KARYOTYPES OF SOME GHANAIAN SHIELD-BUGS AND THE HIGHER SYSTEMATICS OF PENTATOMOIDEA (HEMIPTERA : HETEROPTERA)

By

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DECLARATION

This is to certify that this thesis has not been submitted for a degree to any other University. It is entirely my own work, and all help has been duly acknowledged.

KWAME AFREH NUAMAH

DEDICATION

This work is dedicated to Him, through whom, and of whom are all things, the Lord God Almighty, who makes all things possible; to Grace and my Parents, for their ever present love; and to Professor R. Kumar for his valuable contributions to Entomology in Ghana.

ACKNOWLEDGEMENT

My sincere gratitude goes to Professor R. Kumar, my Supervisor and head of the department of Zoology, University of Ghana Legon, for his keen interest in this work, for his critical guidance and suggestions and for reading through the work. I wish to thank also Mr P.G.O. Kpordugbe for valuable assistance with the technical aspects of the project, and to Professor W.Z. Coker for reading through the manuscript.

I am indebted to Mr M. Adjo (driver), Mr F. Ansah, Mr B. Bremong and the other departmental assistants for assistance in diverse ways. My thanks are also due to the Director, Commonwealth Institute of Entomology for confirming the identity of insects determined by Prof. R. Kumar.

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Finally, I am highly indebted to Mr. N. Owusu, Zoology Department, University of Ghana, Legon for his diligent and meticulous typing of this study.

ABSTRACT

Data on 2n-numbers of some fifty-five (55) species, belonging to six families of some Ghanaian shield bugs, collected in Southern Ghana, West Africa are presented. Microphotographs and tracings of karyotypes observed for each species are produced as figures. Histograms of chromosome numbers of the various families have been constructed and these results together with the existing information in literature, is analyzed and discussed.

In all two hundred and seventeen (217) species of Pentatomoidea were found to be known cytologically in the literature. With the present work the total number of species of shield-bugs where the Karyotypes is now known stands at two hundred and sixty-six (266).

The following karyotype groups appear to emerge from the study: 14 and 12. Under the group 14 is the family Pentatomidae, whilst the families, Scutelleridae, Cydnidae and Plataspidae fall under the karyotype group 12. No basic chromosome number can however be cited for the other families of Pentatomoidea, namely, Dinidoridae, Tessaratomidae, Acanthosomatidae and Urostylidae, because the cytological data for each of these are too scanty, for any such conclusions to be arrived at. The inter-relation of various groups in the superfamily Pentatomoidea are discussed, and the present investigations tend to support the work and conclusions arrived at by morpho-taxonomical studies.

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SECTION 1

GENERAL INTRODUCTION

A significant advance in our knowledge of the higher classification of the terrestrial Heteroptera (Geocorisae) was made by Leston, Pendergrast and Southwood (1954) who, following Evans' (1946) precedent in Homoptera, divided Geocorisae into two groups, namely Pentatomorpha and Cimicomorpha. The grouping was based on evidence from external male genitalia, trichobothria, wings, spermatheca, eggs and the salivary glands. Recently, support in favour of this grouping has been furnished by Southwood (1956, eggs), Pendergrast (1957, internal reproductive organs), Scudder (1959, ovipositor), Miyamoto (1961, alimentary organs) and Cobben (1968, 1978 eggs and mouthparts). Thus now it is well acknowledged that the Pentatomorpha and the Cimicomorpha are natural groups. Objections of China (1955), regarding the basing of taxonomic categories on the internal organs have been well countered by Miyamoto (1961), who rightly contends that the internal structure such as alimentary organs "are one of the basic structures for life and comparatively stable in character".

Within the groups Pentatomorpha and Cimicomorpha, the relationships of various taxa have been the subject of a good deal of attention and characters like the genitalia and alimentary organs have been studied at some length. Despite these studies, wide lacunae exist in our knowledge of these characters in various groups of Heteroptera. Pendergrast (1957) in his detailed survey of the reproductive organs of Heteroptera, listed no fewer than eighteen families in males and eight families in females where the knowledge of these organs is totally lacking. In the rest of the families the position at subfamily and tribal level is not satisfactory, e.g in large families such as the Scutelleridae, the internal male reproductive organs are known only in one species. Though a good deal of work has not been done on the higher classification of the Pentatomoidea, the statements by Pendergrast (1957) that, "there is more disagreement over the family and Subfamily groupings of the Pentatomoidea than in the whole complex of families in the Heteroptera" still holds (vide infra). The systematics of the group is in a very confused state, and as observed by Kumar (1965), "despite our rapidly accumulating information on the families of the Pentatomoidea, we still have a very imperfect understanding of the relationships of various taxa in this vast and complex group".

In recent years, considerable work has been done on the higher classification of Pentatomoidea, particularly on the male genitalia particularly the aedeagi in an expanded condition, structure and function of the ejaculatory reservoir, ovipositor, internal reproductive organs and structure of eggs and mouthparts. Among such workers are, Leston (1954b, 1955, 1958); Southwood (1956); Pendergrast (1957); Scudder (1959); Kumar (1962, 1965, 1968b); and Cobben (1968, 1978). Inspite of this it is still realised that significant contributions remain to be made in this area, and the need for further work in this field cannot be over-emphasized.

As to now, taxonomists are increasingly realising that internal organs are less variable than external characters, and may thus at least in some groups serve as valuable phylogenetic indicators (Louis and Kumar 1972). Manna (1951) strongly encourages cytologists interested in a synthesis of cytological and morphological data to gather detailed information about chromosomes and their behaviour, of many more species of animals and plants, and this is exactly what this project addresses itself to do.

Chromosome cytology has contributed to insect systematics in several different ways which are not always appreciated very clearly by non-cytologists. Though, it cannot be said to be an automatic solution to all systematic problems, in suitable cases, it can provide critical evidence of a unique kind. Cytologists are, among other things, concerned with the cytotaxonomic differences which exist between species. These, only rarely involve major differences in the genetic mechanisms, but often consist of differences in chromosome number, and in their sizes and shapes. According to White (1956), such differences may sometimes be used to distinguish "sibling" or cryptic species that cannot be separated at all, or only with difficulty or uncertainty, on external characters. These are the results of chromosomal rearrangements which have arisen spontaneously and established themselves in phylogeny. One type of rearrangement may lead to a dimunition in chromosome numbers, while another may produce an increase.

The knowledge of how the major differences in genetic mechanisms had arisen in the course of evolution, could be used in establishing the relationships of the insect orders and other 'higher categories' on a firmer foundation. Within a particular species the size range of the chromosomes of a haploid groups is not great, the smallest, usually being no more than one third to half that of the largest. Because, such nuclear cytology provides an independent set of data, which can be critically correlated, and evaluated with the usual morphological findings, it is assuming more and more importance, though it is still in its infancy. However, as rightly pointed out by Schaefer (1964), cytological work is not easy to evaluate, and the conclusions drawn by some authors discredit the accuracy of their work. Commenting on this Cobben (1968) stressed "that detailed knowledge of cytology and ways of recognizing the different chromosomes, and studies on their behaviour are needed". According to him, unless this is done, attempts to apply "chromosome studies to the solution of problems of major relationships, would be a sheer guess work, such that the results would also be contradictory to current classification, especially, when the cytologist is not a taxonomic specialist of the group in question". He cited the work of Manna (1958) as an example of how such problems, have arisen, where extremely remote groups are linked together.

Actually, such are some of the dangers one runs into, in trying to apply cytology in systematics, but this is to be expected, for such problems cannot be wholly avoided in a work of this nature. It is hoped that with time and more work, such difficulties would be overcome, and the actual advantage of cytology in insect systematics, would be seen and accepted, to provide a unique tool in tackling some of systematics problems as existing at present.

Since the time of Montgomery (1901, 1905) and Wilson (1911), the Heteroptera have been undergoing extensive cytological investigations. The main investigations so far have been the use of cytological data along with morphological characters to: (a) evaluate the broad mechanical principle underlying changes in karyotypes, (b) evaluate supergenetic, generic and specific classification. Even though among the different groups of Heteroptera, the Pentatomidae is best known cytologically, (Schachow, 1932; Schrader, 1945a, 1945b, 1960; Manna, 1950, 1951, 1958; Leston 1958, etc.). Generally, though cytology as an additional tool in the field of taxonomy is undeniable, its use is only possible, according to Manna (1958), when we have adequate data at hand, obtained in a planned way of study. Though the Heteroptera are one of the groups of insects that have been the subject of extensive cytological investigation, since the beginning of this century, not all families are known cytologically. Usually, as confirmed by this study, the data are not equally extensive in all families, and in certain cases only a few species have been examined.

In the present study, cytological data on fifty-five (55) species belonging to six families of the superfamily Pentatomoidea is presented. All published information on the karyotypes of the Pentatomoidea is reviewed, and interrelationship within the superfamily are examined.

SECTION 2

MATERIALS AND METHODS

Adult male insects of the group Pentatomoidea which constituted the material for the present investigation, were collected locally from within a radius of seventy-five (75) miles of the University campus, in the South-Eastern cocoa growing areas of Ghana, West Africa, from February 1979 to May 1980. The various insects were collected by use of ultra-violet light traps, using mercury bulbs in the night, butterfly and sweeping nets, and also by hand picking from walls under electric lights, and on leaves of plants, throughout the period of work. At each particular time of collection, more than one method of collection was used as the need arose. The insects soon after their capture were transported alive to the laboratory and dissected under tap water, and their testis directly transferred to the fixative, namely the Carnoy's fixative made up to three (3) parts of isopropanol and one part of glacial acetic acid. These were kept in tubes in an air-conditioned room (average room temperature = 22°C) until squashing. Squashes of testis with Lacto-aceto-orceintain (Warren et al 1960) were made. The Lacto-aceto-orcein stain was made up of thirty millilitres (30 mls) each of the following: distilled water, glacial acetic acid, and lactic acid, plus 2 grams of synthetic orcein, heated gently over water bath for about half an hour to one-hour with regular stirring, after which time the stain was filtered, whilst hot.

Chromosome counts and other observations of the squashes were made with the use of a Reichert binocular optical compound microscope with x10 ocular, 40x and 100x(oil) objectives against a green filter. The number of male specimens of each species dissected for testis material varied according to the availability of the particular species. Efforts were made to collect as many and varied species of the male insects, but since their catch depended on their abundance and availability, limitations were imposed on the numbers. In some cases, such as the Bathycoelia rodhaini Schout only one male specimen was caught and dissected, whilst in others for example, Asparia armigera (Fabr.) and Sepentia misella Stål as many as fifty male specimens were dissected for squashing.

Microphotographs of meiotic stages were taken with a Kam UBX 35 mm camera mounted on a Reichert photomicroscope, with x40 objectives against a green filter. Drawings which are tracings from microphotographs were made of all the original pictures taken, these were indicated as figures. Due to technical problems developed by the photocopying machine used for this purposes, at the last stage of the xeroxing, tracings of the microphotographs of three species were made half the size of the microphotographs. These are: Acrosternum heegeri Fieb., Aeptus singularis (Dallas), and Benia sp. A (Figs. 1-4, 9-12 and 43-46 respectively). In all the stages of meiosis examined, especially at the spermatogonial metaphase, the chromosomes were categorized into different size groups, though in most cases absolute distinction between the different size groups was not usually possible.

Species of Pentatomoidea examined, and their locality and date of collection are given in Table 1. 2n-numbers were determined for fifty-five (55) species of male Pentatomoidea, belonging to six families. Out of this number, microphotographs and tracings are presented for fifty-one (51) species. Distribution of 2n-numbers in the families of Pentatomoidea from literature and those studied cytologically to date are presented separately in tabular and in graphical form. Also distribution of 2n-numbers of families worked on in this study is similarly presented. Specimens used in this work were identified at the Entomology museum of the Zoology Department, University of Ghana, Legon; and confirmed at the Commonwealth Institute of Entomology, London.

SECTION 3

RESULTS

3.1 INTRODUCTION

The Heteroptera are supposed to be generally an easy cytological material, because of their deep staining chromosomes, and heteropycnotic sex chromosomes. Their chromosomes according to Manna (1951), "have no longitudinal differentiation by which one chromosome can be distinguished from the other", and therefore, in families like Pentatomidae where the chromosome number is constant in different species it becomes difficult to compare their chromosome complements. The only other convenient alternative in such a situation is to analyse the karyotypes according to the size of the chromosomes, and to classify them into different size groups. A visual estimation of the size of the spermatogonial and first meiotic metaphase chromosomes has been the usual method employed in these analyses to evaluate phylogenetic relationships.

3.2 MEIOSIS

The general course of meiosis in all the families studied is fairly uniform and the morphology and behaviour of the chromosomes of the group are typical heteropteran. The diploid number of chromosomes is expressed during the spermatogonial metaphase, and the haploid numbers at the spermatocytic metaphase one. In the earliest spermatocyte stage, the chromosomes are generally found in a more or less clumped condition at the central area of the nucleus, leaving a clear gap near the nuclear membrane. The sex chromosomes which are positively heteropycnotic, may sometimes be observed to lie within the central chromosomal mass and sometimes very close to the nuclear membrane. In the early diplotene stage, the tetrad nature of each bivalent becomes evident. Much condensation of euchromatic portions takes place through diplotene. Sex chromosomes, if fused, separate at the prometaphase stage and lose some of their heteropycnotic character. At this point sex-chromosomes can be distinguished from the autosomes, because they are composed of only two instead of four chromatids as in autosomal bivalents.

