of metathoracic spiracle
IR	Intersegmental ridge between thorax and abdomen
K	Wing-anchoring knob of mesothoracic epimeron
LL	Lateral lobe of mesothoracic epimeron or metathoracic episternum
LP	Posterior lobe of mesothoracic epimeron or metathoracic episternum
LR	Lateral ridge of mesothoracic epimeron
M	Sensory membrane of mesothoracic scolopophorous organ
MB	Membrane of forewing
MI	Metacoxal indentation
MM	Metacoxal membrane
MP	Muscle process
N	Notum
O	Ostiole of metathoracic scent gland
OC	Ocellus
P	Posterior end of dorsal opening into metathoracic epimeral lobe
PL	Pleural ridge or sulcus
PN	Postnotum
PP	Postalar bridge and/or postalar projection
PR	Metathoracic coxal process

PT	Posttergite
S	Spiracle or spiracular trachea
SA	Attachment of scolophore
SC	Sclerite of mesothoracic scolopophorous organ
SO	Site of scolopophorous organ
SS	Sclerotized strip
ST	Sternite
SV	Sieve-plate of metathoracic spiracle
T	Tergite
TAM	Functional thoracic-abdominal membrane
TAS	Thoraco-abdominal sclerite
V	Ventral region of mesothoracic epimeron or metathoracic episternum
W	Wing-anchoring ridge or groove of metathoracic episternum
WS	Setae on lateral edge of forewing
X	Xiphus of metathoracic sternum
2PH,	
3PH	Second phragma, third phragma
II-III	Lateral boundary between mesothorax and metathorax

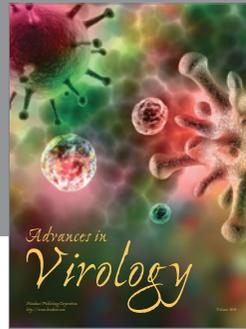
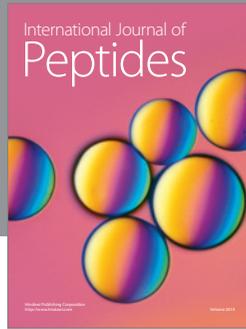
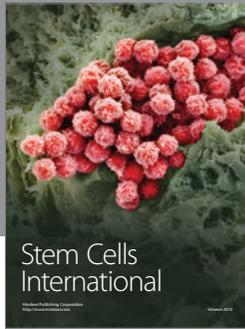
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