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STUDIES ON THE COMPARATIVE MORPHOLOGY
OF SCENT APPARATUS AND ALIMENTARY ORGANS
OF SOME STINK BUGS (PENTATOMIDAE : PENTATOMINAE)
OF PAKISTAN WITH REFERENCE TO PHYLOGENY

BY

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SYNOPSIS

An attempt is made to study the comparative morphology of the scent apparatus and of the alimentary organs within the subfamily *Pentatominae*. The result is compared with the accounts given in the existing literature and the relationship of various group within *Pentatomoidea* on the basis of these characters is briefly discussed.

KEY TO THE LETTERING

ACG : accessory gland; C : coxal cavity; CAEC : gastric caeca; DEP : ventral depression in the reservoir; DRE : duct of the reservoir (dorsal in position); GL : scent gland; IAM : inner arm of valvular apparatus; LDR : duct of the reservoir (ventral in position); MGS : midgut sac (midgut₁); M.G.2 : midgut₂; M.G.3 : midgut₃; MT : malpighian tubule; N : ganglionic nerve; OAM : outer arm of valvular apparatus; OES : oesophagus; OS : ostiole; P : ileum (pylorus); PAG : pterothoracic abdominal ganglion; PT : pterothorax; RE : reservoir; REC : rectum; S.G.A. : anterior lobe of principal salivary gland; S.G.P. : posterior lobe of principal salivary gland; VES : vestibule; VRE : reservoir ventrally.

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INTRODUCTION

During the recent years various aspects of comparative morphology (metathoracic scent gland ostioles, trichobothria, male and female genitalia, eggs, nymphs, male and female internal reproductive organs, chromosomes and etc.) are used in order to solve many of the phylogenetic problems within *Pentatomoidea*. COBBEN'S (1968) list of references extensively covers most of these aspects.

LESTON (1958 b) in his « higher systematics of shield bugs » probably rightly has claimed « there is agreement amongst specialist's that shield bugs warrant superfamily status as *Pentatomoidea*. At family level no two authors agree ». MIYAMOTO (1961) has emphasized this on several places, for instance with reference to *Acanthosomatidae* he has mentioned, « in the current classification of the *Heteroptera*, some authors (LESTON, 1953; SOUTHWOOD, 1956; PENDERGRAST, 1957; SCUDDER, 1959 and etc.) considered this group as a family but others (CHINA and MILLER, 1955 and 1959) have another opinion ». On the lower levels the disagreements seem to be even greater. LESTON (1958 b) referring to various groups, then according to him excluded from the family *Pentatomidae*, such as *Eurygasterinae* and *Halyinae* has specified that the status of many of these are required to be increased or diminished.

After BRINDLEY (1930) scent apparatus morphology on comparative basis in respect to the above mentioned problems has never been used within the superfamily *Pentatomoidea*, although GUPTA (1961 and 1964) and AHMAD and KHANUM (1968) and AHMAD *et. al.* (in press) have emphasized its importance as a systematic tool. BRINDLEY's work of 1930 included only two species representing two different families namely *Acanthosomatidae* and *Pentatomidae* (as they are generally regarded now) and even after her in various specific descriptions of scent apparatus only five species representing three families *Dinidoridae*, *Cydnidae* and *Pentatomidae* including three tribes *Pentatomini*, *Eurydemini* and *Halyini* of the latter have been covered, whereas the descriptions of GUPTA (1960) for *Aspongopus janus* (FABRICIUS) (*Coridius*) and RAI and TREHAN (1964) for *Bagrada cruciferarum* KIRKADLY are erroneous and misleading. The early works of DUFOUR, 1833; KUNCKEL, 1866; KULWIEC, 1898; GULDE, 1902; KERSHAW, 1907 and MUIR, 1907 covering various features of scent apparatus in various species of the superfamily *Pentatomoidea* are in addition to the works reported above. REMOLD (1962) covers functional aspects.

On the contrary, with reference to alimentary organs, after MIYAMOTO's (1961) famous work on « comparative morphology of alimentary organs of *Heteroptera* with the phylogenetic considerations » which included an observation of alimentary organs of forty species, alone from the families *Pentatomidae* and *Scutelleridae* and several species representing *Phyllocephalinae* (*Phyllocephalidae* of MIYAMOTO), *Urostylidae*, *Dinidoridae*, *Plataspidae*, *Cydnidae* and *Acanthosomatidae*, apart from specific descriptions of alimentary organs with reference to functional aspects (DUFOUR, 1833; GLASGOW, 1914; SAREL-WHITEFIELD, 1929; MALOUF, 1933; HAMNER, 1936; ELSON, 1937, HARRIS, 1938; KRETOVICH *et. al.*, 1943; STROGAYA, 1950; VOJDANI, 1954; GOODCHILD, 1963 a; 63 b and 66; RASTOGI, 1961; 1965 and 1966) which have appeared from time to time in the existing literature. The phylogenetic considerations on the basis of the comparative salivary glands morphology alone are in addition to those referred above (KUNCKEL, 1866; BUGNION & POFF,

1908; 1910; BAPTIST, 1941; NUORTEVA, 1954 and 1956; SOUTHWOOD, 1955; KUMAR, 1962, 65, 69 a and b).

In order to add to the descriptions of the scent apparatus and those of alimentary organs within the subfamily *Pentatominae* and in order to bring together the existing literature for a comparison and for a phylogenetic considerations of these characters in correlation with each other, the present study was undertaken.

MATERIAL AND METHODS

Adult pentatomine bugs (Table No. 1) were collected mainly on lucerne (*Medicago sativa*; *Papilionaceae*), young *rawasan* (*Sesbania sesbans*; *Papilionaceae*), and bushes (*Sueda monica*; *Chenopodiaceae*) from various parts of Sind during spring and summer of 1969 and 1970 (April to September). For anatomical studies both, preserved (in CARNOY fixative, 3 parts absolute alcohol and one part glacial acetic acid) and live specimens were dissected under Leitz binocular but good results were only obtained with freshly killed specimens. The structure of the scent apparatus was studied after removing the overlying viscera. Morphological diagrams were made using ocular grid on graph papers. For all measurements ocular micromillimeter graticule was used.

PART I. — THE SCENT APPARATUS MORPHOLOGY

General aspects of the morphology of the scent apparatus

Scent apparatus.

After removing the crop and the over lying viscera, a pair of white racemose, glands are exposed attached to the anterior side (lateral ducts) of a reservoir. On its ventral surface lies usually the convoluted accessory gland which also opens in the lateral ducts of the reservoir. Lateral ducts of each side in between the meso and metathoracic coxal cavities open in their respective semitransparent membranous vestibules. The opening on each side is guarded by a valvular apparatus. In turn each vestibule opens to the exterior through an opening located slightly lateral in between the meso and metathoracic coxal cavities on the metasternum.

The glands.

The glands are racemose spongy in appearance. Each gland lies symmetrically adjacent to the pterothoracic abdominal nerve, facing each other. The glandular tissue is shining white and is easily distinguished

TABLE 1

Species examined	Locality	Common name of the host plants	Botanical name
Family PENTATOMIDAE			
Subfamily I : PENTATOMINAE			
Tribe I : ASOPINI			
Species 1 : <i>Andrallus spinidens</i> (FABR.)	Malir gardens and Hyderabad	Lucerne	<i>Medicago sativa</i>
Tribe 2 : PODOPINI			
Species 2 : <i>Tarisa fraudatrix</i> (HORVÁTH)	Thatta	Bush	<i>Sueda monica</i>
Tribe 3 : EURYDEMINI			
Species 3 : <i>Bagrada hilaris</i> (BURM.)	Malir gardens, Tando-jam and Mirpurkhas	Lucerne and Mustard	<i>Medicago sativa</i> <i>Brassica campestris</i>
Species 4 : <i>Stenozygum speciosum</i> (DISTANT)	Werh and Mirpurkhas	Green creeper of Sind	<i>Salvadora prisica</i>
Species 5 : <i>S. pseudospeciosum</i> GHAURI	Thatta and Malir gardens	Plant without leaves	<i>Capparis decidua</i>
Tribe 4 : AELIINI			
Species 6 : <i>Aeliomorpha lineaticollis</i> (WESTWOOD) .	Malir gardens, Thatta, Hyderabad and Suburbs	Lucerne, Rawason	<i>Medicago sativa</i> <i>Sesbania sesbans</i>

TABLE 1 (contd. and end)

Species examined	Locality	Common name of the host plants	Botanical name
Tribe 5 : SCIOCORINI			
Species 7 : <i>Sciocoris lewisi</i> (DISTANT)	Thatta	Bush	<i>Sueda monica</i>
Tribe 6 : CARPOCORINI			
Species 8 : <i>Dolycoris indicus</i> (STÅL)	Malir gardens	Lucerne	<i>Medicago sativa</i>
Species 9 : <i>Croantha ornatula</i> (H. SCH.)	Thatta	Cholai, Bush	<i>Amaranthus viridis</i> <i>Sueda monica</i>
Tribe 7 : PENTATOMINI			
Species 10 : <i>Nezara viridula</i> L. var. <i>smaragdula</i> (FABR.)	Malir gardens, Thatta and Hyderabad	Lucerne, Rawason	<i>Medicago sativa</i> <i>Sesbania sesbans</i>
Species 11 : <i>Acrosternum graminea</i> (FABR.)	Pipri and Thatta	Indigofera, Rawason	<i>Indigofera oblongifolia</i> <i>Sesbania sesbans</i>
Species 12 : <i>Piezodorus rubrofasciatus</i> (F.)	Malir gardens, Thatta and Hyderabad	Lucerne, Rawason	<i>Medicago sativa</i> <i>Sesbania sesbans</i>
Tribe 8 : EYSARCORINI			
Species 13 : <i>Eysarcoris inconspicuus</i> (H. SCH.)	Karachi University Campus and Malir gardens	Lucerne, Rawason	<i>Medicago sativa</i> <i>Sesbania sesbans</i>
Species 14 : <i>E. modestus</i> (DISTANT)	Malir gardens and Hyderabad	Niazbu	<i>Ocimum basilium</i>

from the surrounding fat bodies which resemble loose mass of aggregate cells. Each gland opens in the lateral ducts of the reservoir through usually an unmarked very thin membranous duct.

The reservoir.

The reservoir is usually located medially in the depression of the metasternum. Anteriorly it is continued into relatively narrow, membranous ducts which lie on each side immediately posterior to the mesosternal ridges and adjacent to the anterior ridges of the metathoracic coxal cavities. The wall of the reservoir appears thicker and more cuticular as compared to the glands. It is very slightly depressed dorso-medially and dorso-laterally and ventrally has the ridges and the furrows. In the freshly killed specimens the reservoir seems to be full of secretion and its walls show remarkable smoothness.

The accessory gland.

The accessory gland usually appears like convoluted and coiled tube on the ventral surface of the reservoir usually occupying median position of the reservoir, having almost the same colour as that of the reservoir. It is only distinguishable from the ventral wall of the reservoir as the raised tubular structure. Usually on the postero-ventral side of the reservoir it is very well fitted in the ventral groove and is very hard to recognize. It opens on each side in the lateral ducts of the reservoir adjacent to the ventro-medial depression.

The vestibule.

The vestibules are semimembranous, whitish, tubes lying on each side between the ridges of the meso and metathoracic coxal cavities and slightly laterad to them. On their proximal end these are connected with the distal portion of the ducts of the reservoir through valvular apparatus. When pressed at the base, the secretion appears moving in their cavities. At their distal end these open through an aperture or ostiole. The vertical lunate ridge of the ostiole is absent.

The valvular apparatus.

The valvular apparatus is usually a semi-lunate, flap-like structure fitted nicely underneath the ridges of each metathoracic coxal cavity. Each valvular apparatus lies on the antero-lateral side of the duct of the reservoir and governs the flow of the secretion from the lateral ducts of the reservoir into the vestibules. The apex of the outer arm is fitted underneath the raised ridges of the metathoracic coxal cavities whereas the inner arm is free. The two arms are separated through an interlying

membrane. When the apex of the inner arm is pulled, the membranous portion of the valvular apparatus is lifted up and the flow of yellowish liquid may be seen into the vestibules.

The tracheation and the nerve supply.

From the pterothoracic abdominal ganglion a median nerve and usually 3 pairs of lateral nerves appear to run posteriad into the dorso-medial groove of the reservoir and at the sides of the ducts of the reservoir respectively. Probably the lateral nerves innervate the muscles of the valvular apparatus. The glands and the reservoir show rich supply of the fine tracheal branches.

Mode of action.

Secretion probably flows from the glandular cells to the lumen of the glands which ejects it into the reservoir, probably through the cumulative pressure. The accessory gland also discharges its content into the reservoir. The muscular contraction probably pulls the outer arm of the valvular apparatus which releases the valve which in turn allows the secretion to enter into the vestibules from where it is ejected outside through the ostioles.

COMPARATIVE SCENT APPARATUS MORPHOLOGY

Family PENTATOMINAE

Sub-family PENTATOMIDAE

Tribe ASOPINI

(Figs. 1-3)

Species examined : *Andrallus spinidens* (FABRICIUS).

Scent glands elongated, narrow somewhat leaflike, placed laterad close to the lateral margins and extending on to the posterior margin of the reservoir; duct of the glands not well marked; reservoir distinctly bilobed, of red rose colour reaching only on to the middle of the metathoracic coxal cavities; accessory glands on the ventral side of the reservoir having six or seven convolutions, placed away from the lateral margins; valvular apparatus lunate; vestibules of uniform width, moderately long and curved, handle-like, with very small rounded ostioles.

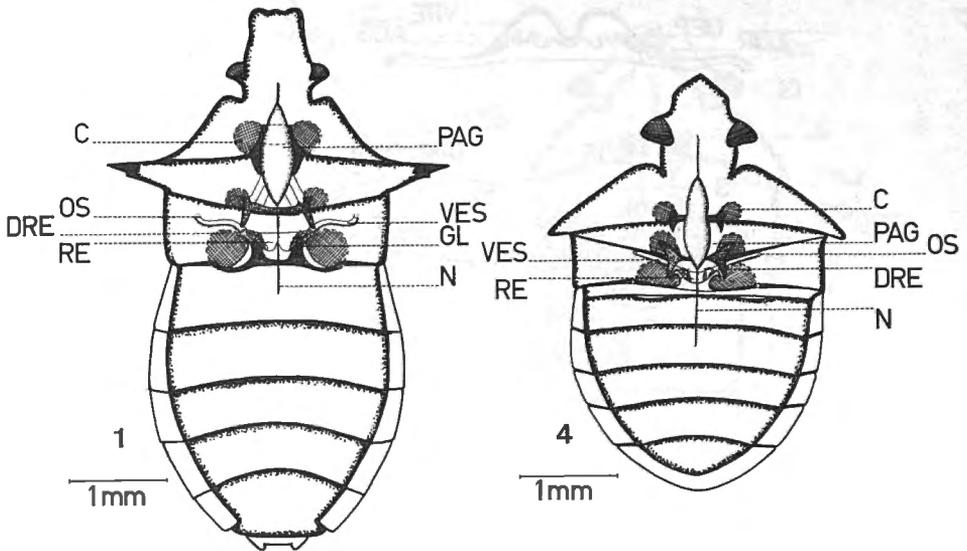


Fig. 1. — *Andrallus spinidens* (FABRICIUS) : scent apparatus entire, dorsal view.

Fig. 4. — *Tarisa fraudatrix* (HORVÁTH) : scent apparatus, dorsal view.

Tribe PODOPINI

(Figs. 4-6)

Species examined : *Tarisa fraudatrix* (HORVÁTH).

Scent glands of irregular form, placed dorsad well away from the lateral margins and extending on to the posterior margin of the reservoir; duct of the glands not well marked; reservoir somewhat « V » shaped, tube-like, semitransparent, whitish, membranous in appearance, hanging between the metathoracic coxal cavities and reaching on to before the middle of the cavities; accessory gland on the ventral surface of the reservoir of « V » shape, corresponding to that of reservoir, smooth, without convolution, placed away from the lateral margins but reaching close to them anteriorly; valvular apparatus smoothly lunate; vestibules almost straight, of uniform width, only slightly tapering distad with very minute rounded ostioles.