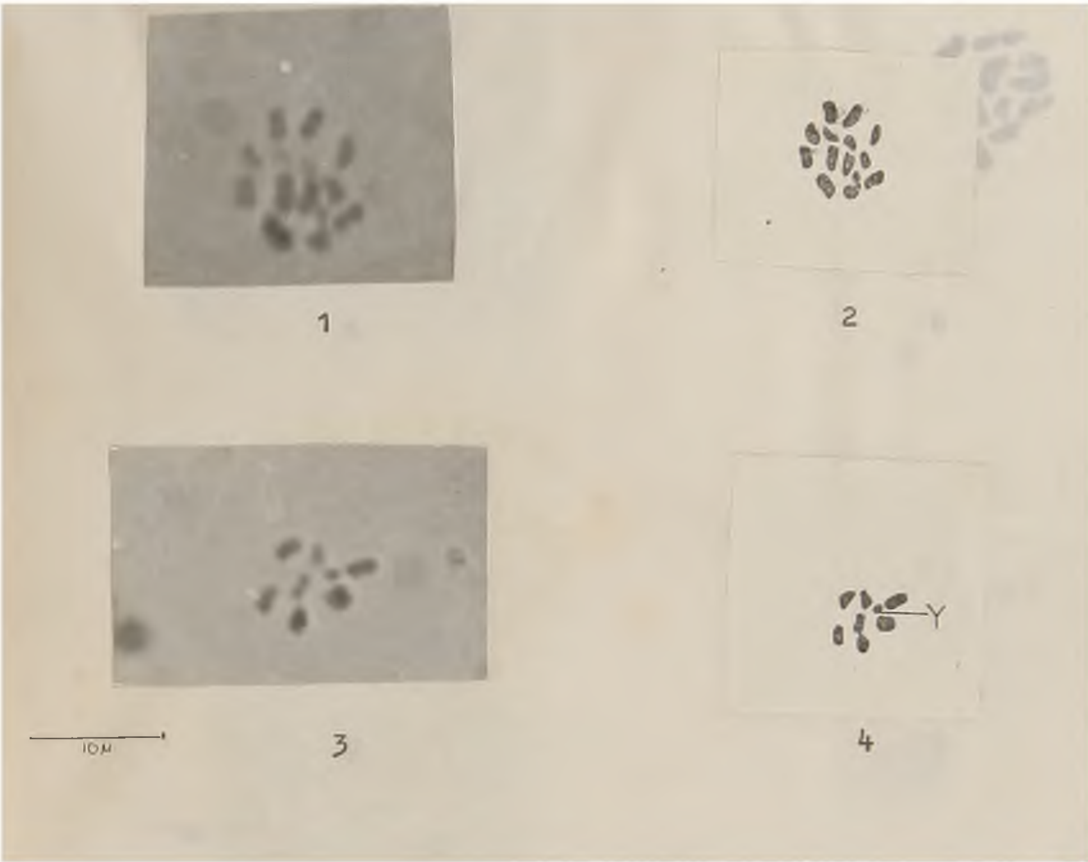
At the first metaphase stage (metaphase I), the autosomal bivalents arrange themselves roughly in the form of a ring on the equatorial plate, and the central part of the plate is generally occupied by one or both the sex chromosomes. When there is only one sex chromosome at the centre, the other generally takes up its position along with the bivalents. In very few cases, the central position is occupied by an autosome. Normally, however more than two elements are not present in the central region. The different species among the various families behave differently in these respects. At the second spermatocytic metaphase (metaphase II), the sex chromosome pair almost invariably lie at the centre (unseparated) surrounded by a ring of autosomes. At Anaphase II, two types of chromosome distribution result, following the segregation of the sex-chromosomes, the X-chromosomes to one pole and the Y-chromosomes to the other pole. Chromosome complements were not determined for the females, so to distinguish the sex-chromosomes from the autosomes, and to establish the sex mechanism, the following criteria were used:-

I. Diffuse stage of prophase I was studied and the sex chromosomes which are positively heteropycnotic at this stage were noted, unfortunately no good microphotograph of this stage was obtained.

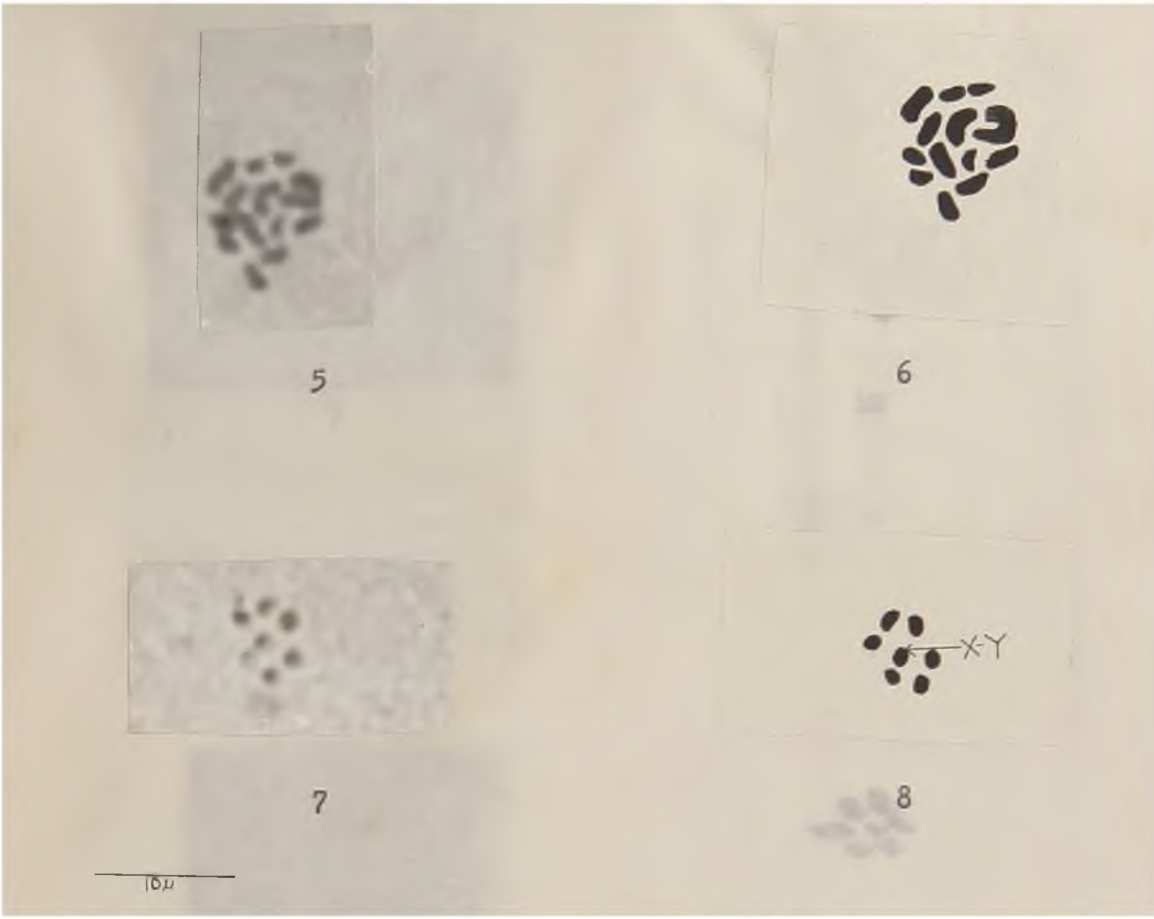
II. Metaphase II feature of autosomes forming a ring around sex-chromosomes provides an easy way of separating these two components of the karyotypes.

III. Segregating patterns at Anaphase II normally result in two types of chromosome distribution which gives an indication of the mechanism of sex-determination: because while the autosomes divide equationally, the sex-chromosomes are segregated, and the Y-goes to one daughter cell, and the X- to the other daughter cell.