Tribe EURYDEMINI

(Figs. 7-15)

Previous description : RAI and TREHAN (1964).

Species examined : *Bagrada hilaris* (BURMEISTER); *Stenozygum speciosum* (DISTANT); *S. pseudospeciosum* GHAURI.

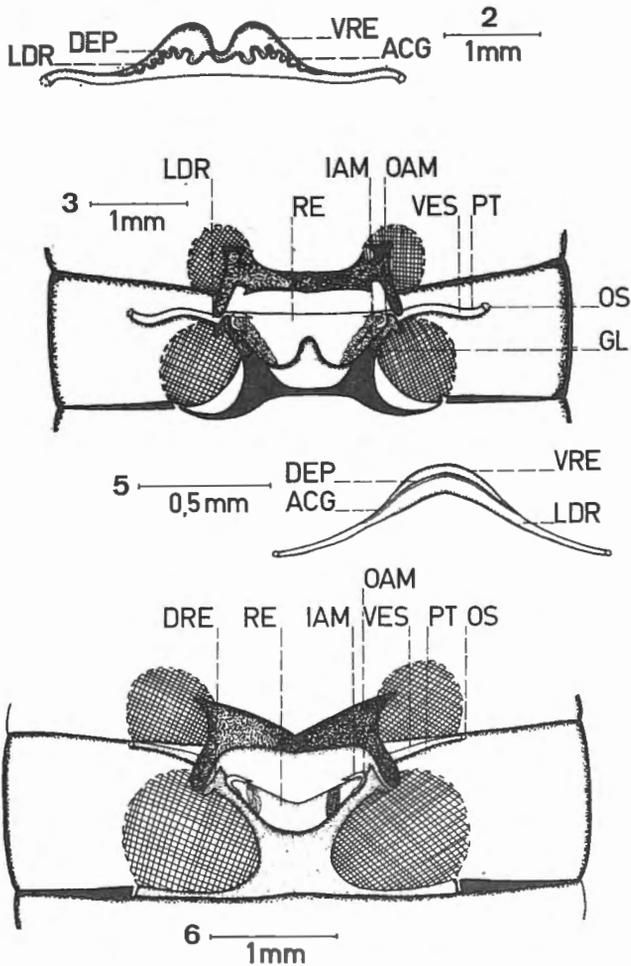


Fig. 2. — *Andrallus spinidens* (FABRICIUS) : scent reservoir, showing accessory gland, ventral view. Fig. 3. — *Andrallus spinidens* (FABRICIUS) : scent apparatus, showing valvular apparatus, enlarged, dorsal view. Fig. 5. — *Tarisa fraudatrix* (HORVÁTH) : scent reservoir showing accessory gland, ventral view. Fig. 6. — *Tarisa fraudatrix* (HORVÁTH) : scent apparatus, showing valvular apparatus, enlarged, dorsal view.

Scent glands leaf-like, placed dorsad, near the sides of the reservoir and usually extending on to the posterior margin; duct of the glands not well marked; colour and shape of the reservoir variable, posterior margin usually somewhat curved, not reaching beyond posterior margin of meta-thoracic coxae; accessory gland on the ventral surface of the reservoir usually « V » shaped without loops, away from the lateral margins; valvular apparatus apparently lunate; vestibules convexly curved with very small ovoid ostioles.

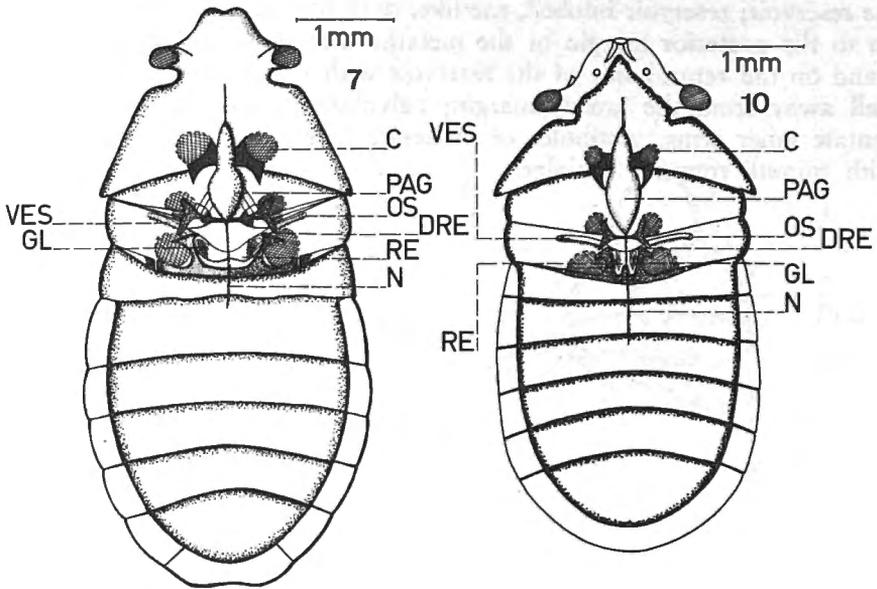


Fig. 7. — *Bagrada hilaris* (BURMEISTER) : scent apparatus entire, dorsal view.

Fig. 10. — *Stenozygum speciosum* (DISTANT) : scent apparatus entire, dorsal view.

Scent glands measure about 0.2 mm in *B. hilaris*, 0.36 mm in *S. pseudospeciosum* and 0.8 mm in *S. speciosum*. Reservoir is slightly whitish and tube-like, « V » shaped in *B. hilaris* and almost transverse and hanging in the middle of the metathoracic coxal cavities in *S. pseudospeciosum* and distinctly bilobed in *S. speciosum*. Similarly the accessory gland is almost « V » shaped in *B. hilaris*, semicircular in *S. pseudospeciosum* and bilobed corresponding to the shape of the reservoir in *S. speciosum*.

RAI and TREHAN in 1964 have described the repugnatorial apparatus (scent apparatus) of *B. cruciferarum* possessing a single sac-like gland adhering to the metathoracic basisternum and to the sternum of the second abdominal segment. Probably they referred to the almost « V » shaped sac-like reservoir of the present species. They have not shown the valvular apparatus, the lateral ducts of reservoir or the ventrally located accessory gland which could have provided an opportunity for comparison.

Tribe AELIINI

(Figs. 16-18)

Species examined : *Aeliomorpha lineaticollis* (WESTWOOD).

Scent glands of irregular form, placed dorsad close to the lateral margins and extending on to about half length of the reservoir; duct of the glands short but quite distinct opening into on the ventral side of

the reservoir; reservoir bilobed, sac-like, dark orange in colour, extending on to the posterior margin of the metathoracic coxal cavities; accessory gland on the ventral side of the reservoir with four to five loops, placed well away from the lateral margin; valvular apparatus with markedly dentate inner arms; vestibules of moderate length slightly tapering distad with minute rounded ostioles.

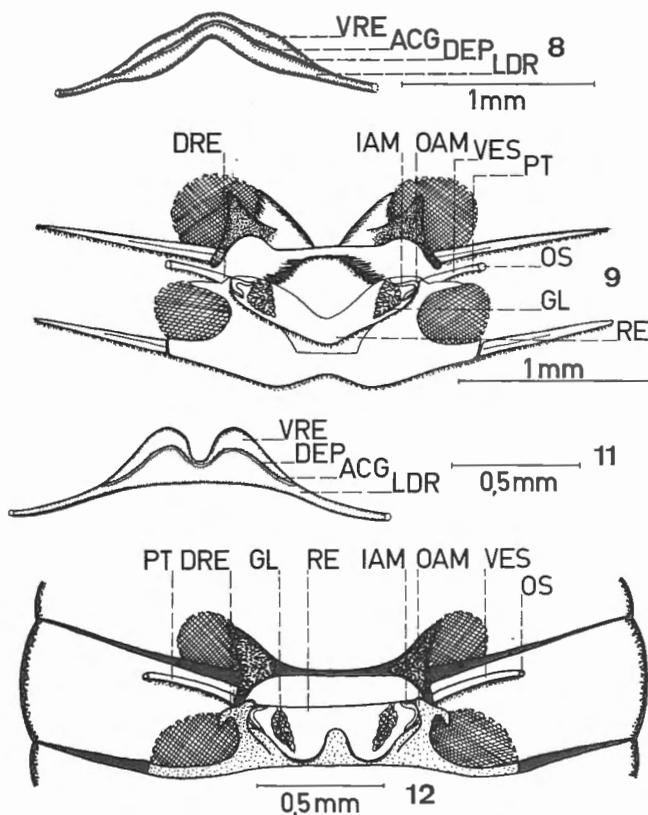


Fig. 8. — *Bagraha hilaris* (BURMEISTER) : scent reservoir, showing accessory gland, ventral view. Fig. 9. — *Bagraha hilaris* (BURMEISTER) : scent apparatus, showing valvular apparatus, enlarged, dorsal view. Fig. 11. — *Stenozygum speciosum* (DISTANT) : scent reservoir, showing accessory gland, ventral view. Fig. 12. — *Stenozygum speciosum* (DISTANT) : scent apparatus, showing valvular apparatus, enlarged, dorsal view.

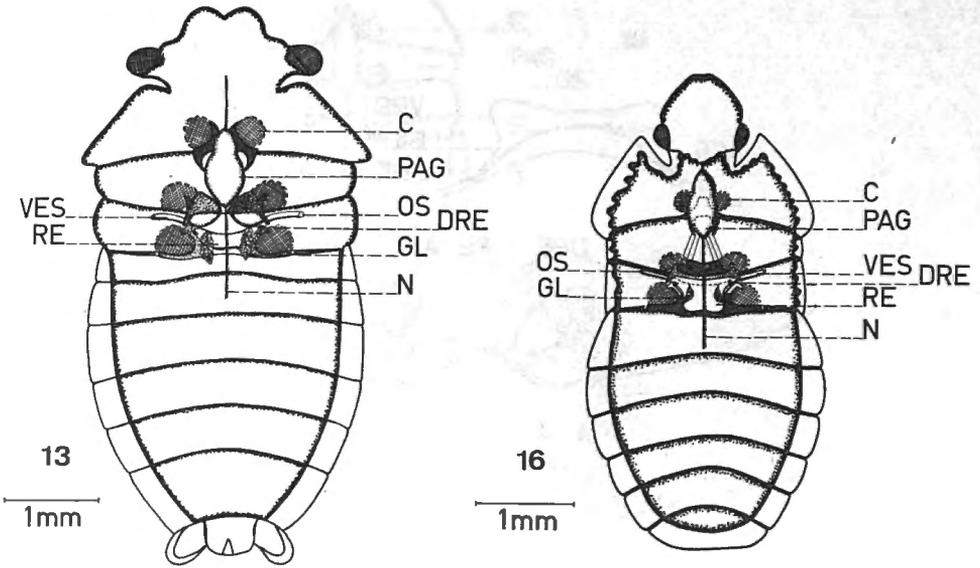


Fig. 13. — *Stenozygum pseudospeciosum* GHAURI : scent apparatus entire, dorsal view.

Fig. 16. — *Aeliomorpha lineaticollis* (WESTWOOD) : scent apparatus entire, dorsal view.

Tribe SCIOCORINI

(Figs. 19-21)

Species examined : *Sciocoris lewisi* (DISTANT).

Scent glands of irregular form, placed dorsad away from the lateral margin and extending on to about half length of the reservoir, with short but distinct collecting ducts; the reservoir smooth heart-shaped, wider anteriorly, orange, extending well beyond the metathoracic coxal cavities on to the third abdominal sternum; accessory gland on the ventral surface of the reservoir placed in the middle of the reservoir and with 5 to 6 convolutions; valvular apparatus with markedly dentate, inner arms; vestibules relatively short slightly tapering almost straight, with small rounded ostioles.

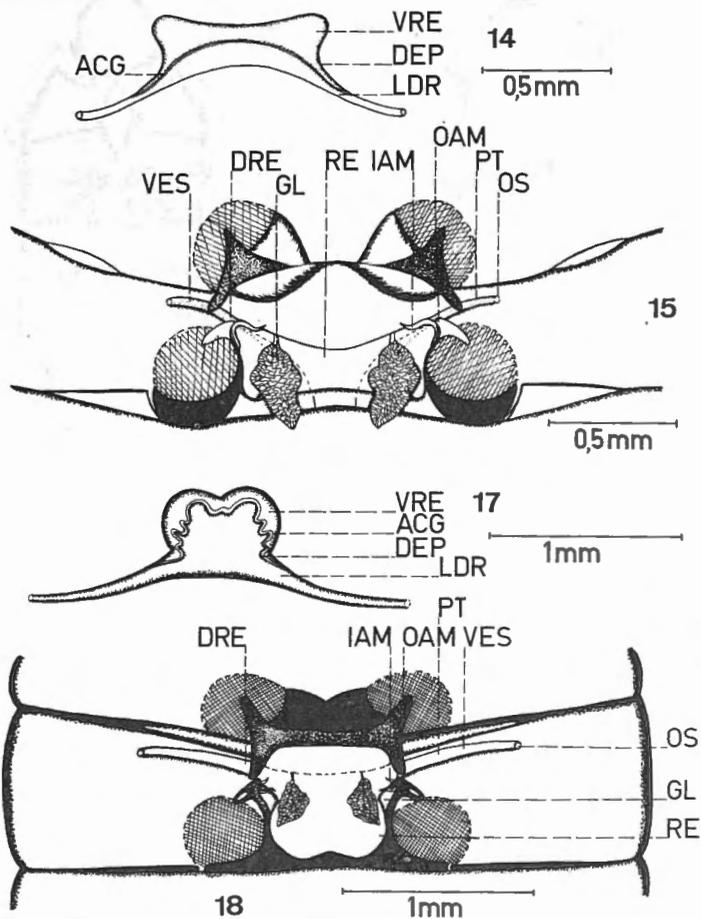


Fig. 14. — *Stenozygum pseudospeciosum* GHAURI : scent reservoir, showing accessory gland, ventral view. Fig. 15. — *Stenozygum pseudospeciosum* GHAURI : scent apparatus showing valvular apparatus, enlarged, dorsal view. Fig. 17. — *Aeliomorpha lineaticollis* (WESTWOOD) : scent reservoir, showing accessory gland, ventral view. Fig. 18. — *Aeliomorpha lineaticollis* (WESTWOOD) : scent apparatus, showing valvular apparatus, enlarged, dorsal view.

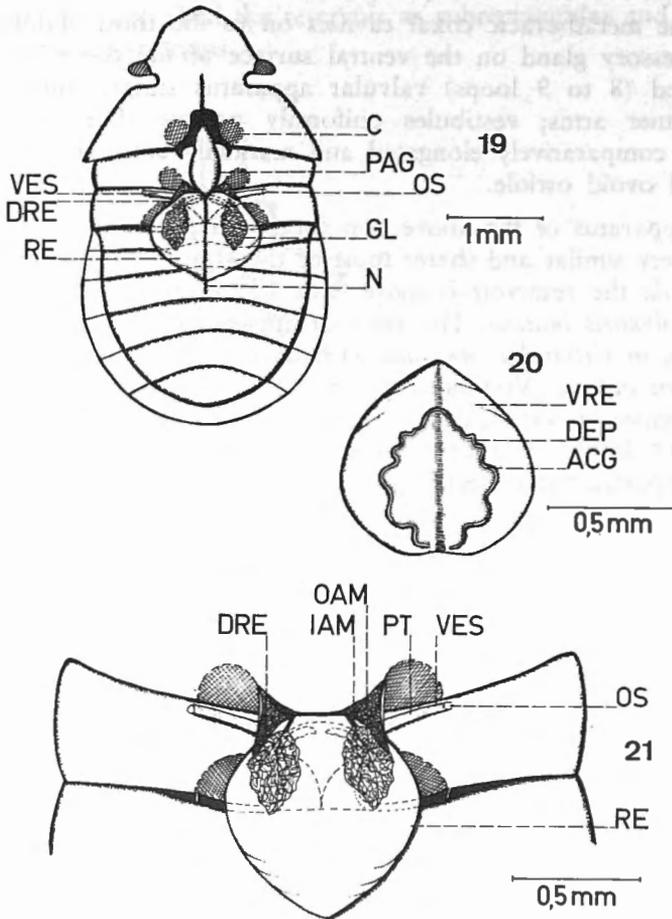


Fig. 19 à 21 : *Sciocoris lewisi* (DISTANT).

Fig. 19. — Scent apparatus, entire dorsal view. Fig. 20. — Scent reservoir, showing accessory gland, ventral view. Fig. 21. — Scent apparatus, showing valvular apparatus, enlarged, dorsal view.

Tribe CARPOCORINI

(Figs. 22-27)

Previous description : BRINDLEY (1930).

Species examined : *Dolycoris indicus* STÅL and *Croantha ornatula* HERRICH-SCHAEFFER).

Scent glands leaf-like, placed dorsad covering the lateral margins of the reservoir, elongated and reaching slightly beyond the reservoir; duct of the glands short but clearly visible; reservoir of orange colour and almost of heart shape with convex posterior margin reaching distinctly

beyond the metathoracic coxal cavities on to the third abdominal segment; accessory gland on the ventral surface of the reservoir irregular, multilooped (8 to 9 loops) valvular apparatus simple lunate to with dentate inner arms; vestibules uniformly narrow short only slightly curved to comparatively elongated and markedly convexly curved, with very small ovoid ostiole.

Scent apparatus of the above two species of the present tribe Carporini is very similar and shares most of the above characters. In *Croantha ornata* the reservoir is more wide in the middle as compared to that of *Dolycoris indicus*. The valvular apparatus is with smooth lunate inner arms in *Croantha ornata* whereas it is with dentate inner arms in *Dolycoris indicus*. Vestibules are arched in *Croantha ornata* whereas these are more or less straight in *Dolycoris indicus*.

BRINDLEY 1930 has studied the scent apparatus of *Palomena prasina* and has reported the collecting ducts of the scent glands to be not well

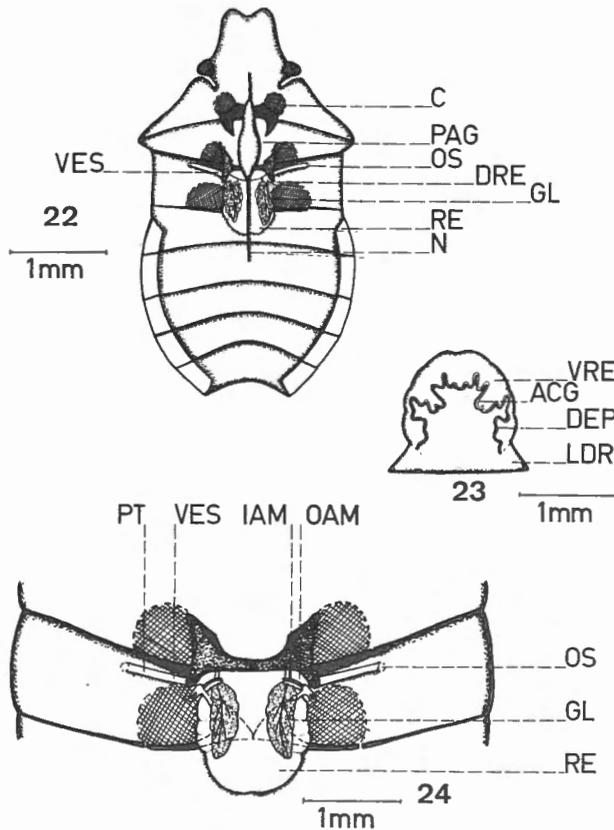


Fig. 22 to 24 : *Dolycoris indicus* (Stål).

Fig. 22. — Scent apparatus entire, dorsal view. Fig. 23. — Scent reservoir, showing accessory gland, ventral view. Fig. 24. — Scent apparatus, showing valvular apparatus, enlarged, dorsal view.

marked and has described the reservoir as subrectangular and the accessory gland with five loops.

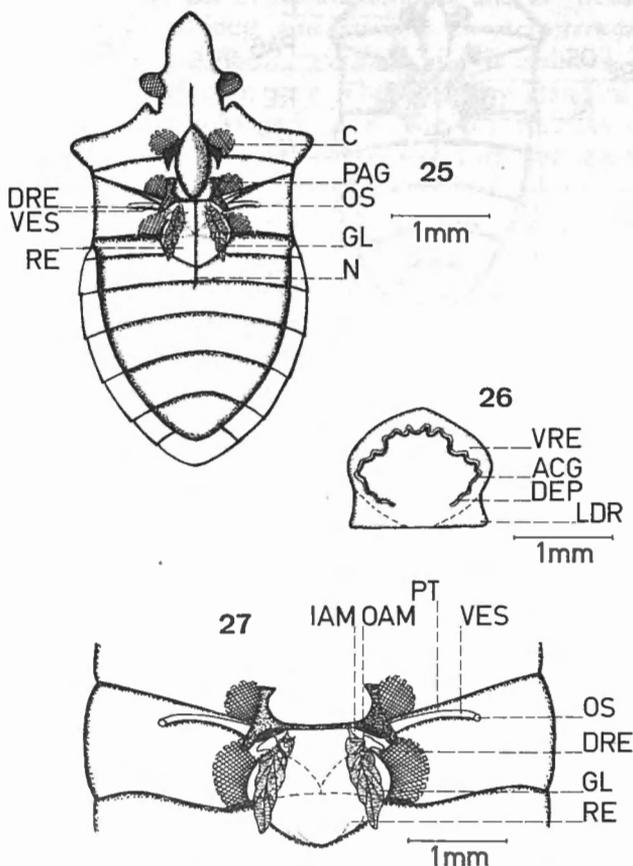


Fig. 25 to 27 : *Croantha ornatula* (HERRICH-SCHAEFFER).

Fig. 25. — Scent apparatus entire, dorsal view. Fig. 26. — Scent reservoir, showing accessory gland, ventral view. Fig. 27. — Scent apparatus showing valvular apparatus, enlarged, dorsal view.

Tribe PENTATOMINI (Figs. 28-36)

Previous descriptions : MALOUF (1933) and GILBY and WATERHOUSE (1967).

Species examined : *Nezara viridula* LINNÉ var. *smaragdula* (FABRICIUS); *Acrosternum graminea* (FABRICIUS) and *Piezodorus rubsofasciatus* (FABRICIUS).

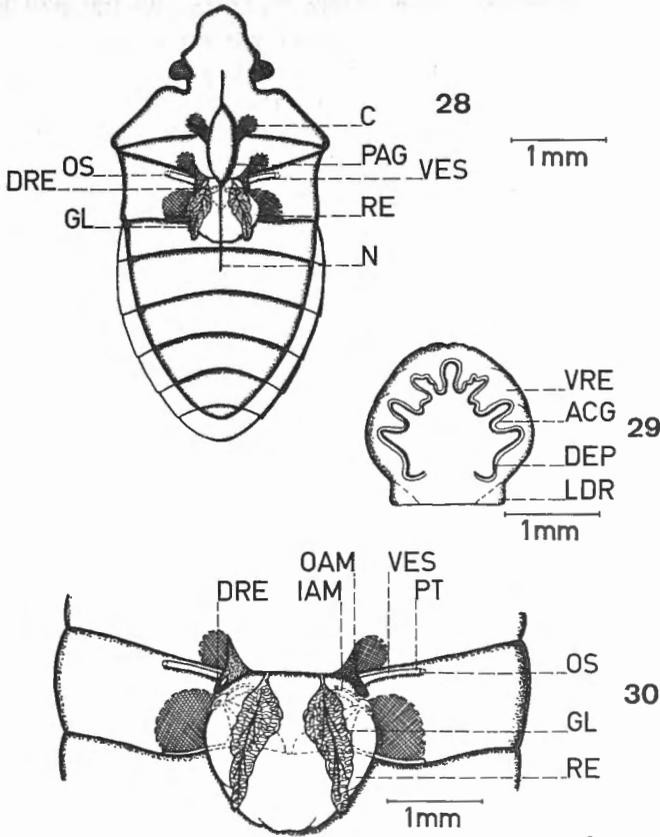


Fig. 28 to 30 : *Nezara viridula* LINNÉ var. *smaragdula* FABRICIUS.

Fig. 28. — Scent apparatus entire, dorsal view. Fig. 29. — Scent reservoir, showing accessory gland, ventral view. Fig. 30. — Scent apparatus, showing valvular apparatus, enlarged, dorsal view.

Scent glands almost leaf-like, of irregular appearance placed dorsad but close to the lateral margins and extending on to beyond the posterior margin of the reservoir or reaching to only anterior half of it; duct of the gland short but distinct, opening into on the ventral side; reservoir yellowish, sac-like with convex posterior margin reaching well beyond the metathoracic coxal cavities on to the third abdominal sternum; accessory gland on the ventral surface of reservoir, usually with two to many (six or seven) loops; valvular apparatus with inner arms usually curved or dentate. Vestibules uniformly narrow almost transverse to slightly convexly curved with very small ovoid ostioles.

In all the 3 species of the present tribe examined the scent apparatus appears very similar. In *Piezodorus rubrofasciatus* the posterior margin

of the reservoir appears convex whereas in *Nezara viridula* and *Acrosternum graminea* the posterior margin is slightly concave in the middle and the valvular apparatus is more or less lunate in *Piezodorus rubrofasciatus* but its inner arm is dentate in *Nezara viridula* and in *Acrosternum graminea*. The vestibule is long and straight in *Acrosternum graminea* whereas it is reduced in *Nezara viridula* and is reduced and slightly curved in *Piezodorus rubrofasciatus*. The accessory gland of *N. viridula* and *A. graminea* are multilooped (6 to 7 loops) whereas in *P. rubrofasciatus* it is a very simple two looped structure but the scent glands reach only on to anterior half of the reservoir in *P. rubrofasciatus* and in *A. graminea* but reach well beyond the posterior margin of the reservoir in *N. viridula*. MALOUF (1933) has not shown the lateral scent glands, the lateral ducts of the reservoir, the accessory gland and the valvular apparatus in (*Nezara viridula*) the species under his examination but GILBY and WATERHOUSE (1967) have illustrated the scent gland complex

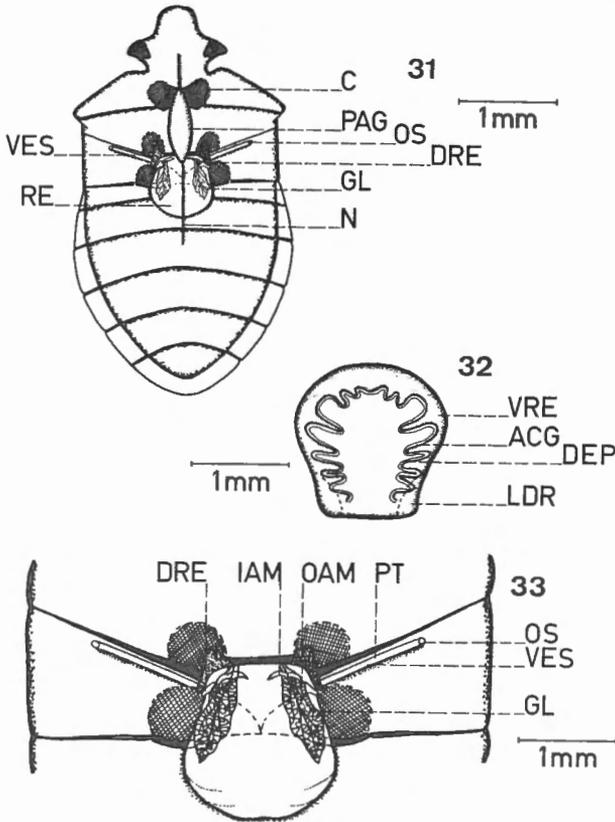


Fig. 31 to 33 : *Acrosternum graminea* (FABRICIUS).

Fig. 31. — Scent apparatus entire, dorsal view. Fig. 32. — Scent reservoir, showing accessory gland, ventral view. Fig. 33. — Scent apparatus, showing valvular apparatus, enlarged, dorsal view.

of *Nezara viridula* variety *smaragdula* (FABRICIUS). They have also shown a sac-like convex scent reservoir which they have reported of orange yellow in colour. The lateral colourless glands which they considered synonymous with the accessory gland in their diagram also occupy extreme lateral position.

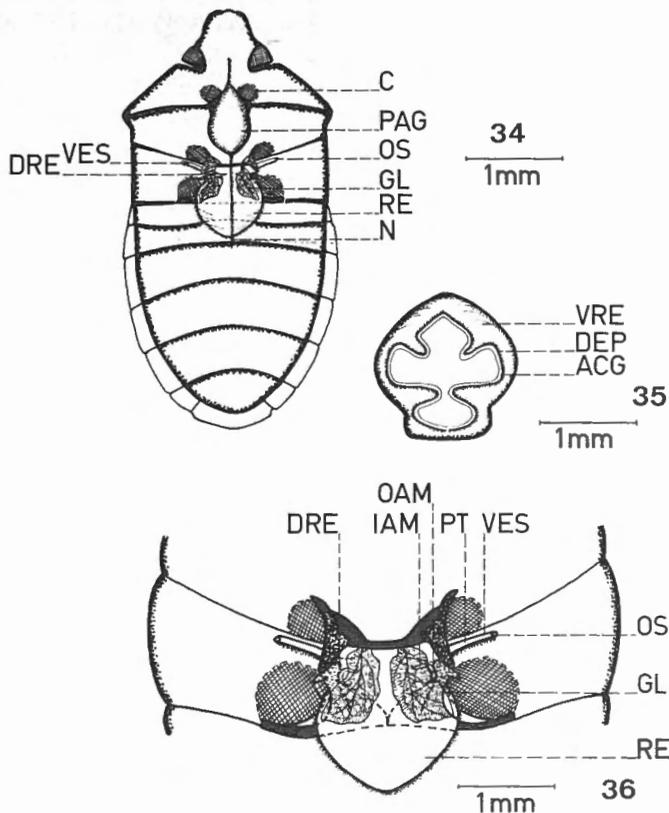


Fig. 34 to 36 : *Piezodorus rubrofasciatus* (FABRICIUS).

Fig. 34. — Scent apparatus entire, dorsal view. Fig. 35. — Scent reservoir, showing accessory gland, ventral view. Fig. 36. — Scent apparatus, showing valvular apparatus, enlarged, dorsal view.

Tribe EYSARCORINI

(Figs. 37-42)

Species examined : *Eysarcoris inconspicuus* (HERRICH-SCHAEFFER and *E. modestus* (DISTANT).

Scent glands leaf-like placed dorsad, away from the lateral margins and extending on to anterior half of the reservoir; duct of the glands distinct, comparatively long and opening into, on the ventral side of the reservoir;

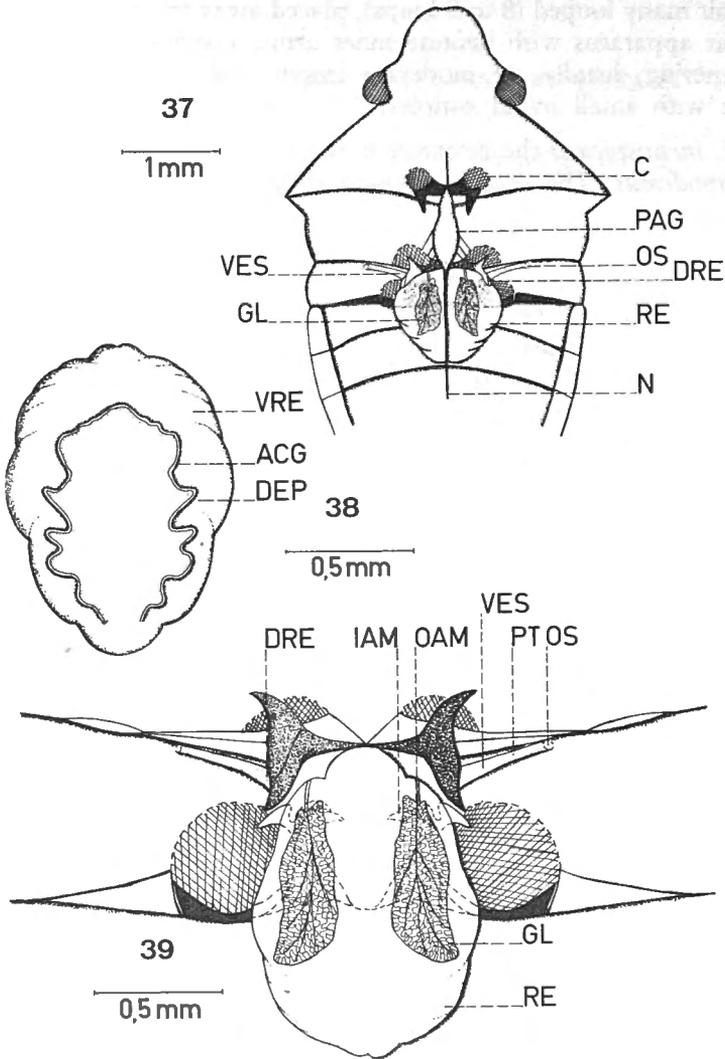


Fig. 37 to 39 : *Eysarcoris inconspicuus* (HERRICH-SCHAEFFER).