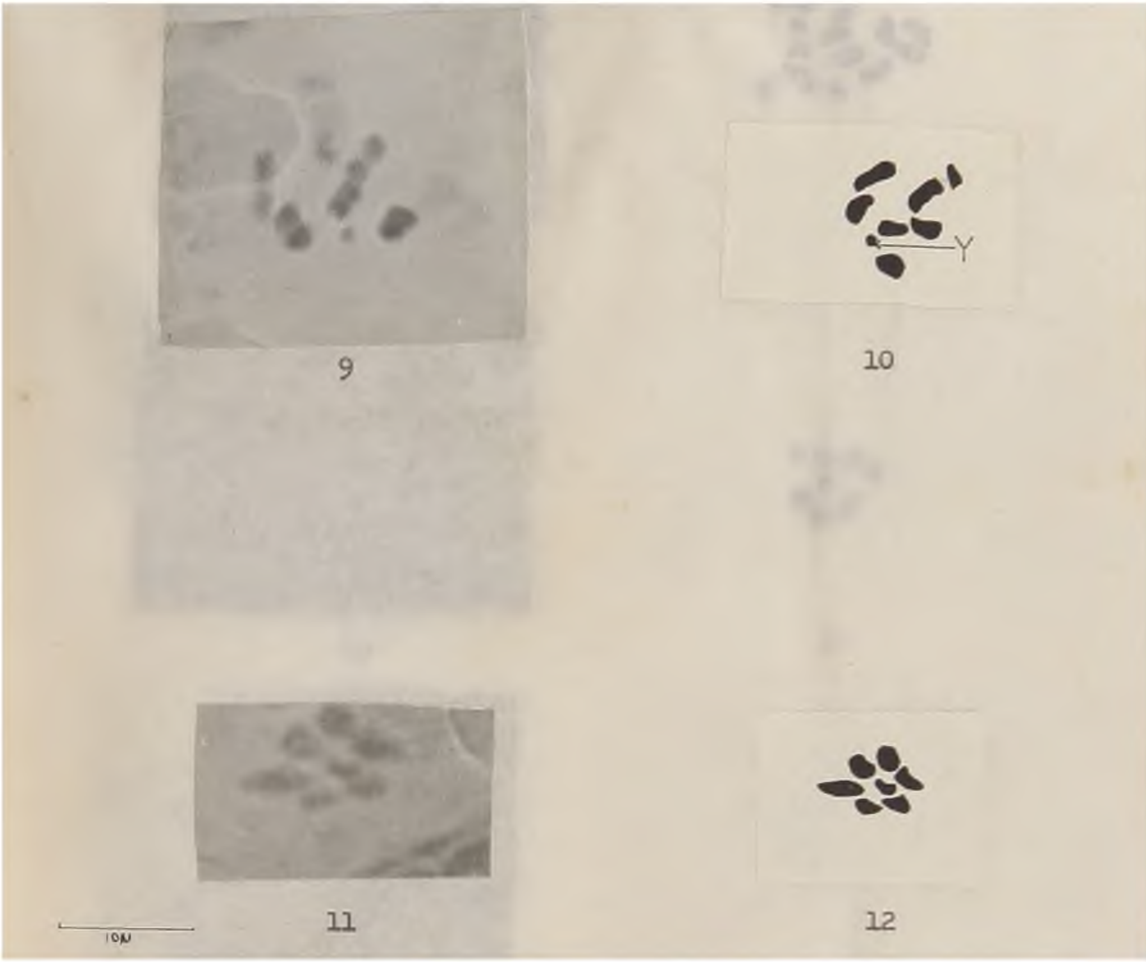
3.3. DESCRIPTION OF MEIOSIS



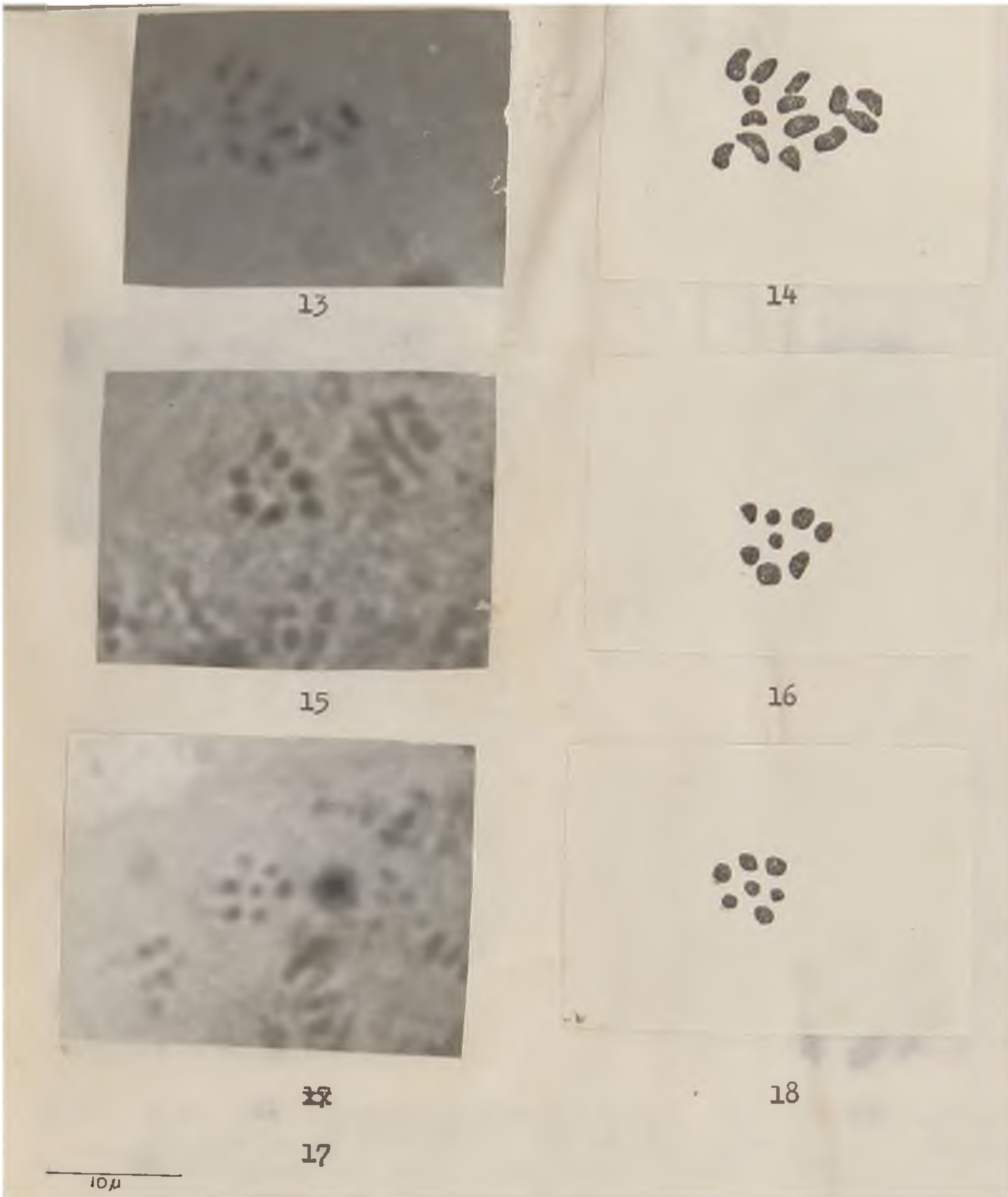
3.3.1 Figs. 1-4: Acrosternum heegeri Fieb. : 1) Microphotograph, 2) Tracing ($\frac{1}{2}$ microphotograph size) of spermatogonial metaphase, showing diploid complements of 14 chromosomes, 3 long, 9 medium and 3 small elements. 3) Microphotograph, 4) Tracing ($\frac{1}{2}$ microphotograph size) of Metaphase 1, arranged regularly on equatorial plate, smallest element is Y-chromosome.



3.3.2 Figs. 5-8: *Aeliomorpha* sp? *griseoflava* Stål 5) Microphotograph, 6) Tracing of Spermatogonial metaphase, the chromosomes are mostly connected. 14 chromosomes (4 long, 7 medium and 3 small elements, 7) Microphotograph, 8) tracing of Metaphase II, polar view, autosomes arranged in a ring with sex chromosomes in a central position.



3.3.3 Figs. 9-12: Aeptus singularis (Dallas): 9) microphotograph, 10) tracing ($\frac{1}{2}$ microphotograph size) of Diakinesis, showing condensation of bivalents, 11) microphotograph, 12) tracing ($\frac{1}{2}$ microscope size) of Metaphase II, polar view chromosome size larger than that of Aeliomorpha sp. (Figs 7-8).



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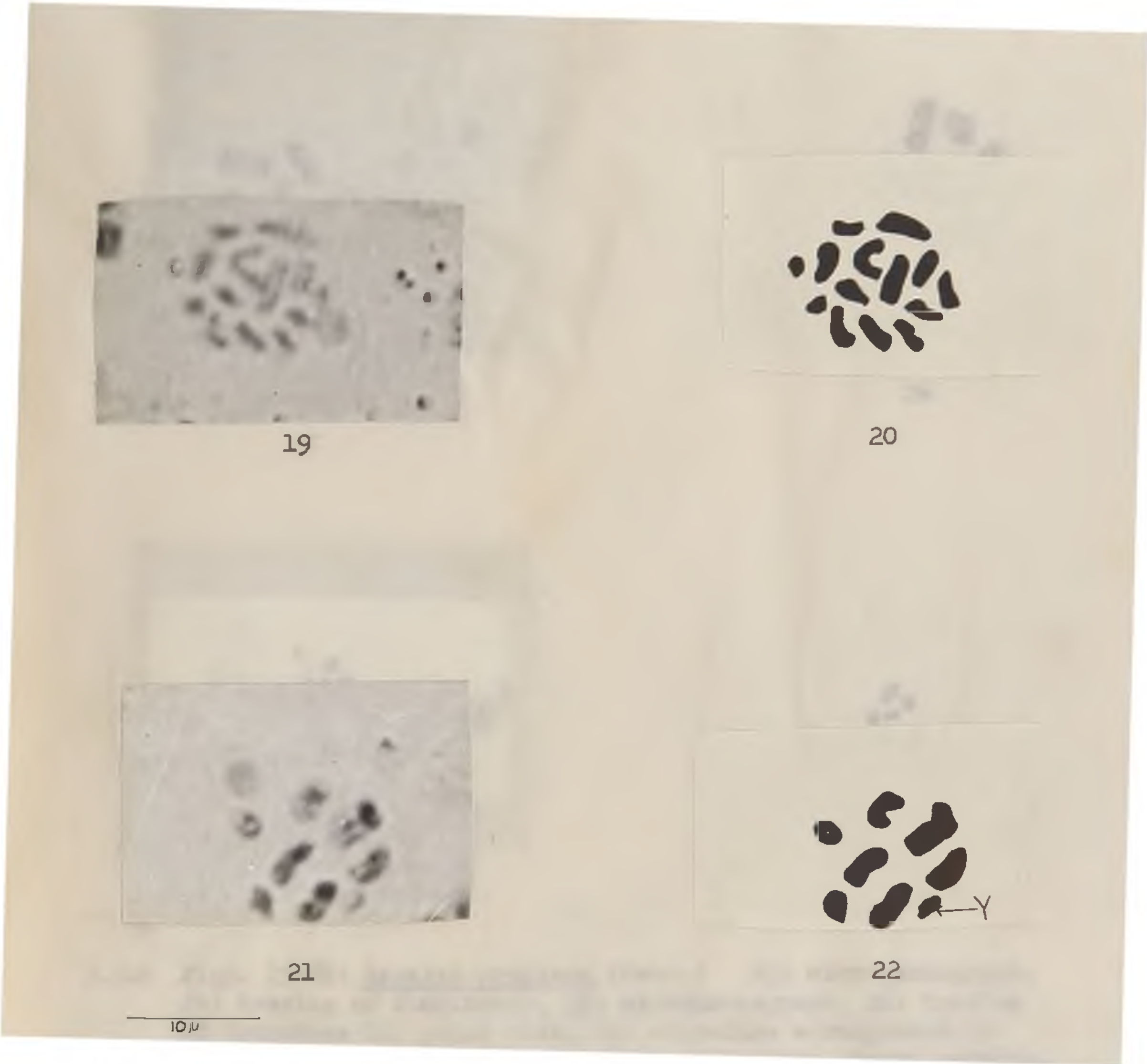

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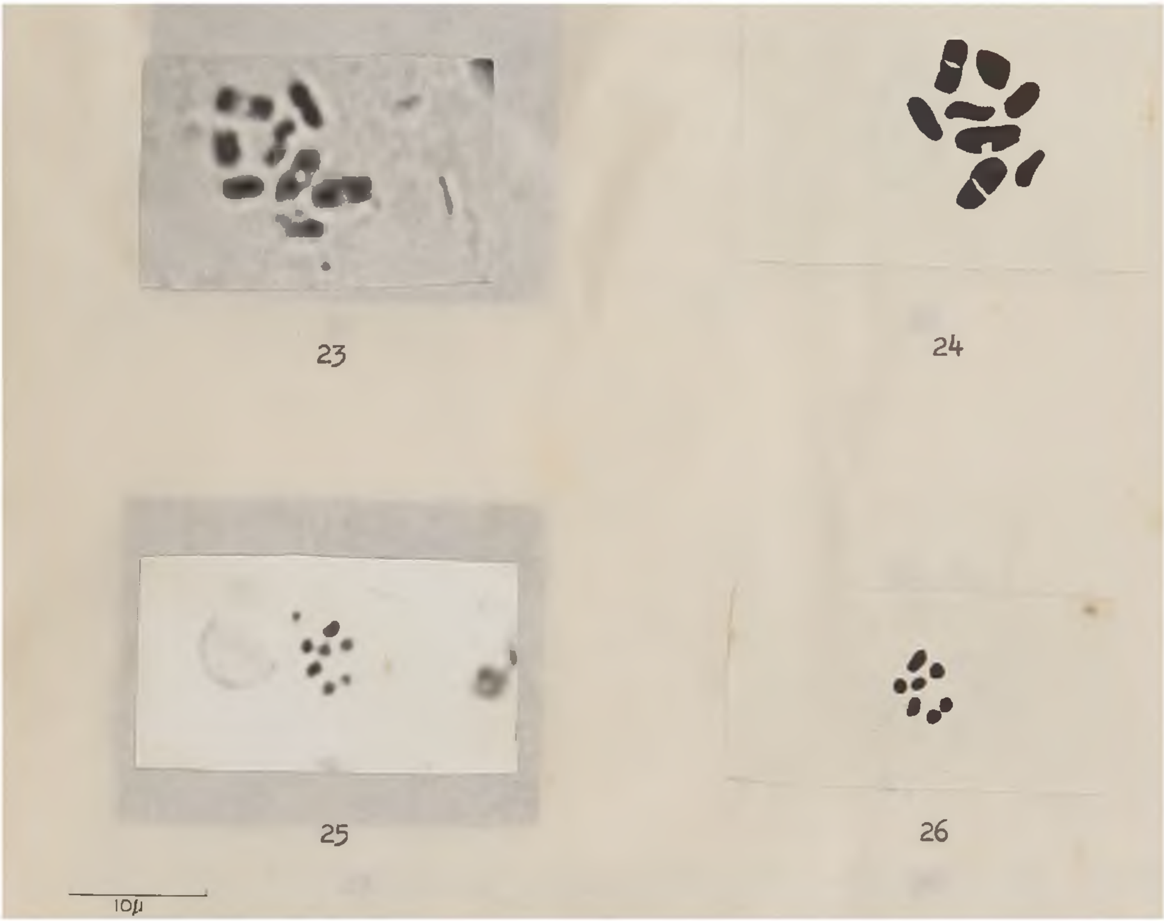
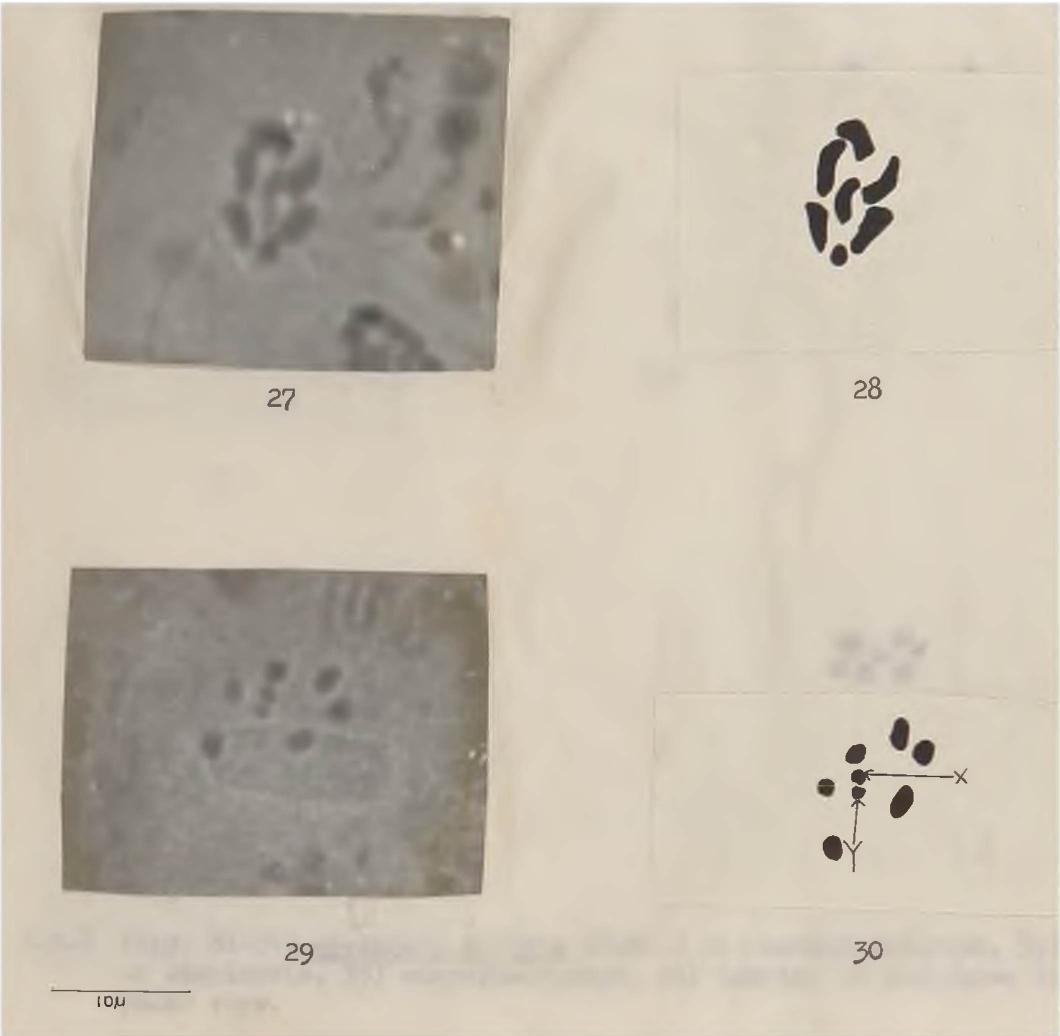
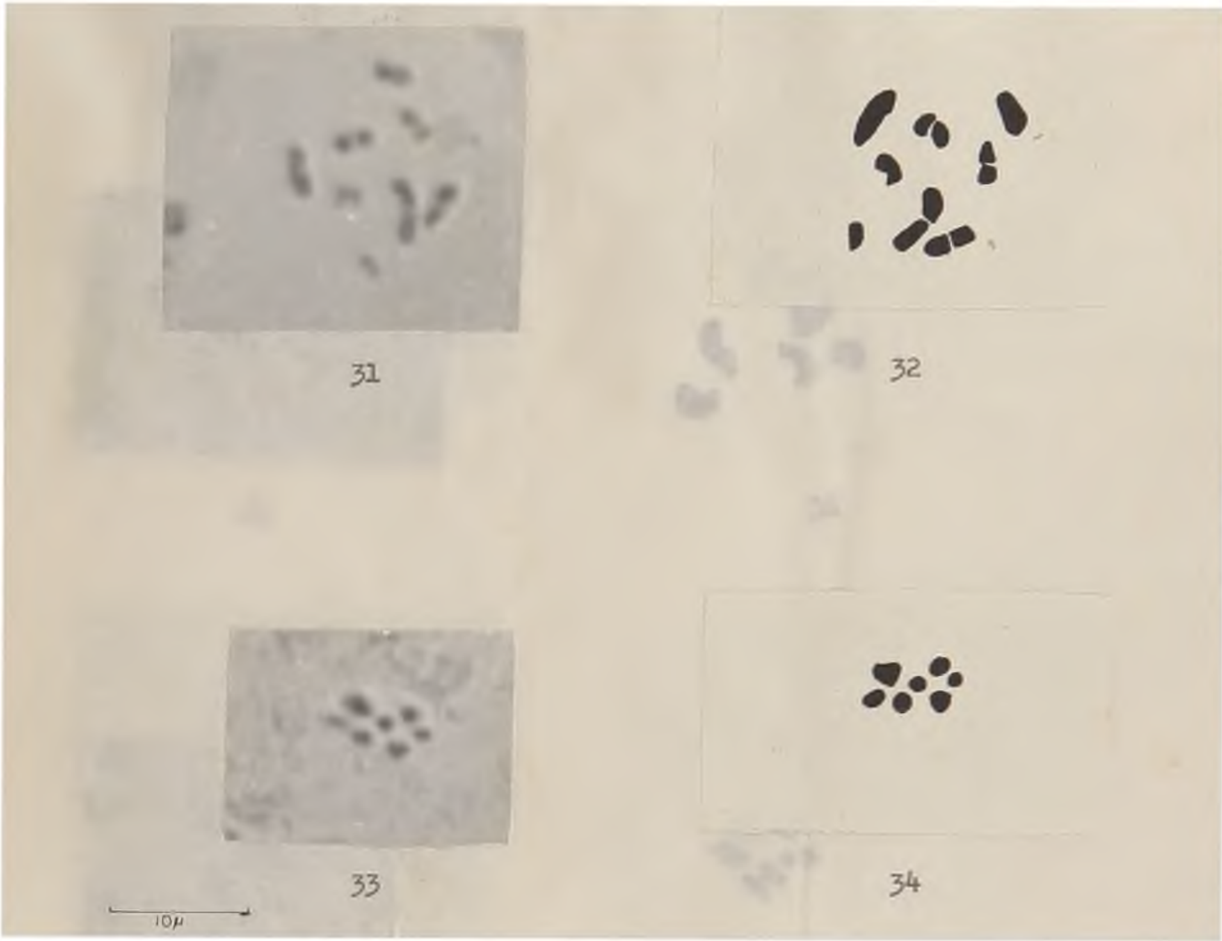