Fig. 37. — Scent apparatus entire, dorsal view. Fig. 38. — Scent reservoir, showing accessory gland, ventral view. Fig. 39. — Scent apparatus, showing valvular apparatus, enlarged, dorsal view.

reservoir of variable size and colour, greatly expanded, almost heart shaped distinctly wider in the middle and with convex posterior margin extending far beyond the metathoracic coxal cavities on to the second abdominal sternum; accessory gland on the ventral surface of the reservoir many looped (8 to 9 loops), placed away from the lateral margins valvular apparatus with dentate inner arms; vestibules wider proximally but tapering distally, of moderate length, only slightly curved in the middle with small ovoid ostioles.

In *E. inconspicuus* the reservoir is remarkably expanded in comparison to *E. modestus*. The accessory gland shows five to ten convolutions in

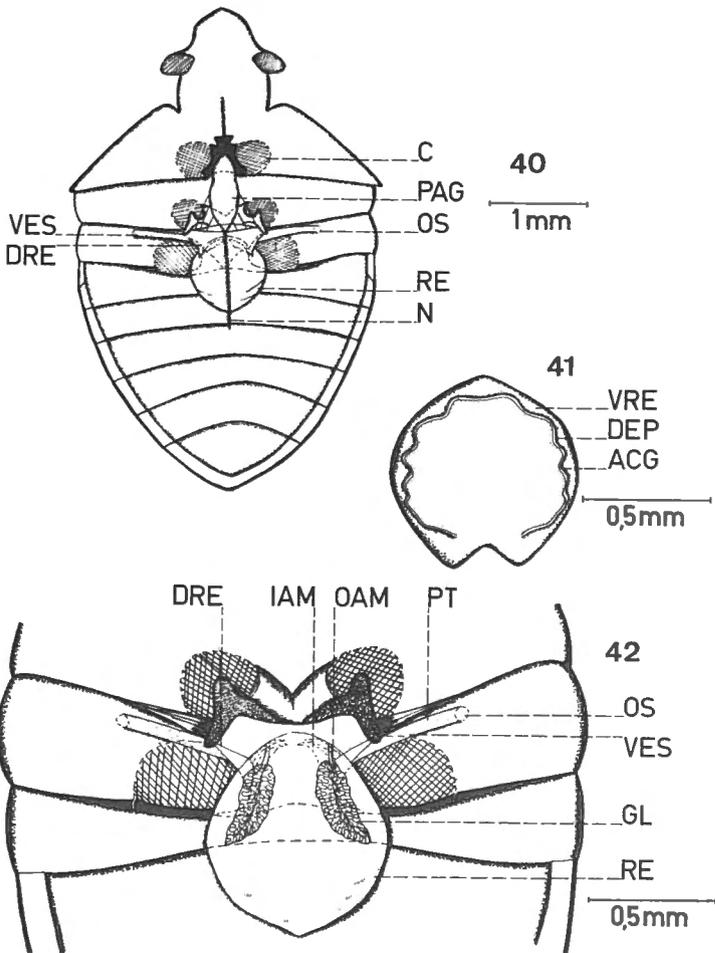


Fig. 40 to 42: *Eysarcoris modestus* (DISTANT).

Fig. 40. — Scent apparatus entire, dorsal view. Fig. 41. — Scent reservoir, showing accessory gland, ventral view. Fig. 42. — Scent apparatus, showing valvular apparatus, enlarged, dorsal view.

E. modestus whereas eight to nine convolutions in *E. inconspicuus*. The vestibules are more elongated and less tapering in *E. modestus* in comparison to markedly tapering and comparatively short vestibles in *E. inconspicuus*.

PART II. — MORPHOLOGY OF ALIMENTARY ORGANS

General aspects of the morphology of the alimentary organs

Alimentary organs.

The alimentary organs include an alimentary canal and a pair of salivary glands opening through long principal salivary ducts independently into the salivary pump. The alimentary canal can be seen apparently divided into a tubular oesophagus a capacious, sac-like midgut₁, a tubular, midgut₂, a sac-like midgut₃, and usually a long tubular midgut₄ provided usually with four rows of gastric caeca, opening into a bulbous pylorus, the anterior part of which is embedded into the terminal portion of the midgut₁. Two pairs of thin coiled and convoluted malpighian tubules seem to arise from either side of the pylorus. This region is continuous and appears like anterior prolongation of a bladder-like posteriorly located rectum.

Oesophagus.

It is usually a thin and elongated tube extending on to the mesothorax. It is of whitish colour and at its junction with midgut₁ usually terminates into a bulbous region, in the lumen of which probably is located the oesophageal valve. Anteriorly it is continued into a poorly developed pharyngeal region.

Midgut₁.

It is always a capacious sac-like structure with usually many anterior and posterior folds. Usually it tapers posteriorly and opens into a tubular midgut₂. Dorsomedially it has a depression in which runs the dorsal heart while in its posterior region is embedded the posterior portion of the mid intestine (the pylorus).

Midgut₂.

It is usually represented by a tubular portion with anterior and posterior constrictions. Sometimes it is greatly expanded in the middle and shows also a median constriction. This opens into a sac-like portion of midgut.

Midgut₃.

This is usually a sac-like or a kidney shaped region, terminating usually posteriad into a small usually rounded portion before entering into the tubular last portion of the midgut.

Midgut₄.

This is usually an elongated tube-like portion, wider than midgut₂ and usually provided with four rows of gastric caeca. This region is without constriction and usually only slightly tapering before entering into the posterior region of the mid intestine the « pylorus ».

Pylorus.

It appears like the anterior prolongation of the posteriorly located bladder-like sacular rectum. It is embedded into the dorso-posterior region of the capacious midgut₁. From its either side arise two pairs of extremely convoluted, coiled and very much elongated malpighian tubules which are remarkably consistent through out the superfamily.

Rectum.

It is the hind most portion of the alimentary canal and usually is bladder-like, tapering at both ends. It terminates posteriorly into a small tubular region, opening to the exterior through the anus.

Salivary glands.

Each gland consists of a principal gland, a principal salivary duct, an accessory gland and an accessory salivary duct. The principal gland is usually distinctly divided into anterior and posterior lobes which may be further subdivided into small lobules. At the junction of the anterior and the posterior lobes arises the principal salivary duct, originating from a ring-like structure in which also opens the accessory salivary duct. The accessory salivary duct immediately after meeting the principal salivary duct coils round and usually shows numerous convolutions and abruptly turns round anteriorly going all the way to the posterior region of the head from where again it turns round posteriad and finally terminates into a slightly wider-diverticula-like accessory gland.

COMPARATIVE MORPHOLOGY OF ALIMENTARY ORGANS

Family PENTATOMIDAE

(Subfamily PENTATOMINAE)

Tribe ASOPINI

(Figs. 43-44)

Previous descriptions : NUORTEVA (1956) (only salivary glands), MIYAMOTO (1961); KUMAR (1962) (only salivary glands).

Species examined : *Andrallus spinidens* (FABRICIUS).

Oesophagus extremely elongated about the same size of the midgut₁ with terminal bulbous portion prominent; midgut₁ elongated, apparently bilobed with a small anterior and a very large posterior lobe and with anterior and posterior folds; midgut₂ tube-like with a distinct constriction anteriorly and in the middle, terminal portion of this region extremely thin; midgut₃ elongated sac-like, with tapering anterior and posterior ends; midgut₄ represented by a very small uniformly thin tube, devoid of gastric caeca; pylorus round, rather small bulbous and appearing like anterior lobe of posteriorly located somewhat slightly expanded rectum.

MIYAMOTO (1961) has illustrated the alimentary organs of *Arma custos* of the four species he has studied for this tribe. This species seems to be sharing most of the above features. However it differs from the present species *Andrallus spinidens* in having a very short oesophagus which is only about one fourth of midgut₁. Probably the entire oesophagus has not been shown in Miyamoto's diagram of *Arma custos*. The constriction which has been noted in the midgut₂, in the present species seems to be absent in *Arma custos*. Midgut₄ is extremely short in MIYAMOTO' diagram and is also devoid of gastric caeca as in other three asopine species examined by him similar to the present species. Rectum is more enlarged and bulbous in Miyamoto's diagram.

Salivary glands.

The principal salivary gland bilobed with the posterior lobe distinctly constricted in the middle. The 2 portions representing 2 sac-like structures with the posterior sac having many folds, anterior lobe short vertically bilobed.

In the MIYAMOTO diagram of *Arma custos*, the posterior lobe of the principal salivary gland is somewhat bilobed with anterior bulbous and posterior sac-like structure, but the middle constriction in the two appears

to be absent. The anterior lobe of the principal salivary gland is small as in the present species and is vertically bilobed.

NUORTEVA (1956) in a diagram of salivary gland of *Picromerus bidens* has shown a bilobed principal salivary gland with the posterior lobe as in MIYAMOTO's diagram. The posterior lobe in their diagrams also has an anterior expanded and a posterior tubular structure without constriction whereas the anterior lobe is small and seems to be bilobed. KUMAR (1962) also has studied *Andrallus spinidens*, and has reported bilobed salivary glands and according to him none of these lobes is further

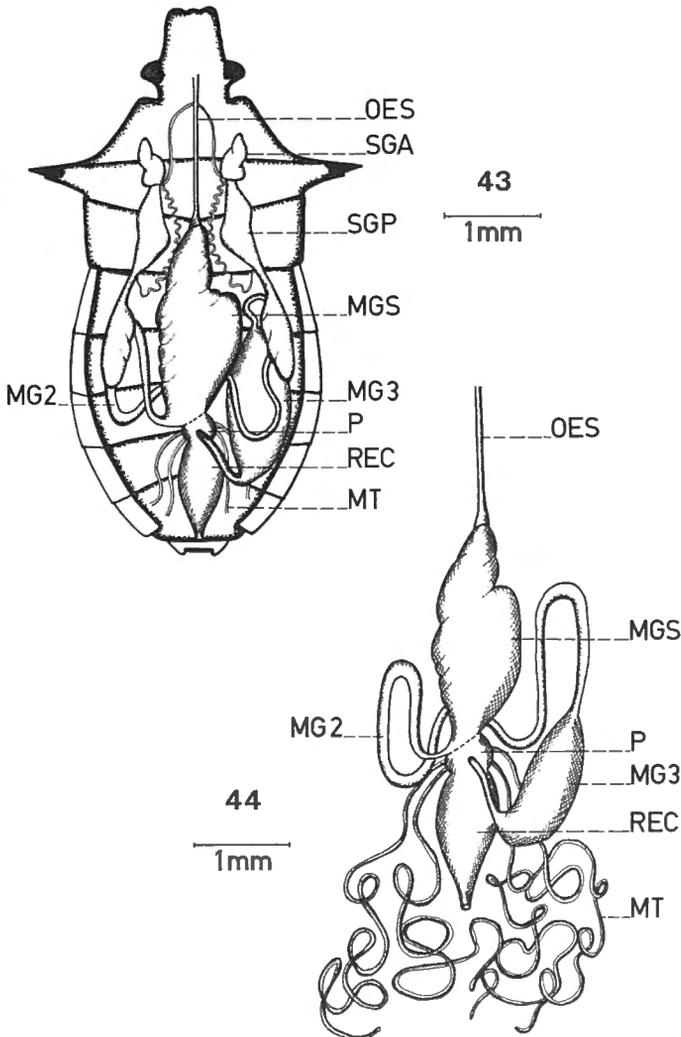


Fig. 43 to 44 : *Andrallus spinidens* (FABRICIUS).

Fig. 43. — Alimentary organs entire, dorsal view (in position). Fig. 44. — Alimentary organs entire, dorsal view.

subdivided. Unfortunately KUMAR has not drawn the salivary glands of the present species which could have provided an opportunity for comparison.

Tribe PODOPINI

(Figs. 45-46)

Previous descriptions : BUGNION and POPFF (1908 and 1910) (only salivary glands); YANAI (1950) & MIYAMOTO (1961).

Species examined : *Tarisa fraudatrix* (HORVATH).

Oesophagus short, distinctly less than one third of midgut₁ with terminal bulbous portion not well marked; midgut₁ elongated, distinctly tapering anteriorly but posteriorly rounded and not expanded; midgut₂ small and wide, tube-like structure, opening into a sac-like slightly wider midgut₃; midgut₃ only tapering posteriorly; midgut₄ short, diverticula-like, apparently without gastric caeca; pylorus very short and small opening into an elongated rectum and both almost of the same width.

YANAI (1950) has illustrated the alimentary canal of *Scotinophara lurida* in which he has shown a short oesophagus without a well marked terminal bulbous portion, a sac-like midgut₁, a tubular midgut₂, a bulbous midgut₃ and a tubular midgut₄ with four rows of gastric caeca.

MIYAMOTO (1961) has examined the *Scotinophara lurida*, *S. horvathi*, *S. scotti*, *Dybowskyia reticulata* and *Graphosoma rubrolineata* WESTWOOD but he illustrated only the alimentary organs of *Scotinophara lurida*. In his diagram the oesophagus is very short and the terminal bulbous portion is not well marked. The posterior portion of midgut₁ is distinctly more expanded and midgut₂ and midgut₃ are also more or less of the same shape as in the present species, but his midgut₄ although originates as a thin diverticula-like-tube but curves round and expands and four rows of gastric caeca are seen covering this structure which was not observed in *Tarisa fraudatrix* (Pylorus, of MIYAMOTO) and rectum in MIYAMOTO's diagram appear distinctly of different widths.

Salivary glands.

The principal salivary gland bilobed with the posterior lobe before middle-terminating into a finger-like process, anterior lobe distinctly longer and wider than the posterior lobe and tapering anteriorly into a small conical projection.

MIYAMOTO (1961) in addition to the salivary glands of *Scotinophara lurida* has illustrated the salivary glands of *S. horvathi*, *S. scotti*, *Dybowskyia reticulata* and *Graphosoma rubrolineata*. He has described finger-like lobules of the principal salivary glands a characteristic of some of

the *Podopini*. In his diagrams of salivary glands of *S. horvathi* and *S. scotti* the anterior conical or finger-like process is well marked as in the present species but the diverticula of the posterior lobe of the principal gland is extremely reduced into a finger-like projection and in the salivary gland diagrams of *Dybowskyia reticulata* and *Graphosoma rubrolineata* the lobules of the posterior lobe of the principal salivary glands are numerous.

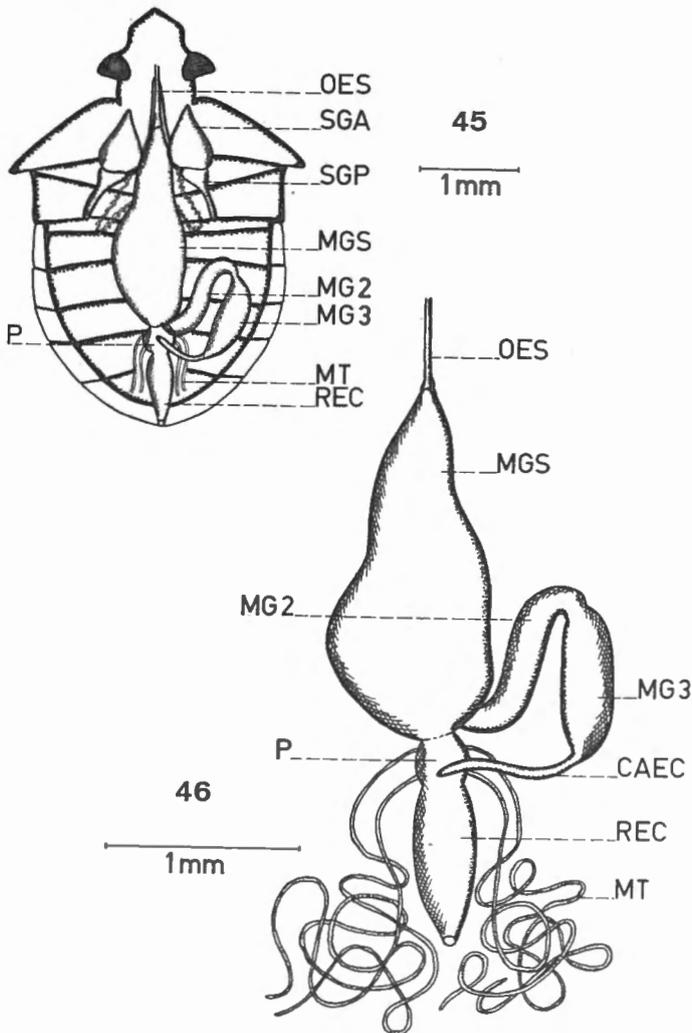


Fig. 45 to 46 : *Tarisa fraudatrix* (HORVÁTH).

Fig. 45. — Alimentary organs entire, dorsal view (in position). Fig. 46. — Alimentary organs entire, dorsal view.

Tribe EURYDEMINI

(Figs. 47-52)

Previous descriptions : SAREL-WHITEFIELD (1929); NUORTEVA (1956) (only salivary glands); MIYAMOTO (1961); KUMAR (1962) (only salivary glands) RAI and TREHAN (1964).

Species examined : *Bagrada hilaris* (BURMEISTER); *Stenozygum speciosum* (DISTANT) & *S. pseudospeciosum* GHOURI.

Oesophagus usually very short, about one third of midgut₁, with bulbous terminal portion prominent; midgut₁ elongated only tapering posteriorly, usually with only anterior folds and usually posteriorly more enlarged; midgut₂ simple, tube-like with uniform width and with anterior and posterior constrictions, midgut₃ small to large, sac-like or kidney shaped; midgut₄ very small to very large with four rows of extremely developed gastric caeca to a region, completely devoid of gastric caeca, pylorus small to large, rounded and appearing like anterior portion of the posteriorly located sac-like rectum.

The three species studied for the present tribe show extreme variation as far as the shapes of midgut₂, ₃ and ₄ concerned. The midgut₂ in the two species of the genus *Stenozygum* is remarkably elongated and the posterior constriction is not well marked whereas in *Bagrada* this region is relatively short and is distinctly with anterior and posterior constrictions. Midgut₃ is almost bulbous in the two species of *Stenozygum* whereas this region is remarkably expanded and appear kidney-shaped in *Bagrada*. Midgut₄ is very much developed and is remarkably thicker with four almost tubular rows of gastric caeca whereas this portion of midgut is extremely reduced and appears like a diverticula without gastric caeca.

MIYAMOTO has studied *Agonoscelis nubila* and two species of *Eurydema* namely *E. rugosa* and *E. pulchra* WESTWOOD. Unfortunately he has not drawn the alimentary organs of any of these. However in *Agonoscelis* MIYAMOTO has noted relatively short midgut₄, and probably as he has mentioned the length of this region is variable in various genera.

RAI and TREHAN (1964) also did not observe gastric caeca in their species *B. cruciferarum*.

Salivary glands.

Principal gland distinctly bilobed with posterior lobe divided into an enlarged bulbous anterior portion and a posterior tubular portion, anterior lobe relatively small and appear conical.

SAREL-WHITEFIELD (1929) in the Sudan millet bug *Agonoscelis versicolor* has shown a trilobed salivary gland probably referring to an

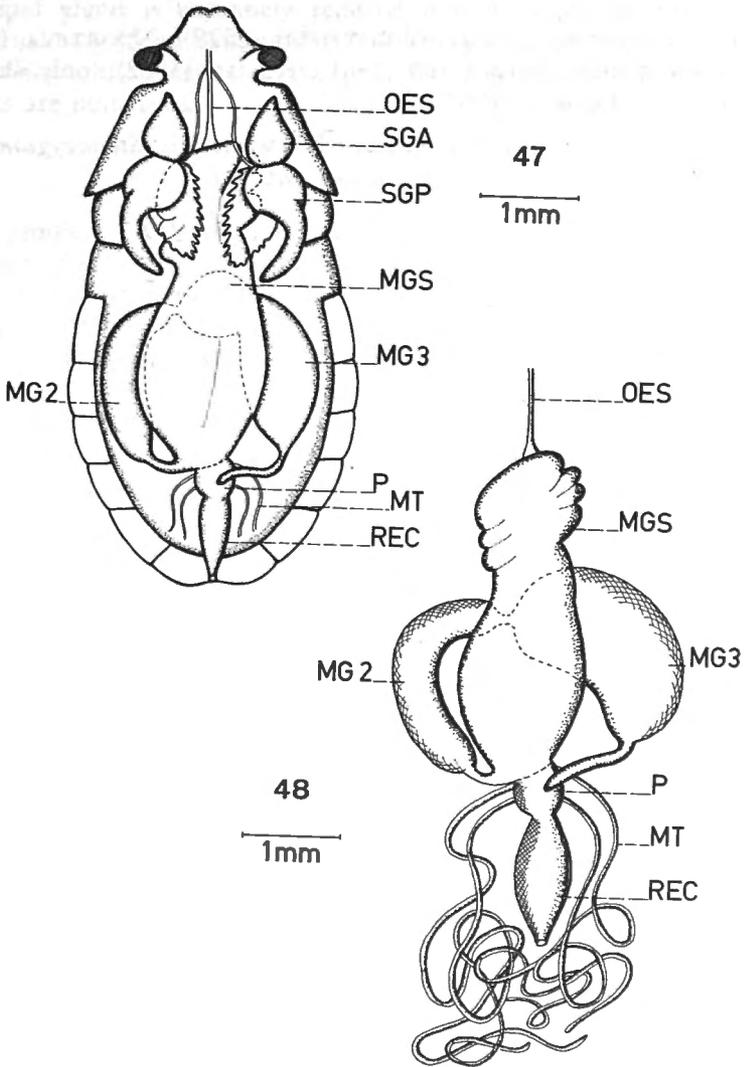


Fig. 47 to 48 : *Bagrada hilaris* (BURMEISTER).

Fig. 47. — Alimentary organs entire, dorsal view (in position); Fig. 48. — Alimentary organs entire, dorsal view.

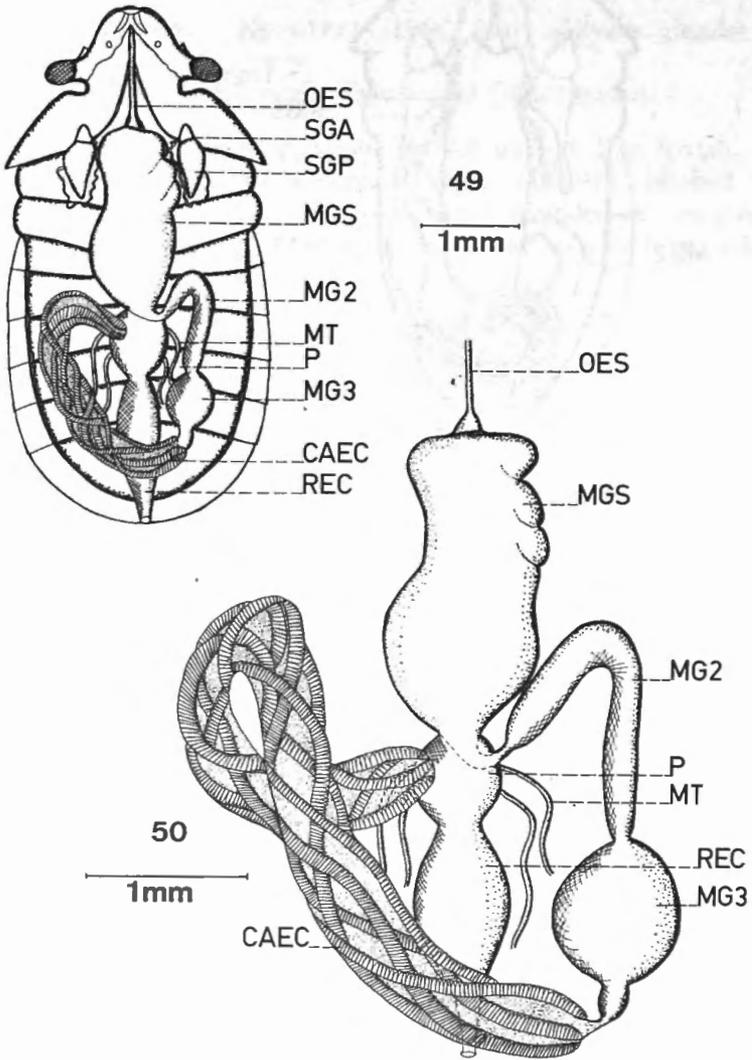


Fig. 49 to 50 : *Stenozygum speciosum* (DISTANT).

Fig. 49. — Alimentary organs entire, dorsal view (in position). Fig. 50. — Alimentary organs entire, dorsal view.

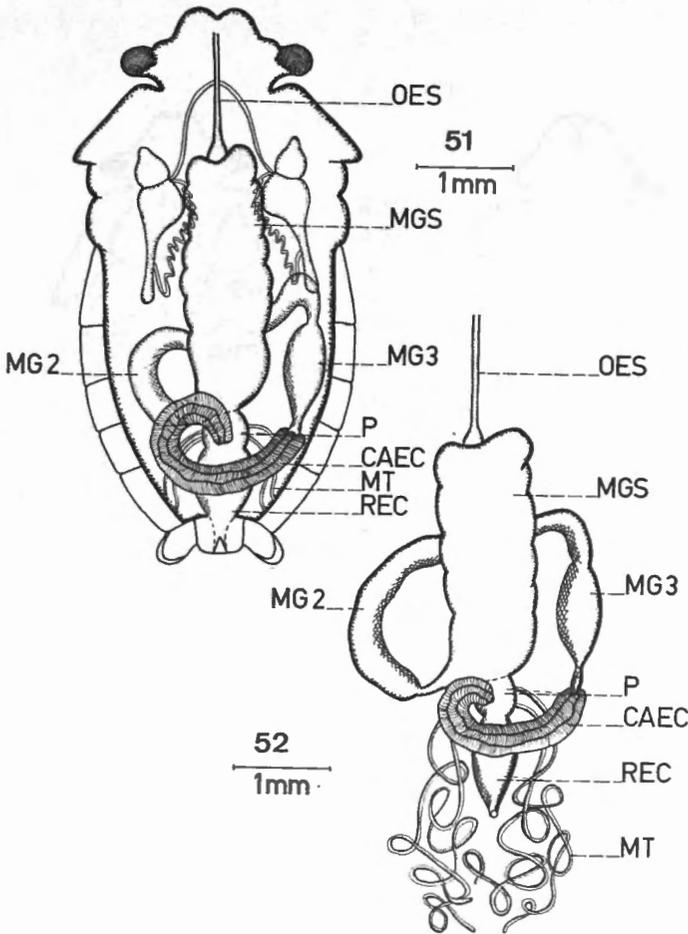


Fig. 51 to 52 : *Stenozygum pseudospeciosum* GHOURI.

Fig. 51. — Alimentary organs entire, dorsal view (in position). Fig. 52. — Alimentary organs entire, dorsal view.

undivided anterior lobe and distinctly bilobed posterior lobe. NUORTEVA in his diagram of *E. oleraceum* has also shown two lobed principal salivary gland with posterior lobe showing anterior bulbous portion and posterior tubular portion. However the anterior lobe he has drawn is lobulated with 3 prominent lobes. KUMAR (1962) has studied the salivary glands of *Agonoscelis nubila* and *Stenozygum speciosum*. Unfortunately KUMAR has not given the diagram of any of the above species which could have provided the opportunity for comparison.

RAI and TREHAN (1964) have also recorded the larger posterior lobe extending into the abdominal cavity.

Tribe AELIINI

(Figs. 53-54)

Previous descriptions : NUORTEVA (1956) (only salivary glands) and MIYAMOTO (1961).

Species examined : *Aeliomorpha lineaticollis* (WESTWOOD).

Oesophagus moderately long, about half of midgut 1 in length, with terminal bulbous portion prominent; midgut₁ distinctly bilobed with posterior lobe relatively greatly expanded and rounded in comparison to somewhat elongated and relatively less expanded anterior lobe; anterior

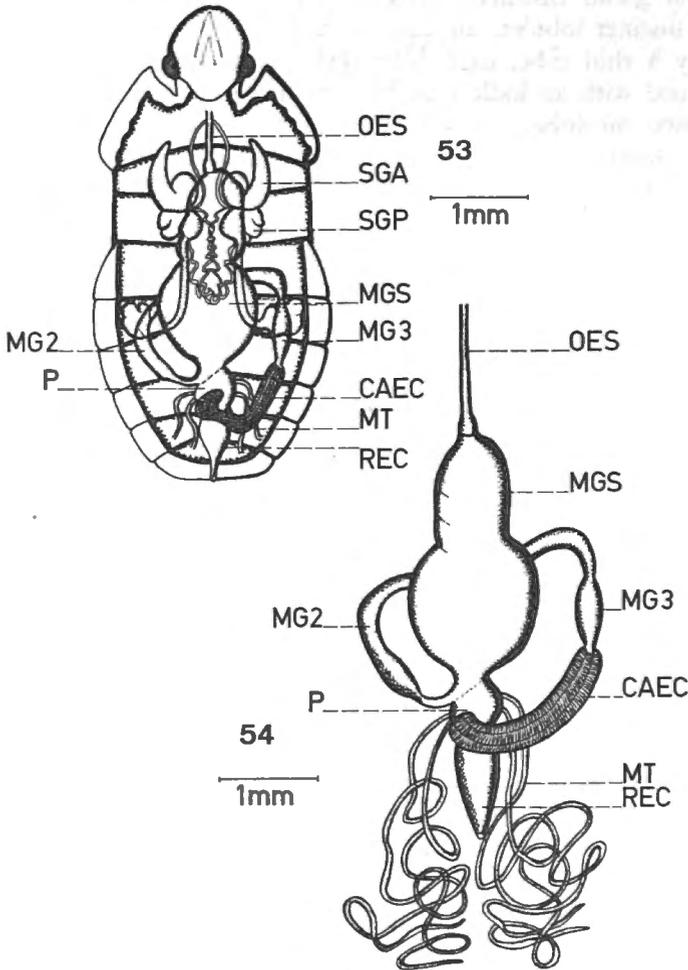


Fig. 53 to 54 : *Aeliomorpha lineaticollis* (WESTWOOD).

Fig. 53. — Alimentary organs entire, dorsal view. Fig. 54. — Alimentary organs entire, dorsal view.

lobe untapering with a few fols, posterior lobe tapering without folds, midgut₂ elongated tube-like, somewhat tapering at both ends, opening into a very short and somewhat rounded midgut₃; midgut₄ relatively wider, elongated, slightly curved, tube-like, distinctly wider than midgut₂; pylorus rounded, slightly curved tapering and appearing like an anterior lobe of posteriorly located elongated, less wide sac-like rectum.

MIYAMOTO (1961) has examined *Aelia fieberi* but unfortunately he has not described or illustrated the alimentary organs of this species, therefore a comparison is not possible.

Salivary glands.

Principal gland distinctly bilobed with a posterior lobe sub-divided into two distinct lobules, an anterior and a posterior bulb-like structure joining by a thin tube, each with several incompletely divided lobules, anterior lobe with an indication of a median longitudinal incision resulting into two sub-lobes, outer very small and rounded, inner curved and smoothly tapering anteriorly into a projection.

NUORTEVA (1956) has illustrated the salivary glands of *Neottiglossa pusilla* of the present tribe and in his diagram also the posterior lobe is sub-divided into an anterior more expanded and a posterior tubular portion but the two are only separated by a small constriction and only the posterior lobe is further sub-divided into small lobules. The anterior lobe in his diagram is also sub-divided into an inner and an outer lobe but the inner is rounded and is with many folds.