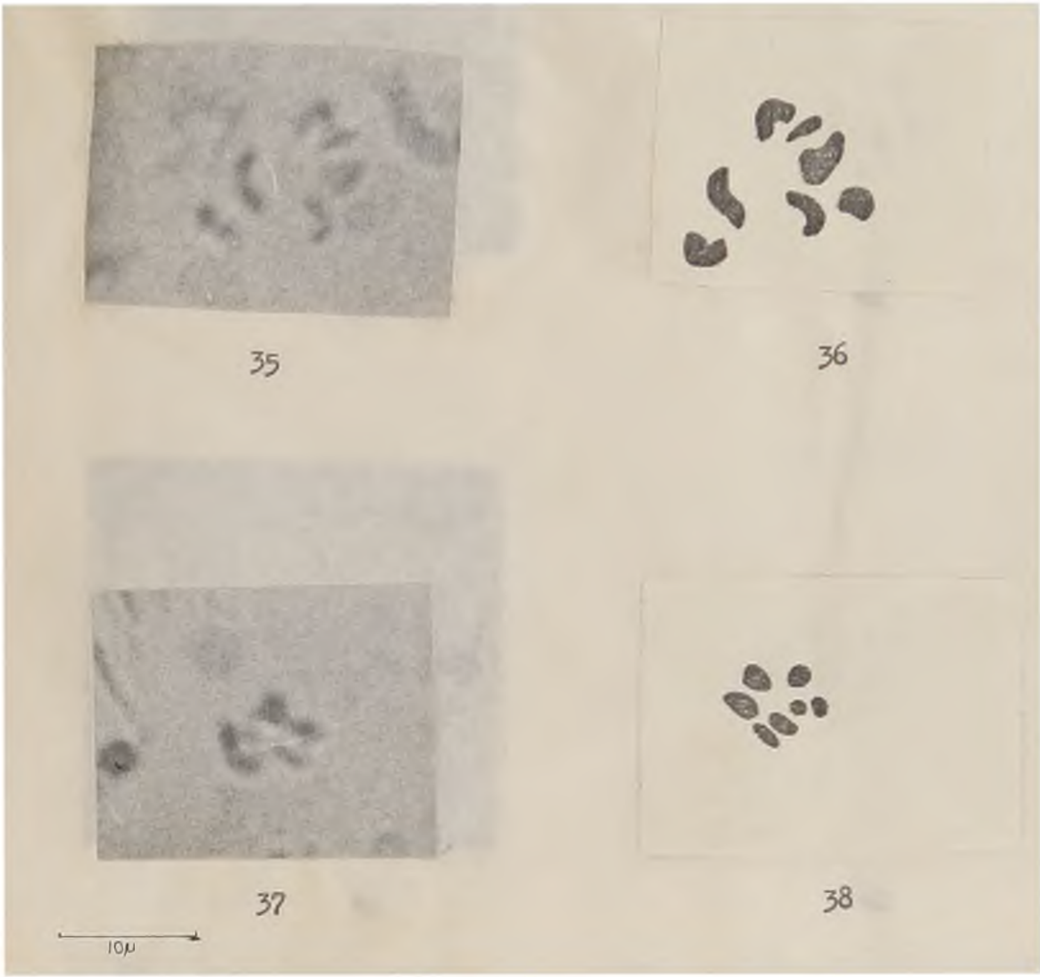
3.3.6 Figs. 23-26: Aspavia armigera (Fabr.) 23) microphotograph, 24) tracing of Diakinesis, 25) microphotograph, 26) tracing of Metaphase II, polar view, the ring-like arrangement of the autosomes on the first division metaphase plates regular, with a high degree of condensation and metaphase elements appear as very small and rounded bodies.



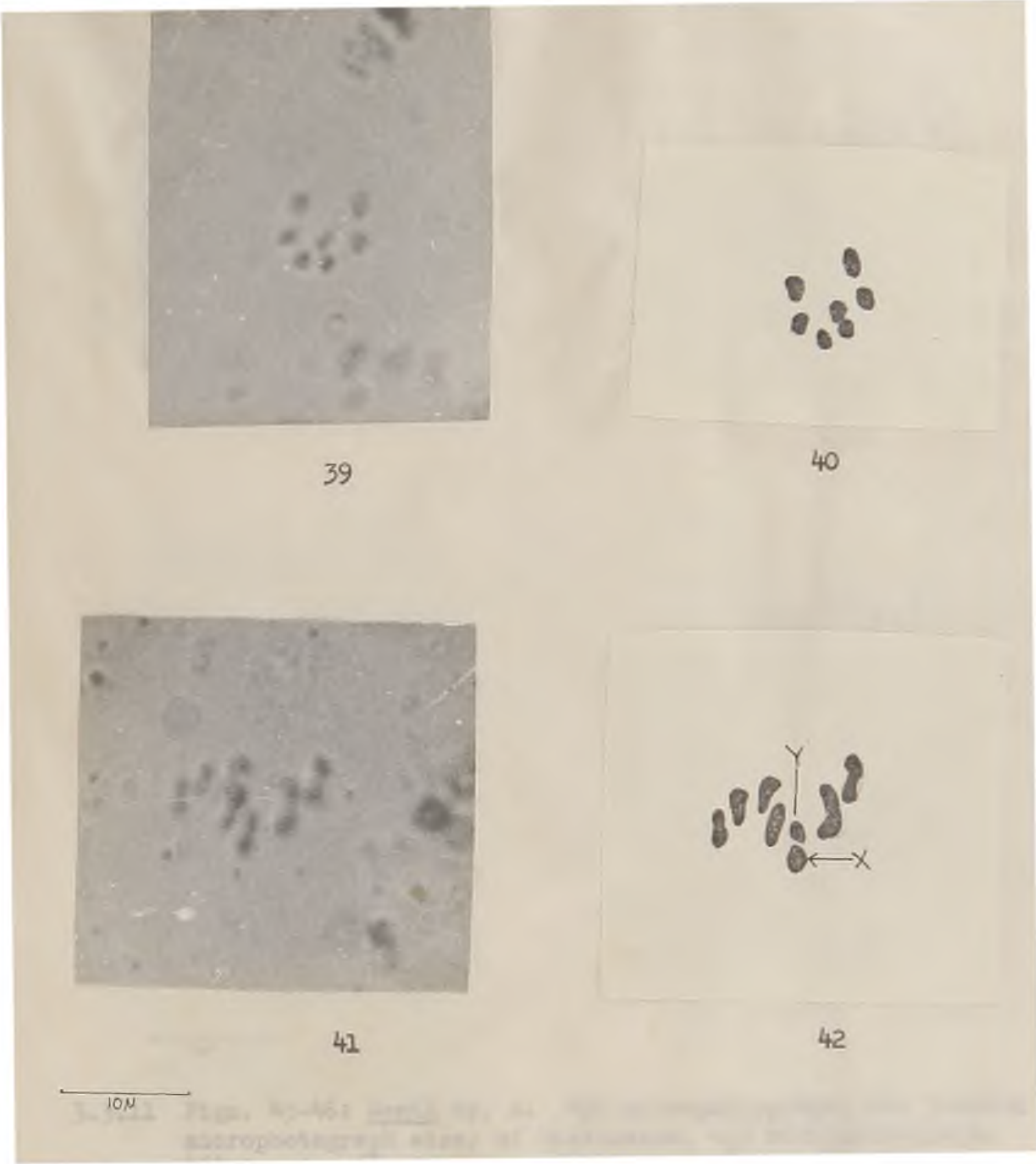
3.3.7 Figs. 27-30: <u>Aspavia hastator</u> (Fabr.) 27) microphotograph, 28) tracing of Diakinesis, 29) microphotograph, 30) tracing of Metaphase II, polar view.



3.3.8 Figs. 31-34: Atelocera serrata (Fabr.) 31) microphotograph, 32) tracing of Diakinesis, 33) microphotograph, 34) tracing of Metaphase II, polar view.



3.3.9 Figs. 35-38: Bathycoelia thalassina (H.-S) : 35) microphotograph, 36) tracing of Diakinesis with 7 elements, 37) microphotograph, 38) tracing of Metaphase II, polar view.



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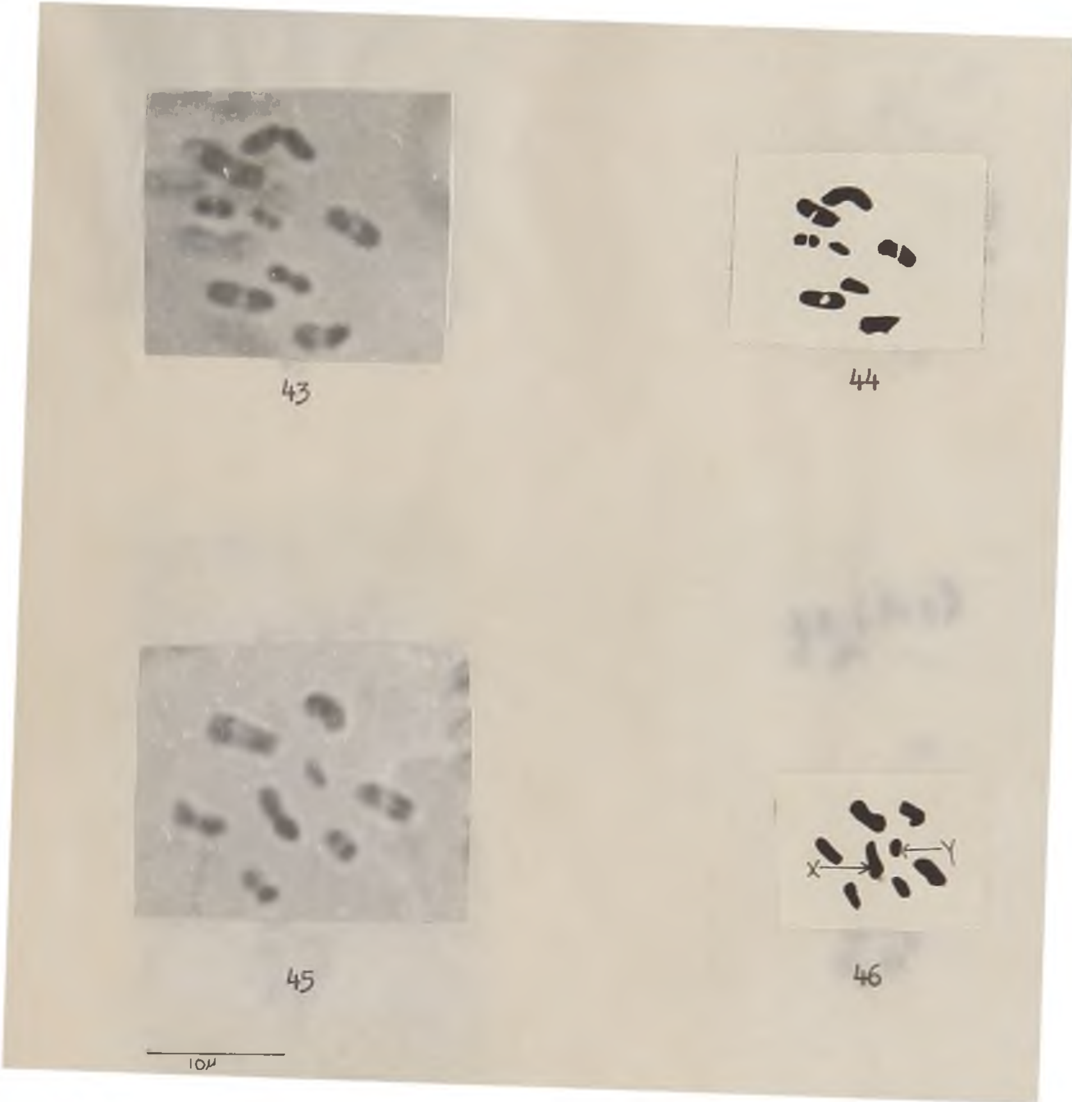

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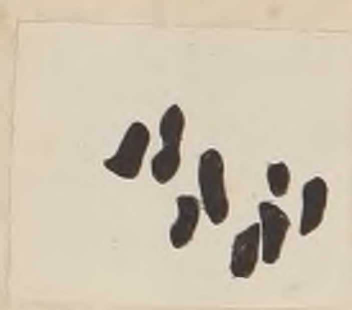

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3.3.13 Figs. 53-58: *Carbula carbula* (Distant) 53) microphotograph, 54) tracing of Diakinesis, elements larger than those of *Carbular capito* (Figs. 47-52), 55) microphograph, 56) tracing of Metaphase II, polar view, 57) microphotograph, 58) tracing of Metaphase II side view. Chromosome elements of *Carbula carbula* larger in size than those of *C. capito*.

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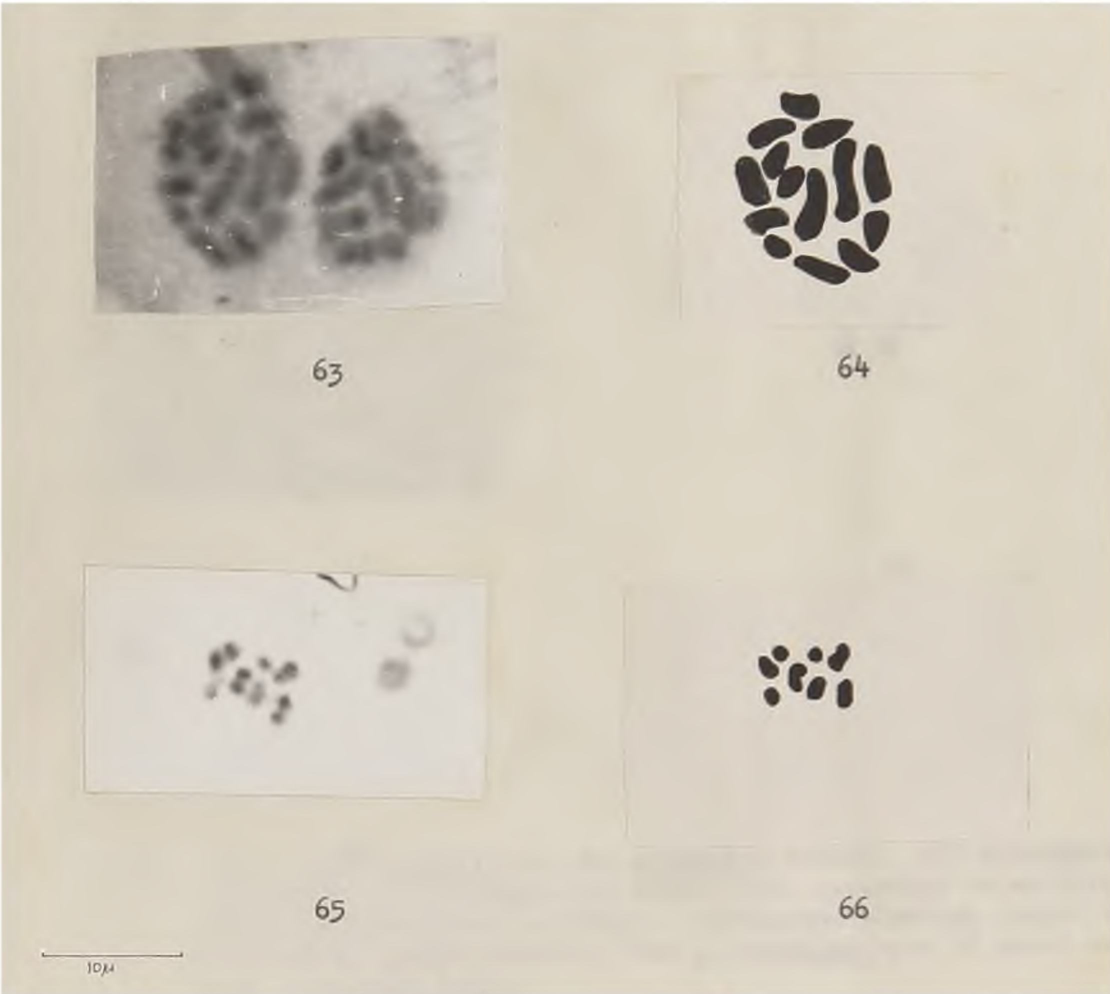

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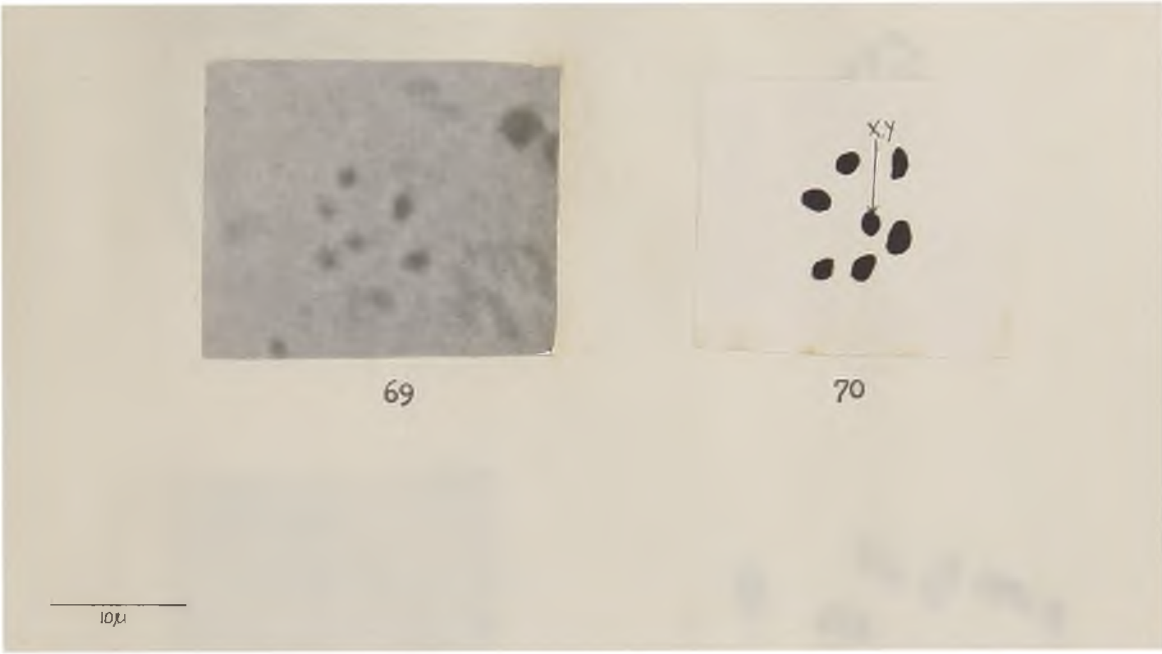
67

68

10µ

3.3.16 Figs. 67-68: Carbula sp. nr. sjostedti Schout. 67) microphotograph, 68) tracing of Metaphase II, polar view, autosomes in an irregular ring, sex chromosome in middle. Chromosome elements larger than those of C. capito, smaller than C. carbular, and of about same size of C. marginella.



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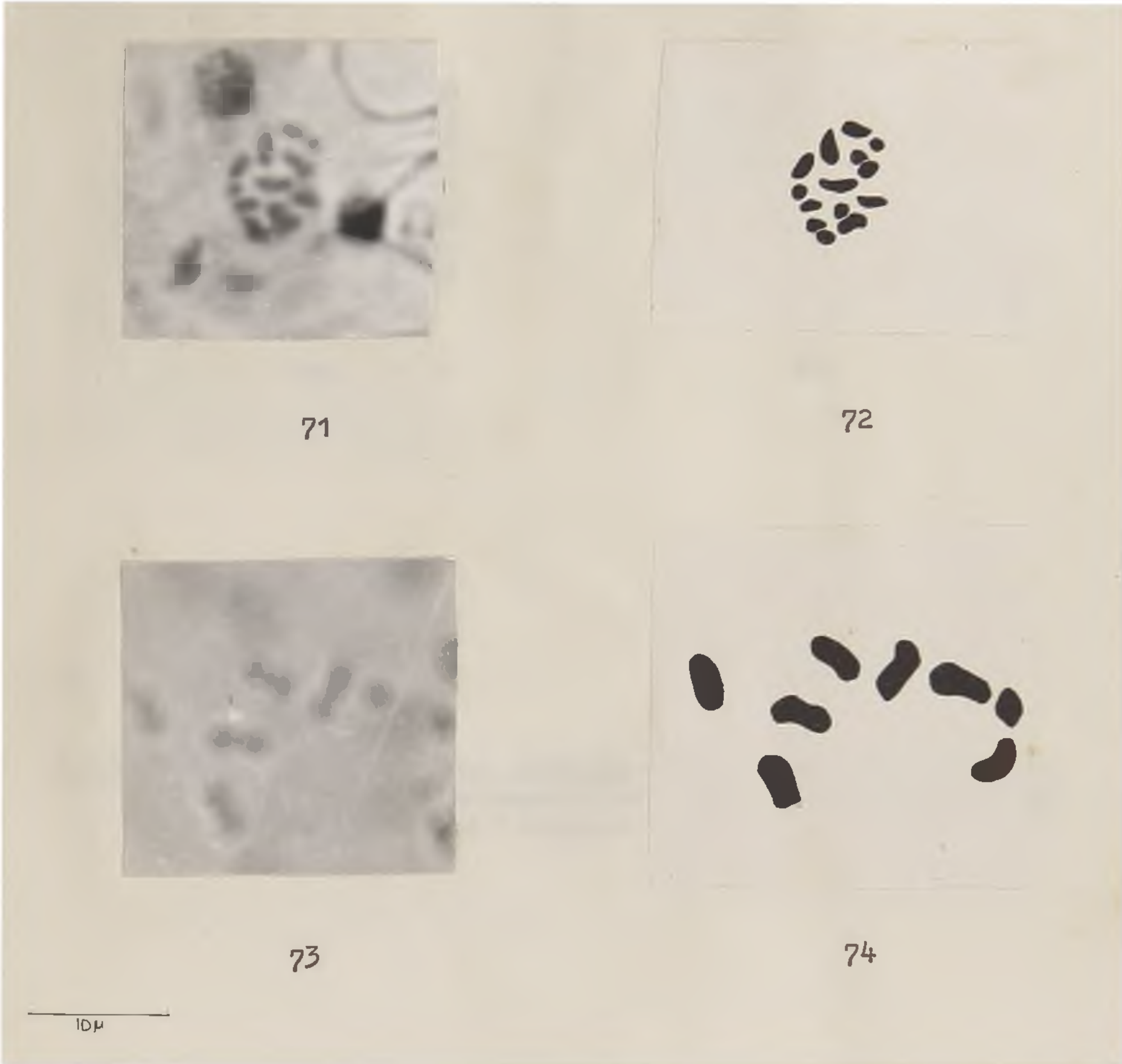

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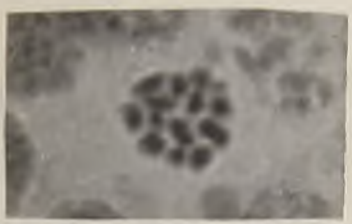

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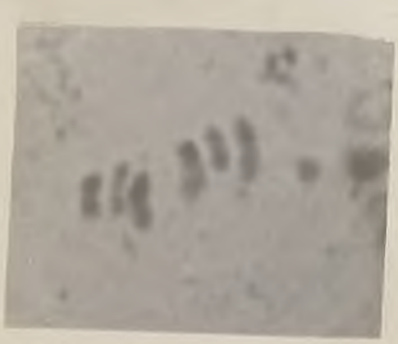
3.3.19 Figs. 75-76: Amaxosana punctata Dist. 75) microphotograph, 76) tracing of Spermatogonial metaphase with 14 chromosomes (2 long, 9 medium and 3 small).