Tribe SCIOCORINI

(Figs. 55-56)

Species examined : *Sciocoris lewisi* (DISTANT).

Oesophagus remarkably elongated, only slightly shorter than midgut₁ with terminal bulbous portion prominent; midgut₁ elongated but relatively short, untapering anteriorly with a few anterior folds, posteriorly slightly more expanded and distinctly tapering; midgut₂ elongated distinctly tapering anteriorly and posteriorly without constrictions; midgut₃ elongated, sac-like, with a distinct constriction near the end, posterior portion bulbous; midgut₄ elongated, slightly curved and thick tube-like, almost of the same width as midgut₂; pylorus bulbous relatively short, appearing like an anterior smaller portion of a sac-like elongated, posteriorly located rectum.

Salivary glands.

Principal gland bilobed, with a relatively short posterior lobe, anterior portion of posterior lobe bulbous, smoothly tapering into a posterior

projection, anterior lobe broader at proximal end with an indication of median longitudinal incision, anteriorly projecting into a conical process.

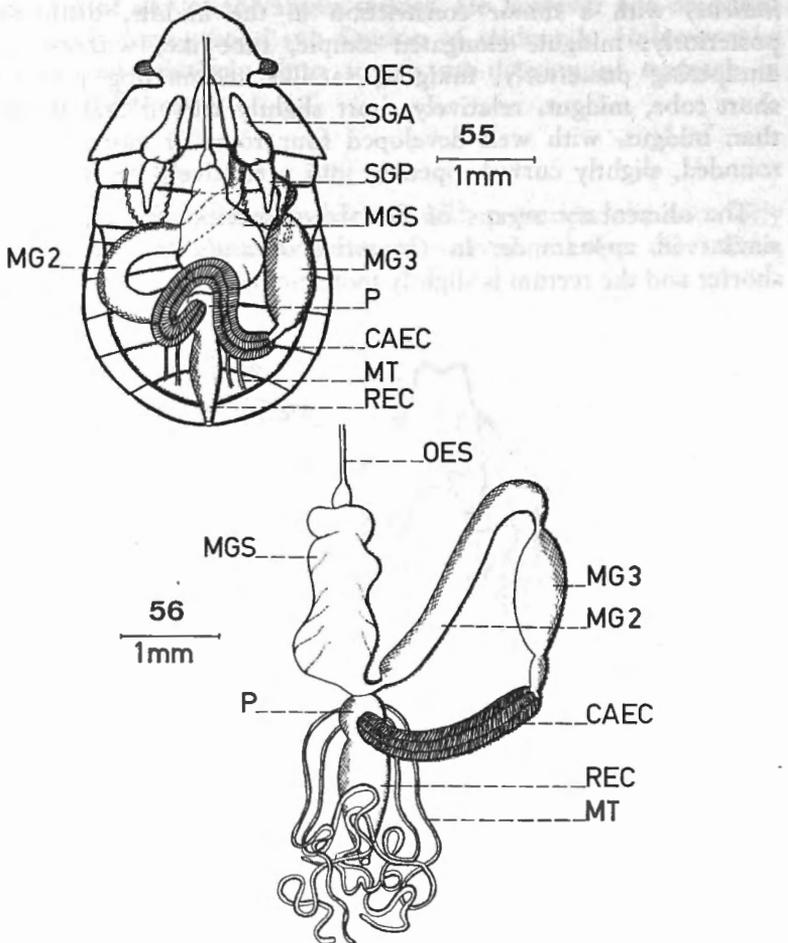


Fig. 55 to 56 : *Sciocoris lewisi* (DISTANT).

Fig. 55. — Alimentary organs entire, dorsal view (in position). Fig. 56. — Alimentary organs entire, dorsal view.

Tribe CARPOCORINI (Figs. 57-60)

Previous descriptions : BUGNION and POPFF (1908) and (1910); NUORTEVA (1956) (only salivary gland) and MIYAMOTO (1961).

Species examined : *Croantha ornatula* (HERRICH-SCHAEFFER) and *Dolycoris indicus* (STÅL).

Oesophagus elongate, comparatively long, distinctly more than half of midgut₁, with terminal bulbous portion prominent; midgut₁ elongated with many anterior folds, untapering anteriorly, sometimes (*Dolycoris indicus*) with a minor constriction in the middle, distinctly tapering posteriorly; midgut₂ elongated simple, tube-like, without constrictions, untapering posteriorly, midgut₃, sac-like terminating posteriad into a short tube, midgut₄ relatively short slightly curved and distinctly wider than midgut₂ with well developed four rows of gastric caeca; pylorus rounded, slightly curved, opening into a relatively short sac-like rectum.

The alimentary organs of the above species of Carpacorini are very similar in appearance. In *Croantha ornatula* the midgut₃ is slightly shorter and the rectum is slightly more elongated than in *Dolycoris indicus*.

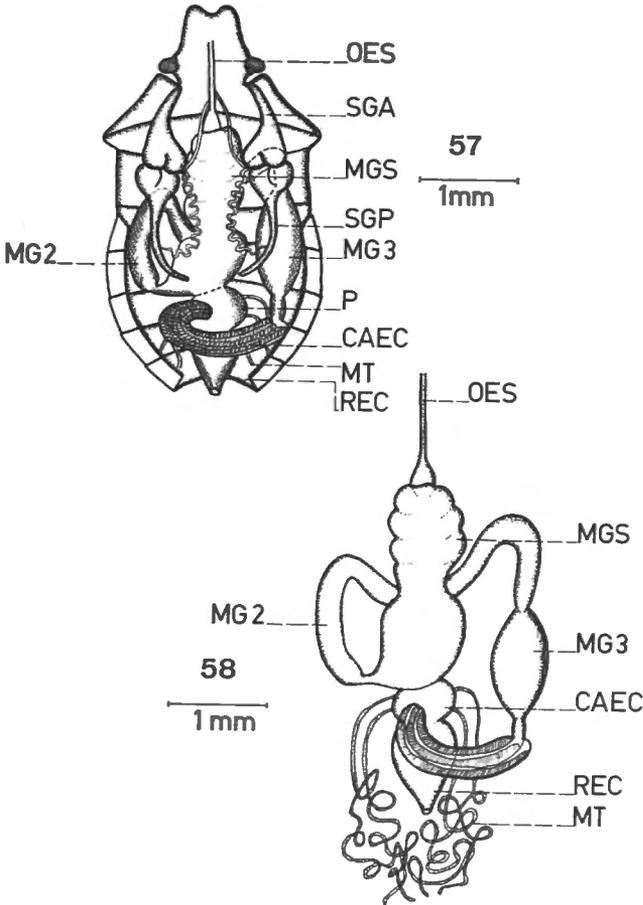


Fig. 57 à 58 : *Dolycoris indicus* (STÅL).

Fig. 57. — Alimentary organs entire, dorsal view (in position). Fig. 58. — Alimentary organs entire, dorsal view.

MIYAMOTO (1961) has examined six species of the present tribe i.e. *Rubiconia intermedia*, *Halyomorpha picus*, *Palomena angulosa*, *Carpocoris purpureipennis* and *Dolycoris baccarum*, but unfortunately he did not give diagram of any of the above species. He however has described an extra ordinarily long second sub-division of midgut in *Halyomorpha* and very thick and relatively short fourth sub-division of stomach in *Halyomorpha* and *Palomena*.

Salivary glands.

Principal salivary gland distinctly bilobed with posterior lobe anteriorly rounded and posteriorly extended into a curved tubular diverticula,

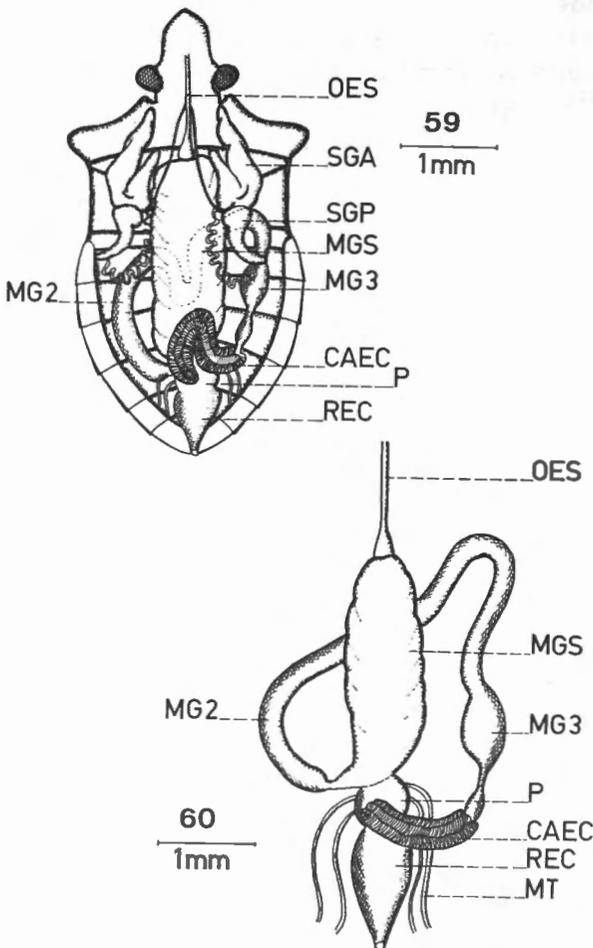


Fig. 59 to 60 : *Croantha ornatula* (HERRICH-SCHAEFFER).

Fig. 59. — Alimentary organs entire, dorsal view (in position). Fig. 60. — Alimentary organs entire, dorsal view.

anterior lobe proximally rounded and anteriorly terminating into a curved and elongated projection.

The salivary glands of *Croantha ornatula* and *Dolycoris indius* slightly differ in that in *Croantha ornatula* the anterior lobe is vertically significantly bilobed whereas in *Dolycoris indicus* although there is an indication of a lateral inner lobe but its projection is entirely wanting. In *Croantha ornatula* the posterior tubular portion of the posterior lobe is slightly wider and relatively shorter in comparison to *Dolycoris indicus*.

NUORTEVA (1956) has illustrated the salivary glands of *Chlorochroa juniperina*. In his diagram also the anterior lobe of principal salivary gland is rounded proximally and distally is projected and curved whereas the posterior lobe is extended posteriorly into a tube-like structure which has many folds.

Although MIYAMOTO (1961) has not drawn the salivary gland of any species he studied of the present tribe *Carpocorini* but he has also noted a longitudinal incision in the anterior lobe near the middle.

Tribe PENTATOMINI

(Figs. 61-66)

Previous descriptions : BUGNION and POPFF (1908; 1910) (only salivary glands); ANCONA (1932); MALOUF (1933); HAMNER (1936); HARRIS (1938) and MIYAMOTO (1961).

Species examined : *Nezara viridula* LONNÉ (var.) *smaragdula*; *Piezodorus rubrofasciatus* (DALLAS) and *Acrosternum graminea* (FABRICIUS).

Oesophagus short, slightly less than head of midgut₁ with bulbous terminal portion prominent; midgut₁ elongated with several folds (mostly on anterior region), distinctly bilobed; midgut₂ usually tubular sometimes with marked sac-like expansion in the anterior region, size variable; midgut₃ small spindle-like; midgut₄ elongated expanded, a curved, tube-like structure distinctly wider than midgut₂ and with distinct four rows of gastric caeca; pylorus round, appearing anterior lobe of expanded posteriorly located small to large bladder-like rectum.

Variations appear in the shapes of second and third midgut regions. In *Acrosternum graminea* midgut₂ is a simple tube without constrictions and without sac-like expansion in the anterior region. Whereas in *Nezara viridula* (var. *smaragdula*) an anterior sac-like structure is present which is larger than midgut₃. In *Piezodorus rubrofasciatus* the tube emerging from midgut₁, is extremely narrowed (anterior of midgut₂) and then expands into a tube of uniform width until it opens in the midgut₃. In *Acrosternum graminea* the rectum is smaller and comparatively compressed anteroposteriorly. Whereas in *Nezara viridula* (var. *smaragdula*) it is intermediate in condition and is extremely expanded and is bladder-like in *Piezodorus rubrofasciatus*.

ANCONA (1932) while describing the alimentary organs of *Alizires tax-coensis* divided the midgut₁ region into three parts « the proventriculo », the « intestino medio » and the « estomago » and the midgut₂, « the intestino posterior ».

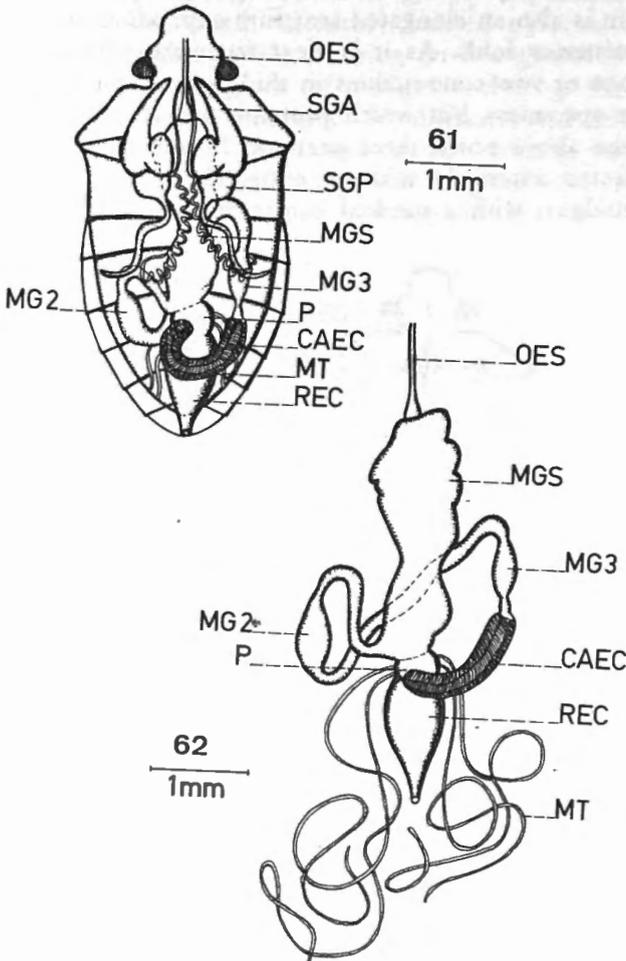


Fig. 61 to 62 : *Nezara viridula* LINNÉ var. *smaragdula* (FABRICIUS).

Fig. 61. — Alimentary organs entire, dorsal view (in position). Fig. 62. — Alimentary organs entire, dorsal view.

MALOUF (1933) in *Nezara viridula* has called the first midgut region, the crop (part of foregut) on the basis of similar histological structures that according to him, he found in oesophagus and this region, allotting the posterior portion of midgut₃ a definite number (midgut₃). MALOUF divided the midgut region into four parts (first, second, third and fourth

stomach). HAMNER (1936) working on *Solubea pugnax* has commented that ANCONA probably misinterpreted this structure and that it varies in shape apparently due to the food content. He had drawn a very much elongated oesophagus with a prominent rounded terminal bulbous portion and which is distinctly more than half length of midgut₁ and the latter in his diagram is also an elongated structure expanding anterioposteriorly with a few anterior folds. As it is clear from the present studies there are usually one or two constrictions in this region which although somewhat vary in specimens but which probably led ANCONA to divide this region into the above noted three parts. In HAMNER's diagram the midgut₂ is connected anteriorly with an extremely narrow tube and posteriorly with midgut₃ with a marked constriction, similar to the structure

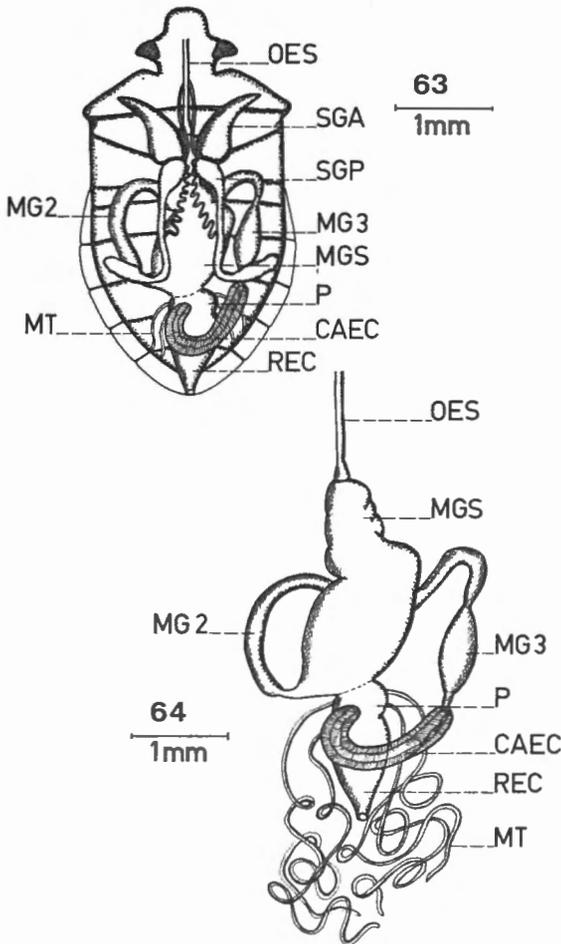


Fig. 63 to 64 : *Acrosternum graminea* (FABRICIUS).