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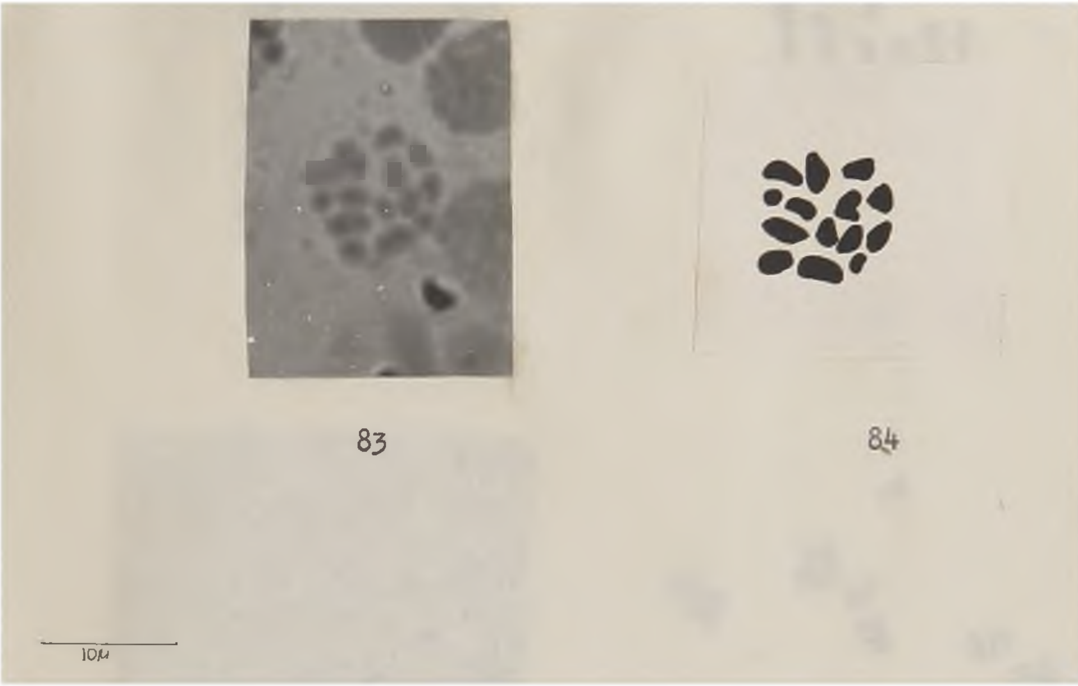
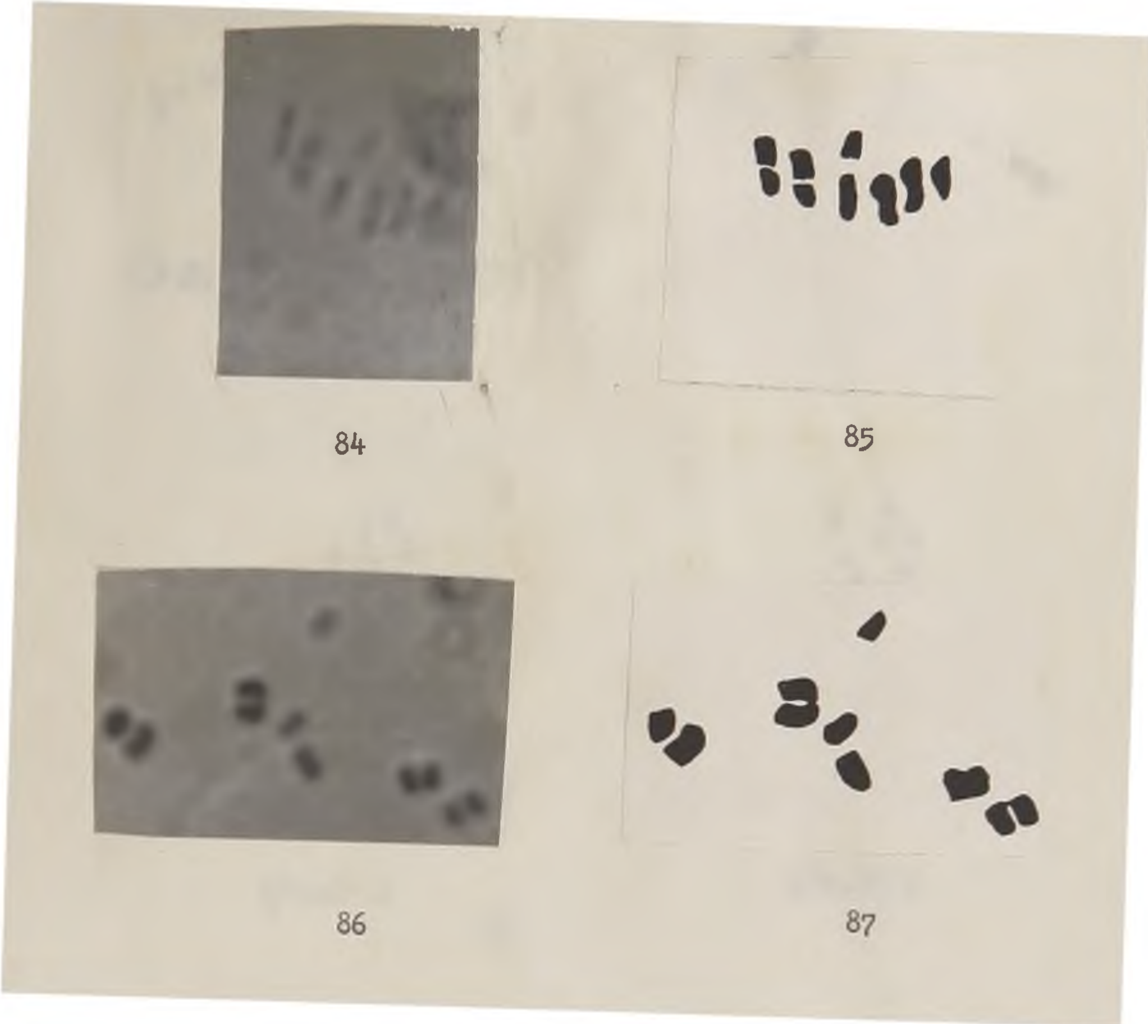
3.3.20 Figs. 77-78: Durmia haedula Stål 77) microphotograph, 78) tracing of Metaphase II, side view.

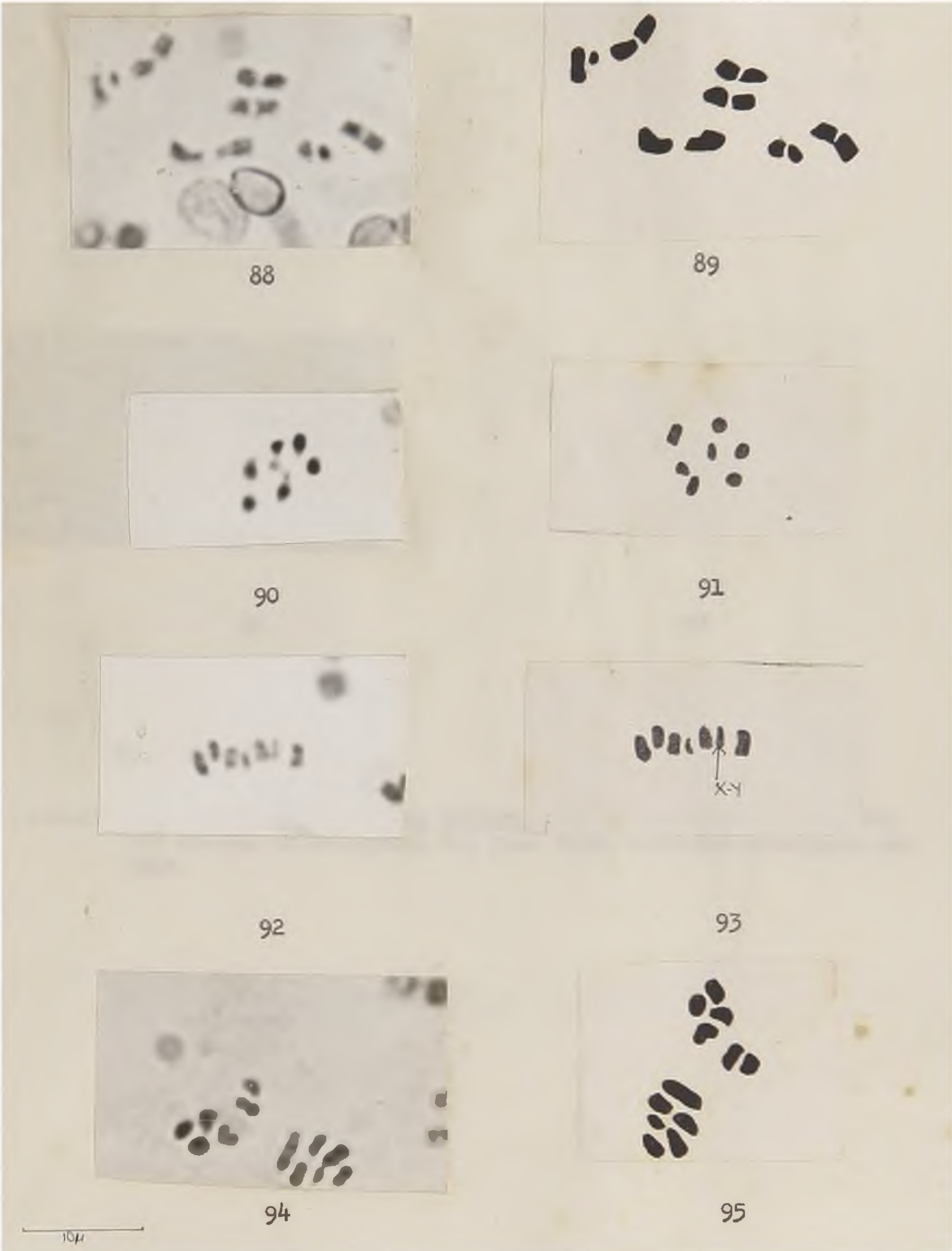
3.3.21 Figs. 79-82: <u>Durmia lutulenta</u> Stål 79) microphotograph, 80) tracing of Metaphase II, polar view, 81) microphotograph, 82) tracing of Late Anaphase II.



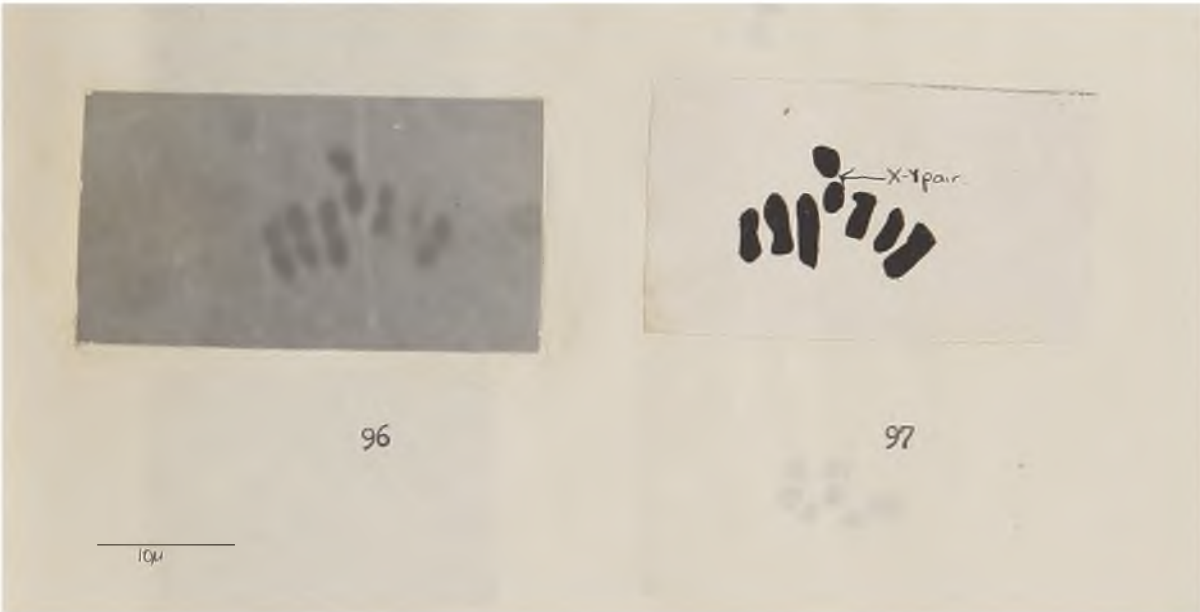
3.3.22 Figs. 83-84: Durmia sp. 83) microphotograph, 84) tracing of Spermatogonial metaphase with 14 chromosomes (3 long, 9 medium and 2 small).



3.3.23 Figs. 84-87: Dymantis grisea Jen Haar: 84) microphotograph, 85) tracing of Metaphase II, side view, 86) microphotograph, 87) tracing of Diakinesis.

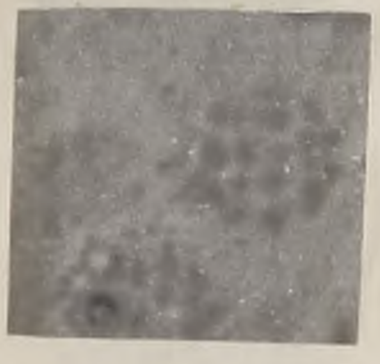


3.3.24: Figs. 88-95: *Eysarcoris inconspicuus* (H.-S) 88) microphotograph, 89) tracing of Diakinesis, 90) microphotograph, 91) tracing of Metaphase II, polar view, 92)microphotograph, 93) tracing of Metaphase II, side view with heteromorphic sex pair, 94) microphotograph, 95) tracing of Early Anaphase.



3.3.25 Figs. 96-97: Halyomorpha reflexa (Sign) 96) microphotograph, 97) tracing of Metaphase II, side view, with heteromorphic sex pair.

3.3.26 Figs. 98-101: *Lerida punctata* (Palisot Beauvois) 98) microphotograph, 99) tracing of Diakinesis, 100) microphotograph, 101) tracing of Metaphase II, polar view.

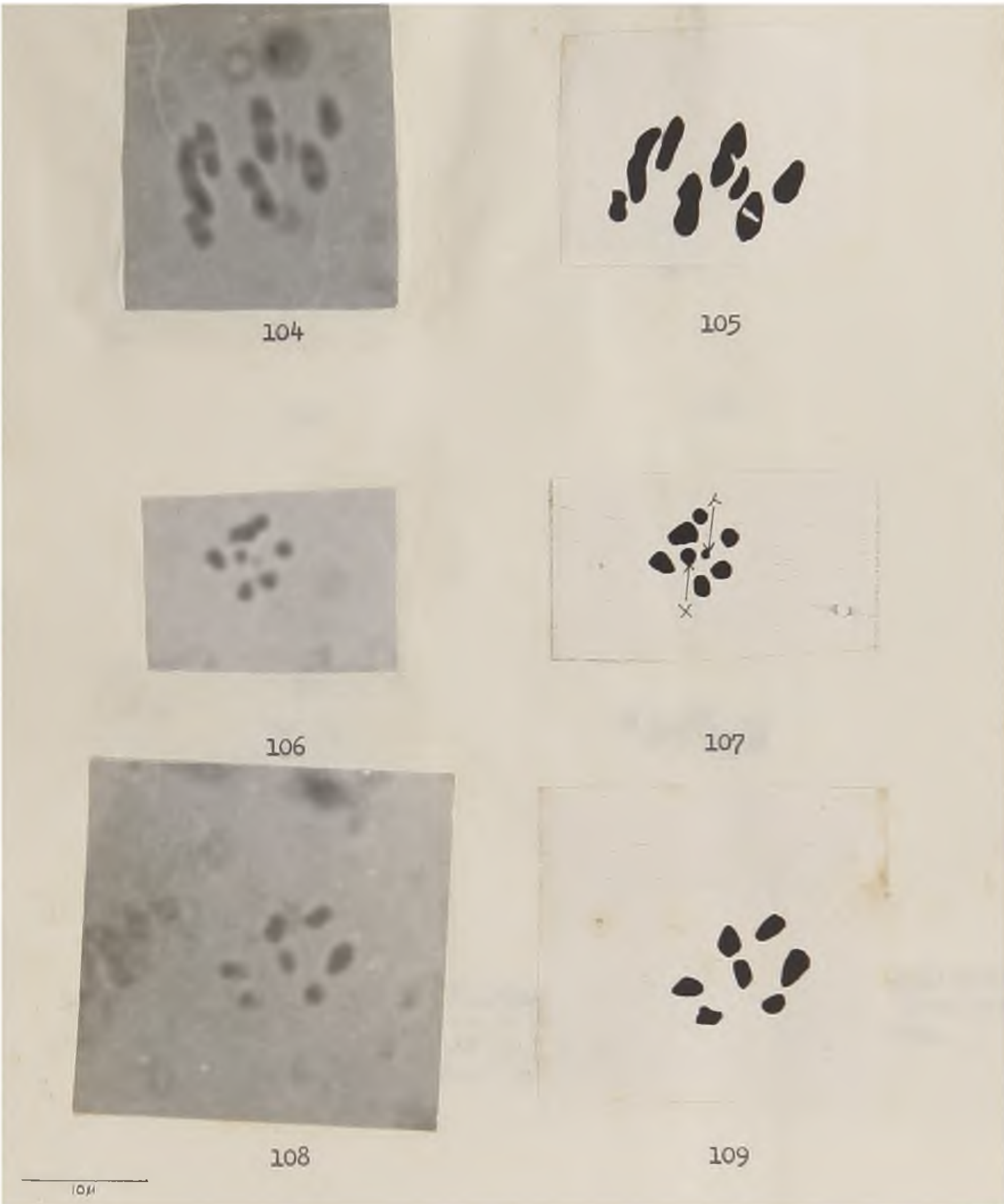


102

103

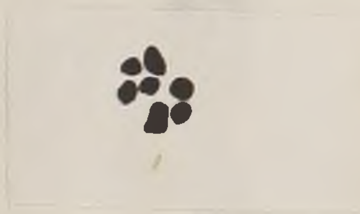
10μ

3.3.27 Figs. 102-103: *Macrorhaphis acuta* (Dall) 102) microphotograph, 103) tracing of spermatogonial metaphase of 14 chromosomes.



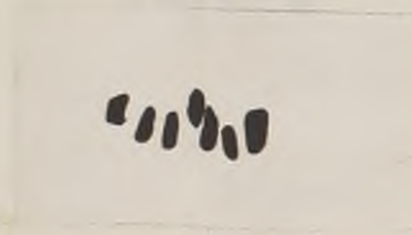
3.3.28 Figs. 104-109: Nezara viridula (Linn.) 104) microphotograph, 105) tracing of Diakinesis, 106) microphotograph, 107) tracing of Metaphase I, sex chromosomes in central position of irregular ring-like arrangement, 108) microphotograph, 109) tracing of Metaphase II, polar view.