Fig. 63. — Alimentary organs entire, dorsal view (in position). Fig. 64. — Alimentary organs entire, dorsal view.

in *Piezodorus rubrofasciatus*. Midgut₃ in his diagram is anteriorly sac-like, expanded, and has a constriction posteriorly dividing this region into a very large bladder-like anterior portion and a very small ovoid posterior portion, similar to the structure in *Nezara viridula*.

In HAMNER's diagram the rectum is greatly expanded, bladder-like in comparison to very small, anteriorly located pylorus, similar to in *P. rubrofasciatus*. HARRIS (1938) working on *Murgantia histrionica* distinguished four distinct regions of midgut including the «crop» of MALOUF (1933) and called it midgut₁. He differentiated this region from oesophagus histologically for he found circular muscles surrounding the longitudinal muscles in this region whereas longitudinal muscles external in position in his midgut₁, (crop) of MALOUF (1933).

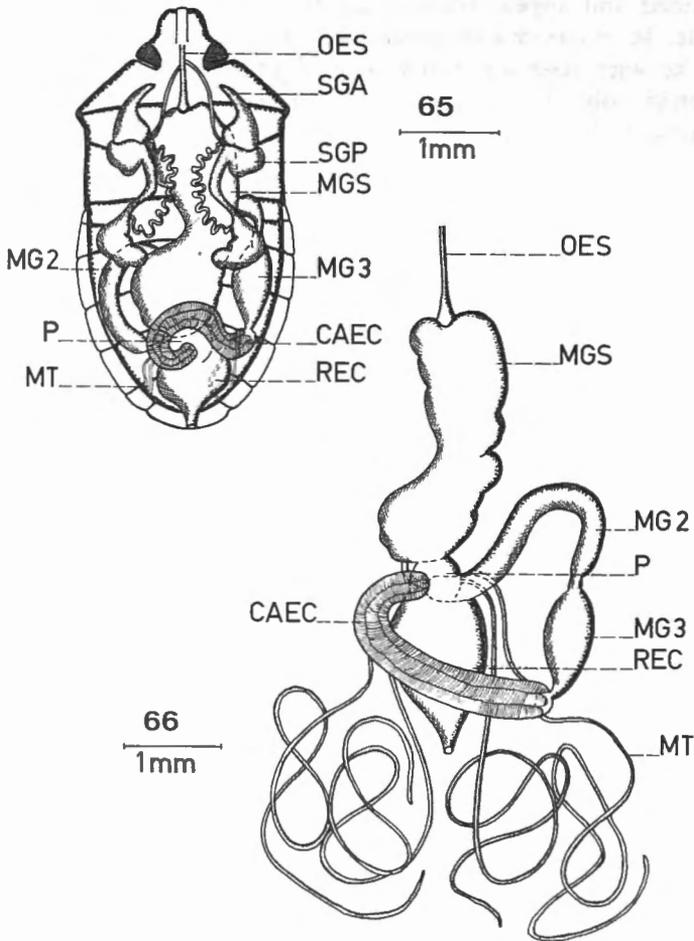


Fig. 65 to 66 : *Piezodorus rubrofasciatus* (FABRICIUS).

Fig. 65. — Alimentary organs entire, dorsal view (in position). Fig. 66. — Alimentary organs entire, dorsal view.

MIYAMOTO (1961) has not drawn the alimentary organs of the two species *N. antennata* and *Piezodorus rubrofasciatus* that he examined.

Salivary glands.

Principal salivary glands bilobed but the posterior lobe extremely elongated reaching on to middle of third abdominal sternum with usually the posterior lobe expanding posteriad into a thickened portion. The anterior lobe curved and tapering anteriorly.

The salivary glands also show a little variation in the terminal portion of the posterior lobe of the principal salivary glands. In *N. viridula* & *A. graminea* these are simple only slightly expanded (*A. graminea*) but in *P. rubrofasciatus* the posterior lobe of the principal salivary glands are expanded and appear bulbous in shape with a slight constriction in the middle. In HAMNER's diagram of *Solubea pugnax*, the anterior lobe is hand-like with four anteriorly located finger-like projections whereas his posterior lobe is elongated tube-like without terminal expanded portion almost similar to in *N. viridula*.

Tribe EYSARCORINI

(Figs. 67-70)

Previous descriptions : SOUTHWOOD (1955) (only salivary glands); MIYAMOTO (1961); KUMAR (1962) (only salivary glands).

Species examined : *Eysarcoris inconspicuus* (HERRICH-SCHAEFFER); *E. modestus* (DISTANT).

Oesophagus relatively short to elongated, slightly more than one third to distinctly more than half of midgut₁ with terminal bulbous portion prominent; midgut₁ relatively short to elongated untapering anteriorly and only slightly tapering posteriorly with many folds; midgut₂ relatively long, like a wide tube usually very slightly tapering anteriorly and posteriorly without constrictions; midgut₃ elongated sac-like, distinctly bilobed into an anterior much elongated and a small posterior rounded portion; midgut₄ elongated wide, distinctly wider than midgut₂, tube-like, with four rows of well developed gastric caeca; pylorus rounded appearing like a rounded bulb and an anterior lobe of posteriorly located elongated sac-like rectum.

In the two species of the presently studied genus *Eysarcoris* the midgut₁ seems to be varying considerably in length although in both the species oesophagus is of about the same length (slightly shorter in *E. inconspicuus*) but because the midgut₁ is also remarkably elongated in the same species (*E. inconspicuus*), in that species oesophagus seems to be remarkably short. Also the long size of the midgut₁, might be attributed to the significantly larger and longer size of *E. inconspicuus* in comparison to *E. modestus*.

Although MIYAMOTO (1961) has examined four species of the present genus i.e. *E. ventralis*, *E. guttiger*, *E. fallax* and *E. parvus* and two species of the genus *Sepontia* and *Carbula* (i.e. *S. aenea* and *C. humerigera*) but he did not give the diagrams of the alimentary organs of any of these species. However he has described relatively a short midgut, region in the species of *Eysarcoris* and *Sepontia*.

Salivary gland.

Principal gland distinctly bilobed with extremely prominent and distinctly curved posterior lobe; anterior portion of posterior lobe somewhat rounded and expanded whereas beyond the curve tube-like, anterior

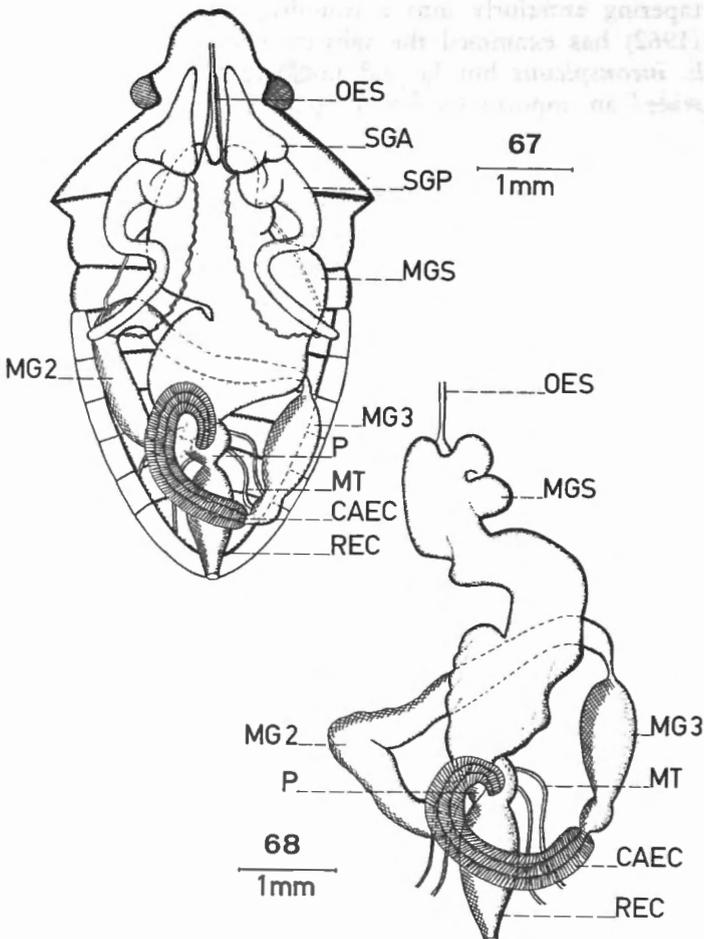


Fig. 67 to 68 : *Eysarcoris inconspicuus* (HERRICH-SCHAEFFER).

Fig. 67. — Alimentary organs entire, dorsal view (in position). Fig. 68. — Alimentary organs entire, dorsal view.

lobe with a broad bulbous proximal end and somewhat conical and projecting terminal process.

In the larger species i.e. *E. inconspicuus* the anterior lobe is with a distinctly elongated terminal projection whereas in *E. modestus* it is short and loge-like. The posterior lobe in *E. inconspicuus* is significantly larger and longer and is relatively with more prominent curve beyond middle. Whereas in *E. modestus* the curve is slight and the terminal tube-like portion is short.

SOUTHWOOD (1955) illustrated the salivary glands of *Stollia fabricii*. His diagram appears similar to those of *E. modestus* except that the anterior lobe is without the conically projected anterior end and the anterior margin in his diagram is smoothly rounded and the anterior lobe appears more or less kidney-shaped with a proximal wider portion, slightly tapering anteriorly into a rounded less wide terminal portion. KUMAR (1962) has examined the salivary glands of one of the present species *E. inconspicuus* but he did not give the diagram which could have provided an opportunity for comparison.

PHYLOGENETIC CONSIDERATIONS BASED ON THE CHARACTERS OF SCENT APPARATUS AND THOSE OF ALIMENTARY ORGANS

Before discussing the phylogeny and relationships of various groups within the superfamily *Pentatomoidea* on the basis of the above characters, probably it would be adequate here to consider whether these characters are consistent and are not entirely effected with the changing habitat and environmental conditions.

With reference to scent apparatus, BRINDLEY (1930) has noted, « the possession of scent glands in bugs is of long standing is suggested by their widespread occurrence in the group ». With reference to salivary glands, SOUTHWOOD (1955) has remarked : « It appeared from a study of these papers that the form of the salivary glands is constant in related species and unlike that of the alimentary canal it did not vary greatly with the feeding habits ». MIYAMOTO (1961) has also agreed with SOUTHWOOD (1955), for the first part of his hypothesis on the basis of his studies on the internal characters and has concluded that the internal anatomy in certain organs being variable even within a group, a family, or sub-family but some structures of the internal organs less variable and as much useful as external organs and one of them according to him might have been the structure of the salivary glands.

As SOUTHWOOD (1955) has noted that the alimentary canal did vary greatly with the feeding habits, some of the early workers (ELSON, 1937) also have held a similar view. CHINA (1955) while discouraging the usage of internal structures for establishing relationships has concluded, « the internal organs are basically no less variable than external structures ». Although ELSON (1937) believed that change of habitat did

modify the structure of alimentary canal he has also held « Plant feeding pentatomids are the most primitive one which gave rise to semi and true predatory pentatomids ». Similarly GOODCHILD (1963b) has also considered *Dalsira bohndorffi* (Pentatomidae : Phyllocephalinae) to be highly evolved on the basis of the structure of the alimentary canal, although he has regarded that change of food habits such as from sap-sucking to feeding on a rather solid or semi solid diet did modify the structure of alimentary canal and in 1966 he has attempted to trace the phylogeny of Hemiptera on the basis of their feeding habits and those of alimentary organs.

PUCHKOV (1956) in the « basic trophic groups of phytophagous hemipterous insects and changes in their characters of feeding during the process of development has remarked » the tendency to change in cha-

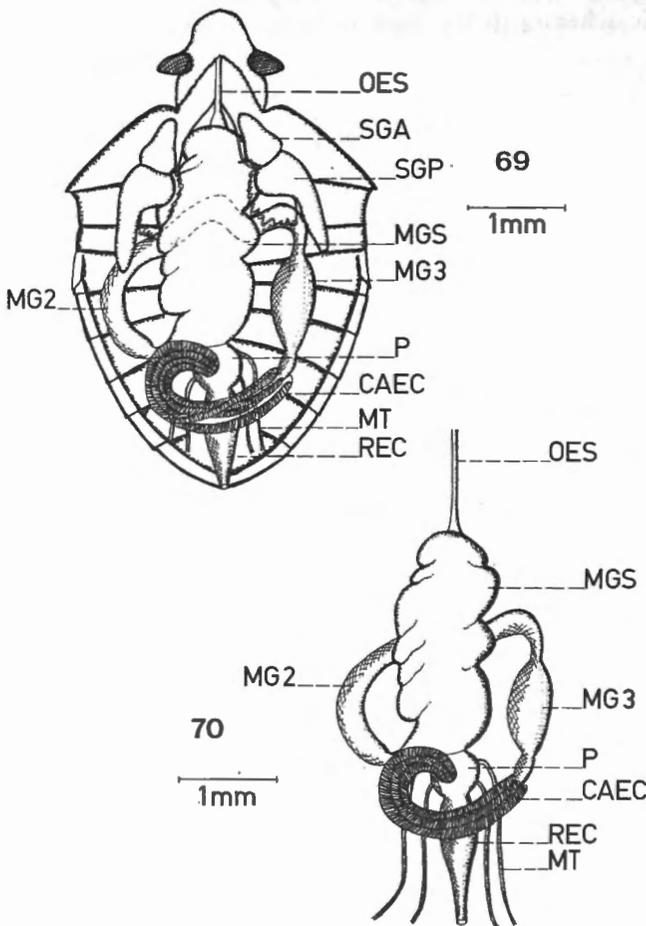


Fig. 69 to 70 : *Eysarcoris modestus* (DISTANT).

Fig. 69. — Alimentary organs entire, dorsal view (in position). Fig. 70. — Alimentary organs entire, dorsal view.

acters of feeding is distinctly strengthened in spp. of the families *Lygaeidae* and *Coreidae* but it is still more strongly expressed in species of the families *Pentatomidae* and *Cydnidae* ». Thus agreeing with MIYAMOTO (1961) it might be inferred that the structure of alimentary organs although has been considered to vary according to the food habits of the bugs, on the one hand but the structure is also dependent on the systematic position of the bug on the other. The present authors also believe that the alimentary organs are one of the most important organs for life and that the changes in habitat and environmental conditions have always offered a challenge to a population which has always been met with by successful mutations leading to the right kind of adaptations. Moreover it is not the purpose of the present studies to introduce a new system of classification only on the basis of these two characters alone rather in the present attempt it is proposed to view already existing phylogenetic schemes in the light of these characters.

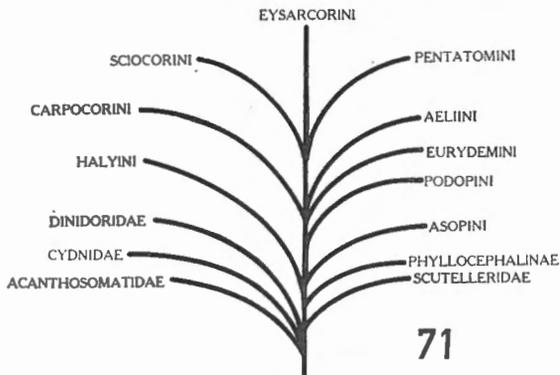


Fig. 71. — Phylogenetic tree showing relationship of various groups within the superfamily *Pentatomoidea*

BRINDLEY (1930) with reference to convoluted many looped accessory gland in the scent apparatus has commented, « the remarkable linear accessory gland which curves round the ventral surface of the organ might have arisen by enlargement and elongation from a primitive type such as that of *Nabis* ». This clearly suggests that simple, un-convoluted accessory gland of some, pentatomids (*Eurydemini*, *Podopini* and *Aso-pini*) should be considered primitive which by enlargement and elongation gave rise to more convoluted accessory gland of rather advanced *Pentatominae*, *Aeliini*, *Sciocorini*, *Carpocorini*, *Pentatomini* and *Eysarcorini* and extremely convoluted accessory gland of *Cydnidae* (ROTH, 1961) and *Dinidoridae* (AHMAD *et. al.* in press).

On the other hand BRINDLEY in the same work (1930) has asserted, « the view taken here is that the modification of the stink glands has

always taken the form of reduction or loss of parts ». In the light of this point of view the highly convoluted accessory gland seems to be a primitive feature which by loss of part gave rise to simple unconvoluted, almost straight accessory gland of the above Pentatomine species which finally entirely disappeared in the rather advanced families *Miridae*, *Tingidae* and *Coreidae*. AHMAD *et al.* (in press) considering that BRINDLEY (1930) in *Anorbus rubiginosus* (*Coreidae*) and GUPTA (1964) in *Leptocoris costalis* (*Alydidae*) have reported large reservoir and the latter has reported broad and comparatively short vestibules, have argued that these characters relate *Dinidoridae* (in at least some features) with comparatively advanced groups like *Coreidae* or it probably reflects convergent evolution.

KUMAR (1962) also noted that the internal male reproductive organs of both *Dinidoridae* and *Acanthosomatidae* showed resemblances to *Pyrhocoridae* and to *Coreidae* but their salivary glands remarkably differed from the latter families and for this KUMAR concluded that the pyrrhocorid resemblances might be a matter of parallel evolution only.

AHMAD *et al.* (in press) have noted extremely convoluted accessory gland similar to *Scaptocoris divergens* (*Cydnidae*) as illustrated by ROTH (1961) in *Coridius janus* (*Dinidoridae*). AHMAD *et al.* elsewhere (in press) have held following KUMAR (1962) that cydnids in the characters of the salivary glands represent the transitory state between *Pentatomidae* at one hand and *Acanthosomatidae*, *Dinidoridae* and *Scutelleridae* on the other.

AHMAD *et al.* (in press) and AHMAD *et al.* (in press) elsewhere considering *Dinidoridae* with some of the primitive features (of those of scent apparatus and alimentary organs) i.e. elongated bean-form scent glands reaching on to posterior of reservoir moderately long oesophagus with prominent terminal bulbous portion, large and expanded midgut₂ region which is wider than midgut₄ region and greatly expanded midgut₃ region together with shorter, less sinuate accessory salivary duct and absence of basal convolution of the accessory gland have regarded an early offshoot (of probably some primitive pentatomoids) which evolved and specialized in many characters i.e. scent glands with distinct collecting ducts, greatly expanded, pear-shaped reservoir reaching on to the third abdominal sternum, extremely convoluted (many looped) accessory gland located extremely laterad, close to the ventral edges of the reservoir, uniformly wide, short and sub-rectangular vestibules with very large ovoid ostioles; bladder-like expanded midgut₂ and midgut₃ and very long and tubular midgut₄ region which is with usually two rows of gastric caeca and occasionally at random with three to four rows of gastric caeca, pleurilobed principal salivary glands and etc.

This conclusion is in agreement with COBBEN (1968), « Eggs of *Asopongopus* (*Dinidoridae*) are placed in chains and this manner of deposition must have already occurred before the pentatomoids had evolved a distinct pseudooperculum and before the backward shift of egg burster

was complete ». Some of the above characters i.e. accessory gland located extremely laterad, close to the ventral edge of the reservoir, uniformly broad, short and sub-rectangular vestibules with very large ovoid ostioles; bladdered-like midgut₁ and midgut₂ regions and very long and tube-like midgut₄ region with two rows of gastric caeca (at places three to four rows) clearly demarcate *Dinidoridae* from other pentatomid subfamilies and this assumption is in agreement with LESTON (1955) and (1958a), PENDERGRAST (1957), SCUDDER (1959), MIYAMOTO (1961), KUMAR (1962), COBBEN (1968), AHMAD *et. al.* (in press) and AHMAD *et. al.* (in press, elsewhere) although CHINA and MILLER (1955) and (1959) and PUCHKOV (1961) have considered this group as a subfamily within *Pentatomidae*.

The phylogenetic considerations below family level are still more difficult when most of the species of any group have not been worked upon. With reference to the characters of the salivary glands, MIYAMOTO (1961) has remarked, « Distinct finger-like lobules of the principal salivary glands seem to be characteristic to the *Scutellerinae* and some of the *Podopinae*, (*Podopini*) but somewhat similar condition is found in *Erthesina* of the *Pentatominae*. Therefore the sub-divisions of the lobes may not be important, to the classification of sub-families ». However AHMAD and KHANUM (1968) have suggested that the number of loops in the accessory gland, colour and shape of the scent reservoir in the freshly killed state, might throw some light on the relationships between various taxons at tribal and above tribal levels.

GOODCHILD's (1963b) diagram of the alimentary organs of *Dalsira bohndorffi* (*Pentatomidae* : *Phyllocephalinae*) shows greatly elongated pylorus, the anterior part of which is embedded within the first region of midgut and a very long and very wide (wider than anterior lobe) posterior lobe of the principal salivary gland isolates it from the species belonging to the subfamily *Pentatominae*. MIYAMOTO (1961) has concluded, « Although this family has been treated as a sub-family of the *Pentatomidae* by most authors, the presence of the filter chamber alone of the *Heteroptera* is very remarkable for this group, other structure than stomach, pylorus, and malpighian tubules is also distinguishable in detail from pentatomid subfamilies, but the rows of gastric caeca on the midgut and the condition of accessory gland near head are most related to the *Pentatomidae* than to other families ». The differences in the characters of the alimentary organs including those of the salivary glands although clearly separate *Phyllocephalinae* from other subfamilies of *Pentatomidae* but with these characters alone the group probably does not warrant a family status. MIYAMOTO (1961) has also indicated only a mild suggestion to raise the status of the group, « the writer prefers for the present to treat the *Phyllocephalinae* as a family ». The characters of the *Phyllocephalinae* as compared to other pentatomoid families (MIYAMOTO, 1961 and KUMAR, 1962, 1965, 1969 a, b, and COBBEN, 1968) and subfamilies not only help designate the status of the group but also provide a measure to help evaluate the status of lower categories below family level

within *Pentatomidae*. COBBEN (1968) has also not found this group very different from the rest of the subfamilies within *Pentatomidae* and he has allotted it a subfamily rank.

The present studies could not provide anyone character or a set of characters to differentiate the groups usually regarded today of the status of subfamilies within the family *Pentatomidae* (*Podopini*, *Asopini* and etc.) from the subfamily *Pentatominae*. In the scent apparatus morphology the *Podopini* resembles the *Asopini* and also the species of *Pentatominae* (of the tribe *Eurydemini*) in that in all the species studied of these groups, the scent glands are not provided with well marked collecting ducts, the scent reservoir is relatively small, never extending beyond the posterior margin of metacoxae and usually hanging between the meso and metacoxae, with simple, arch-like or plainly straight accessory gland without convolutions (in *Asopini*, *Andrallus spinidens*, a few convolutions are noted) and valvular apparatus which is always with a smoothly lunate inner arm. In the structure of alimentary organs, as well, these show distinct similarities, for in all, the oesophagus is moderately elongate (extremely elongated in *Asopini*, *A. spinidens*, similar to that in *Sciocoris lewisi*) with prominent terminal bulbous portion and the midgut₂ region is relatively wide and longer than midgut₄ region which is usually devoid of gastric caeca. In the presently studied species *Bagrada hilaris*, and *B. cruciferarum* studied by RAI and TREHAN (1964) of the tribe *Eurydemini* also the gastric caeca are absent whereas in the species of *Stenozugum* the same are greatly developed. MIYAMOTO (1961) has illustrated gastric caeca in the midgut₄ region of *Graphosoma lineatum* (*Podopini*) that he studied. The salivary glands in all the studied species of *Eurydemini* are simple distinctly bilobed and although the posterior lobe is extended into anterior bulbous and a posterior tubular region these do not appear further subdivided. SAREL-WHITEFIELD (1929) has noted trilobed principal salivary gland in *Agnoscelis versicolor* but KUMAR (1962) contradicting (SAREL-WHITEFIELD, 1929) has reported distinctly bilobed principal salivary glands in the two species of the same genus i.e. *A. nubila* and *A. rutila*. MIYAMOTO (1961) has observed, « distinct finger-like lobules of the principal salivary glands seem to be characteristic to the *Scutellerinae* and some *Podopinae* but somewhat similar condition is found in *Erthesina* (*Halyini*) ».

LESTON (1953) raised the *Podopini* to subfamily status but held that further investigations might lead to diminish its status. The studies of BARBAR and SAILER (1953) lead to the same conclusion. LESTON (1954) has noted the similarity between *Asopini* and *Podopini*. PENDERGRAS (1957) has stated that the *Podopinae* (*Podopini*) and *Asopinae* (*Asopini*) are so close to the *Pentatominae* that they should either be lowered in rank or that the other subfamilies should be raised in status. McDONALD (1966) on the basis of the male and female genitalia has concluded, « the male and female genitalia of the *Asopinae* & *Podopinae* show remarkable similarity to one another and to the *Pentatominae*. I think on this basis

these subfamilies (*Asopinae* and *Podopinae*) should be down graded and given tribal status within the *Pentatominae* ».

Relationships within the *Pentatominae*.

As noted above of all the groups presently studied within this subfamily the scent apparatus morphology seems to divide them fairly clearly in two major groups (1) *Asopini*, *Podopini* and *Eurydemini* group. In the former group the collecting ducts of the scent glands are not well marked, the reservoir is relatively small never extending beyond meta-thoracic coxae, the accessory gland is usually simple, plainly accurate and unconvoluted (in *Asopini* a few loops are present) and the inner arm of the valvular apparatus is smoothly lunate, whereas in the latter group the collecting ducts of the scent glands are usually well marked (BRINDELY (1930) in a carporine species, *Palomena prasina* has reported that the collecting ducts are not well marked), accessory gland with prominent convolutions and the inner arm of the valvular apparatus is distinctly dentate. The same conclusions seem to be drawn on the basis of those of alimentary organs in that in the former group the oesophagus is moderately elongated (comparatively longer in *Asopini*), midgut₂ region comparatively wider and longer than the midgut₄ region which is usually greatly reduced and usually is without gastric caeca. The principal salivary glands in this group are usually very simple (in *Asopini* the posterior portion of the posterior lobe appears bulging). *Halyini* on the other hand (on the basis of description of scent apparatus by AHMAD and KHANUM (1968) seems to be again an early offshoot of some pentatomins which evolved and advanced in many respects. The small scent glands located on the antero-lateral side of the reservoir, without well marked collecting ducts, with large reservoir, heart-shaped, reaching on to the second abdominal sternum, the accessory gland with many loops, the valvular apparatus with a dentate inner arm and the proximally extremely wide vestibules which only taper distally opening to the exterior through (narrow transverse aperture or ostiole). MIYAMOTO (1961) has noted subdivisions of the anterior and posterior lobes of the principal glands in *Erthesina* (*Halyini*) and his diagram of the alimentary organs of that species is in agreement with the above conclusion.

It appears that early pentatomine ancestors resembled the present day *Asopini* in many characters. Small reservoir never extending beyond meta-thoracic coxae, plain and simple accessory gland with only a few loops, curved vestibules, long oesophagus, long and tubular midgut₂ region wider and longer than a very reduced midgut₄ region which is without gastric caeca and simple bilobed salivary glands, all seem to support this assumption. GLASGOW (1914) also has held that the *Asopinae* (*Asopini*) might be taken as representing the stock from which all other *Heteroptera* developed. ROSTAGI (1966) has regarded that the absence of caeca in *Asopinae* (*Asopini*) is justified in view of their semi predatory nature and

COBBEN (1968) has also held as noted above that ancestors of heteroptera were carnivorous. This stock probably at one hand gave rise to *Podopini* and *Eurydemini* and on the other to *Aeliini*, *Sciocorini*, *Carpocorini*, *Pentatomini*, and *Eysarcorini*. A few species of both *Podopini* and *Eurydemini* owing to their semi-predatory habits retained a very reduced midgut₁ region entirely devoid of gastric caeca but other species probably with a change in their feeding, developed a relatively longer midgut₁ region with four rows of prominent gastric caeca.

In the other group the simple only a few looped accessory gland probably by enlargement and elongation developed an accessory gland of many looped condition. *Aeliini* probably represents the earliest offshoot of this line which retained comparatively bilobed reservoir, only slightly extending on to the metathoracic coxae and with simple only a few looped accessory gland and elongated oesophagus, long and wide midgut₂ region and simple salivary glands. From this line also probably evolved *Sciocorini* at one hand which retained long and narrow oesophagus and greatly elongated and wide midgut₂ region but which specialized in many characters i.e. very short vestibules highly dentate inner arms of valvular apparatus and a very short midgut₁ region. COBBEN (1968) has noted *Sciocoris cursitans* deviating in the structure, deposition and orientation of the egg from the family Pentatomidae. *Carpocorini* and *Pentatomini* probably also arose from similar ancestral form and have retained a comparatively smaller reservoir only a few looped accessory gland (*Palomena prasina* BRINDLEY, 1930), long oesophagus and a relatively longer midgut₂ region, whereas *Pentatomini* represents a more advanced condition with a very developed and many folded midgut₁ region and a greatly enlarged rectum (as compared to the pylorus., *Eysarcorini* seems to be the most advanced in all the pentatomines with very large scent reservoir, many looped accessory gland, and comparatively broad vestibules, relatively short oesophagus, very large midgut₁ region almost filling the entire abdominal cavity), relatively short but broad midgut₂ region and with an elongated rectum.

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SUMMARY

1. Comparative morphology of scent apparatus and alimentary organs of fourteen pentatomine species belonging to eight tribes including two of those which are to date regarded of the status of subfamilies within the family *Pentatomidae* were studied from Sind region, West Pakistan.

2. The results were compared with the accounts given with reference to scent apparatus for three other families, *Acanthosomatidae*, *Cydnidae* and *Dinidoridae* and one other tribe (*Halyini*) and two of those already included in the present study.

3. Relationship of the family *Dinidoridae* with *Cydnidae*, *Acanthosomatidae* and *Scutelleridae* was briefly discussed.

4. *Phyllocephalinae* on the basis of alimentary organs was considered of the rank of subfamily contrary to MIYAMOTO (1961) who gave it a family rank.

5. Two of the subfamilies within the family *Pentatomidae* as these are generally regarded today i.e., *Podopinae* and *Asopinae* were proposed to be diminished in rank to the tribes within *Pentatominae* following BARBER and SAILER (1953), PENDERGRAST (1957) and McDONALD (1966).

6. *Halyini* was also considered an early offshoot of the ancestral form, which evolved and specialized in many characters.

7. *Asopini* was considered very close to the ancestral form.

8. *Podopini* and *Eurydemini* were considered derived from this ancestral form by a reduction in the convolutions of the accessory scent gland whereas *Aeliini*, *Sciocorini*, *Carpocorini*, *Pentatomini* and *Eysarcorini* which were considered evolving from the ancestral form by enlargement and elongation in the accessory gland resulting into many looped condition.

9. *Aeliini* was considered an early offshoot of this line of evolution which was considered to be followed by *Sciocorini* and *Carpocorini*. The former was considered evolved and specialized in many characters.

10. *Pentatomini* was considered advanced in many respects, still retaining many of the primitive characters whereas *Eysarcorini* was considered the most advanced group within the subfamily *Pentatominae*.

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