110



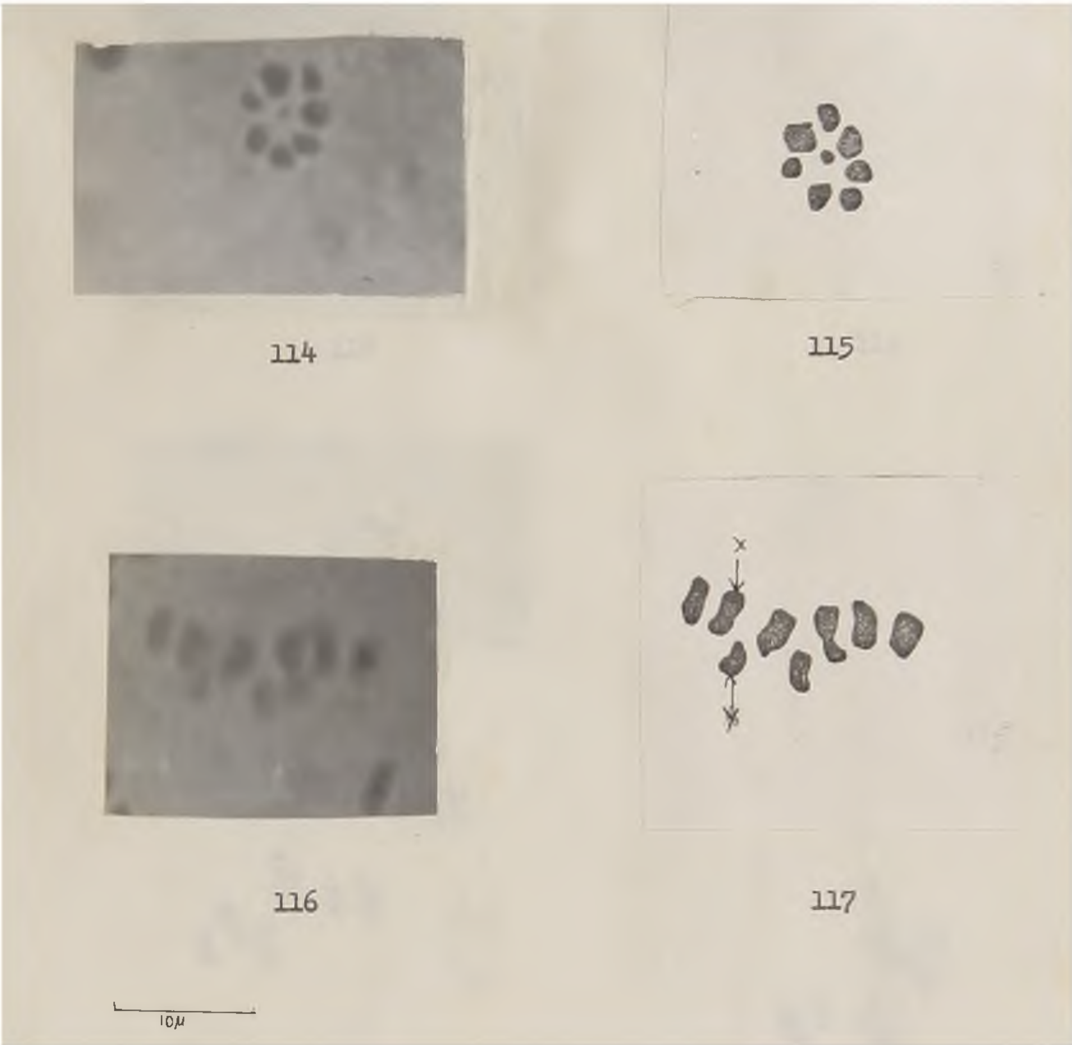
111

112



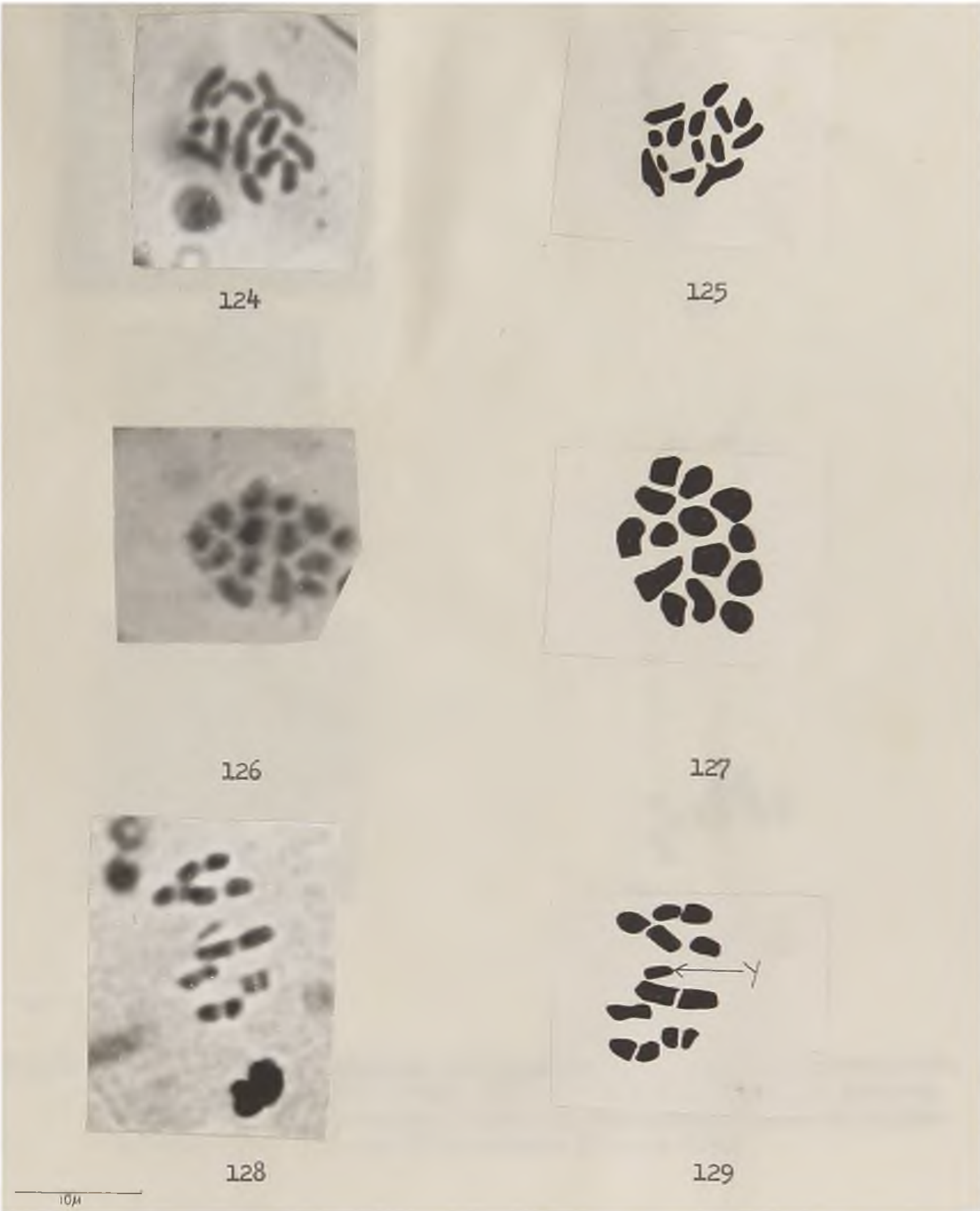
113

3.3.29 Figs. 110-113: *Nezara viridula* var *smaragdula* (Fabr.) 110) microphotograph, 111) tracing of Metaphase II, polar view. Chromosome elements smaller than in *N. viridula*, 112) microphotograph, 113) tracing of Metaphase II side view.

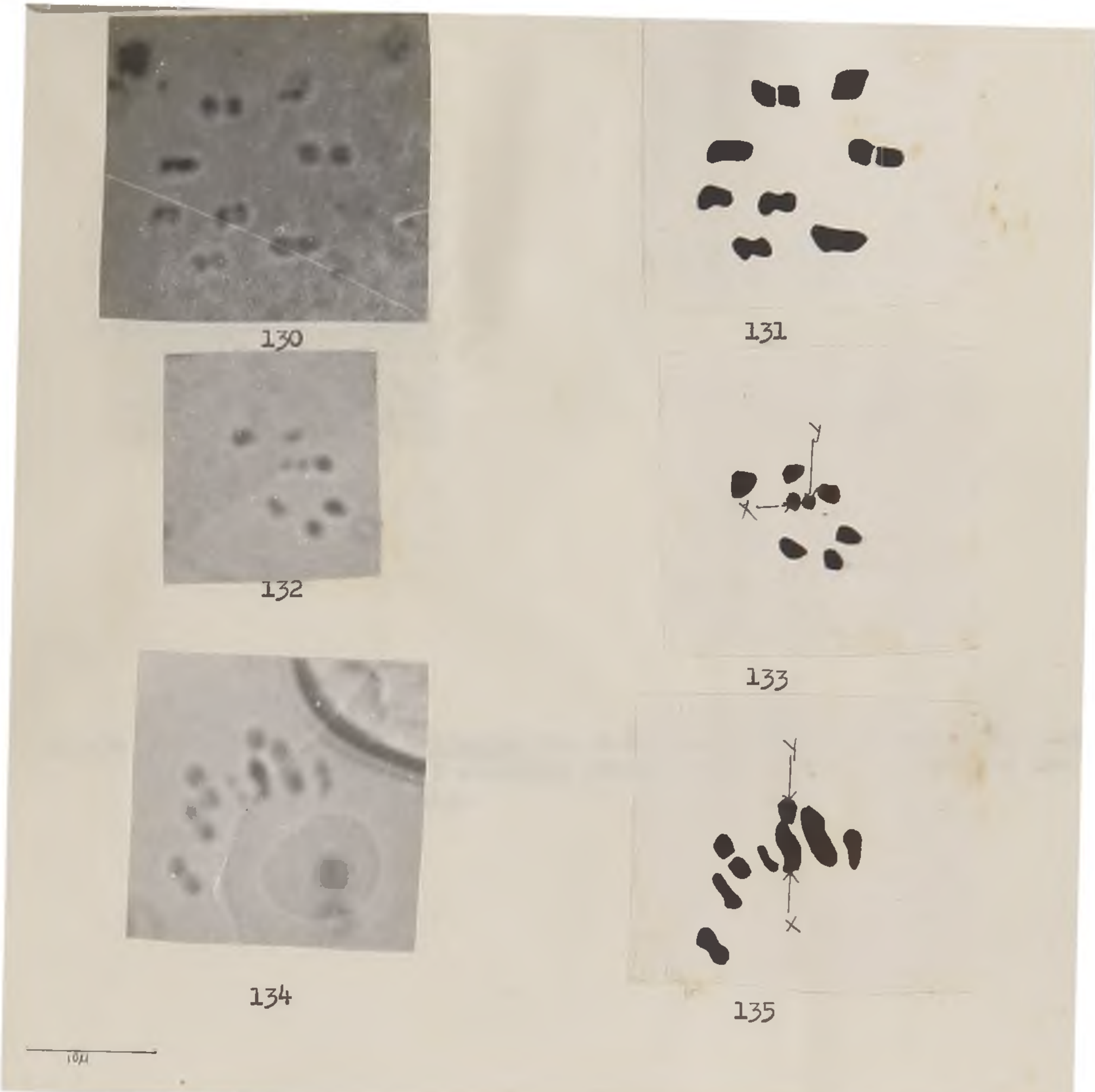


3.3.30 Figs. 114-117: *Nezara viridula* var *torquata* (Hutton) 114) microphotograph, 115) tracing of Metaphase I, 116) microphotograph, 117) tracing of Metaphase II side view. Generally the chromosome elements are larger than those of *N. viridula* and *N. viridula* var *smaragdula*.

3.3.31 Figs. 118-123: Antestia sp. 118) microphotograph, 119) tracing of Spermatogonial metaphase of 14 chromosomes (2 long, 2 medium, 8 submedium and 2 small), 120) microphotograph, 121) tracing of Metaphase II polar view, 122) microphotograph, 123) tracing of Metaphase II, side view.

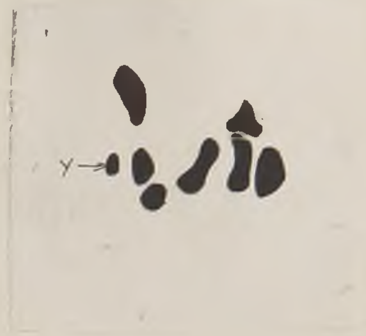


3.3.32 Figs. 124-129: Antestia sp. s.l 124) microphotograph, 125) tracing of Pro-spermatogonial metaphase, 126) microphotograph, 127) tracing of Spermatogonial metaphase with 14 chromosomes (2 long, 4 medium, 6 submedium and 2 small), 128) microphotograph, 129) tracing of Diakinesis.



3.3.33 Figs. 130-135: Antestia sp? immunda Linn. 130) microphotograph, 131) tracing of Diakinesis, 132) microphotograph, 133) tracing of Metaphase I, irregular ring-like arrangement, 134) microphotograph, 135) tracing of Metaphase II side view.

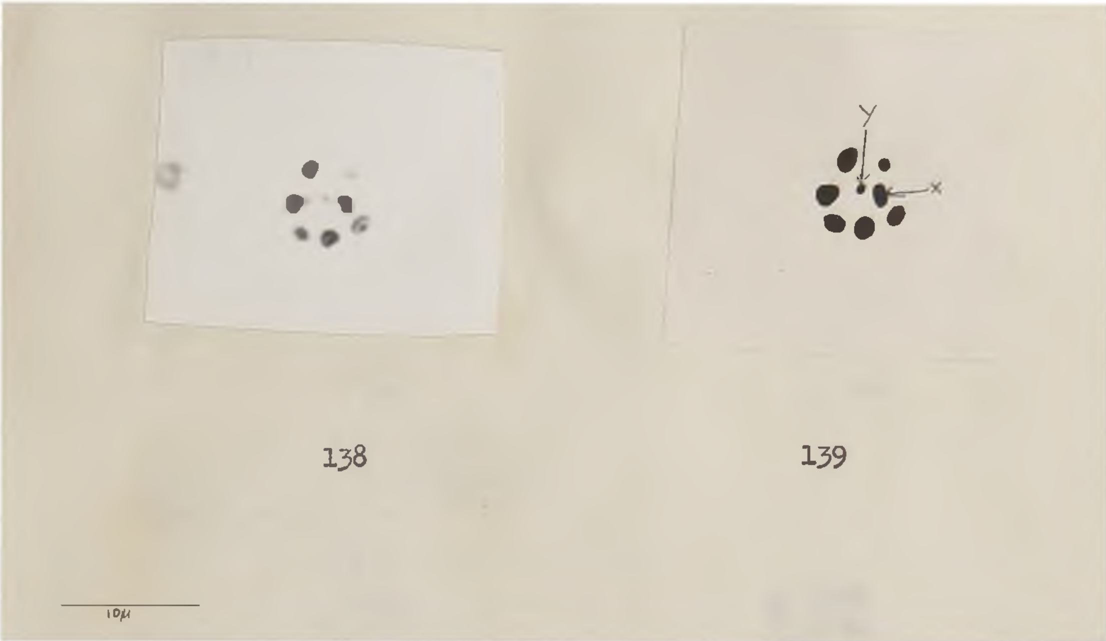
136



137

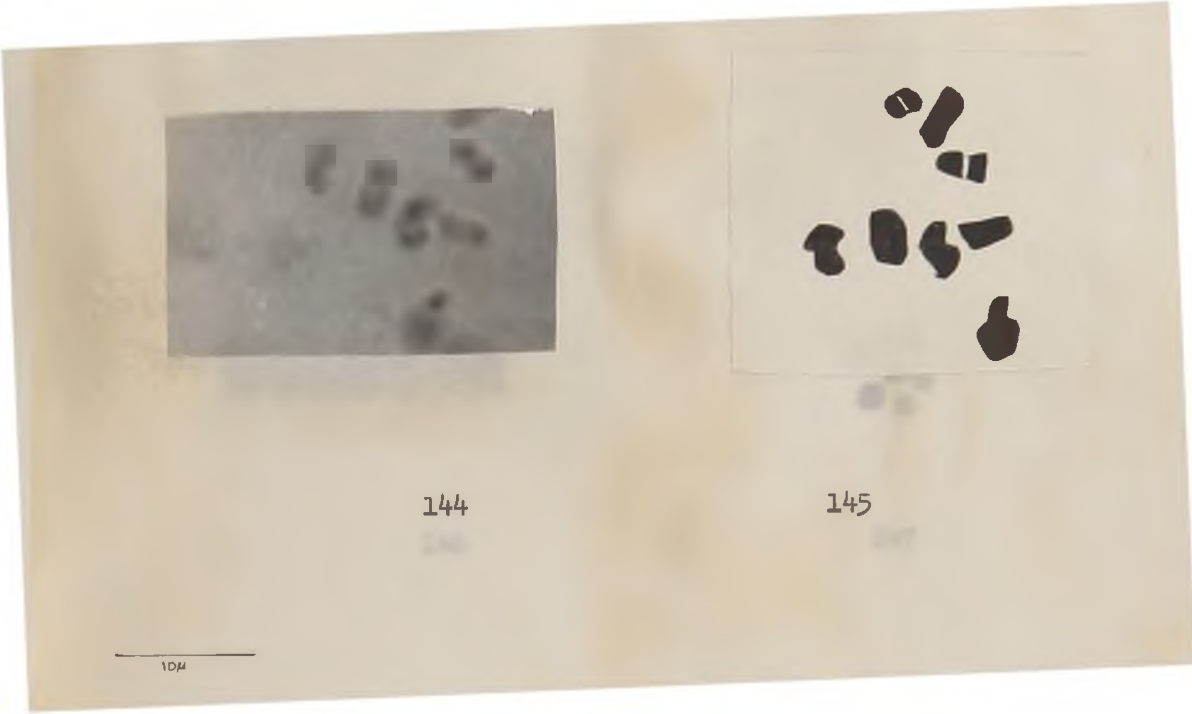
10μ

3.3.34 Figs. 136-137: Antestiopsis sp. s.l 136) microphotograph, 137) tracing of Diakinesis, 7 elements present with 1 missing probably due to imperfect squasning.



3.3.35 Figs. 138-139: *Piezodorus hybneri* (Gmelin) 138) microphotograph, 139) tracing of Metaphase I.

3.3.36 Figs. 140-143: <u>Scotinophara fibulata</u> (Schouteden) 140) microphotograph, 141) tracing of Metaphase I, irregular chromosome arrangements, 142) microphotograph, 143) tracing of Metaphase II polar view.



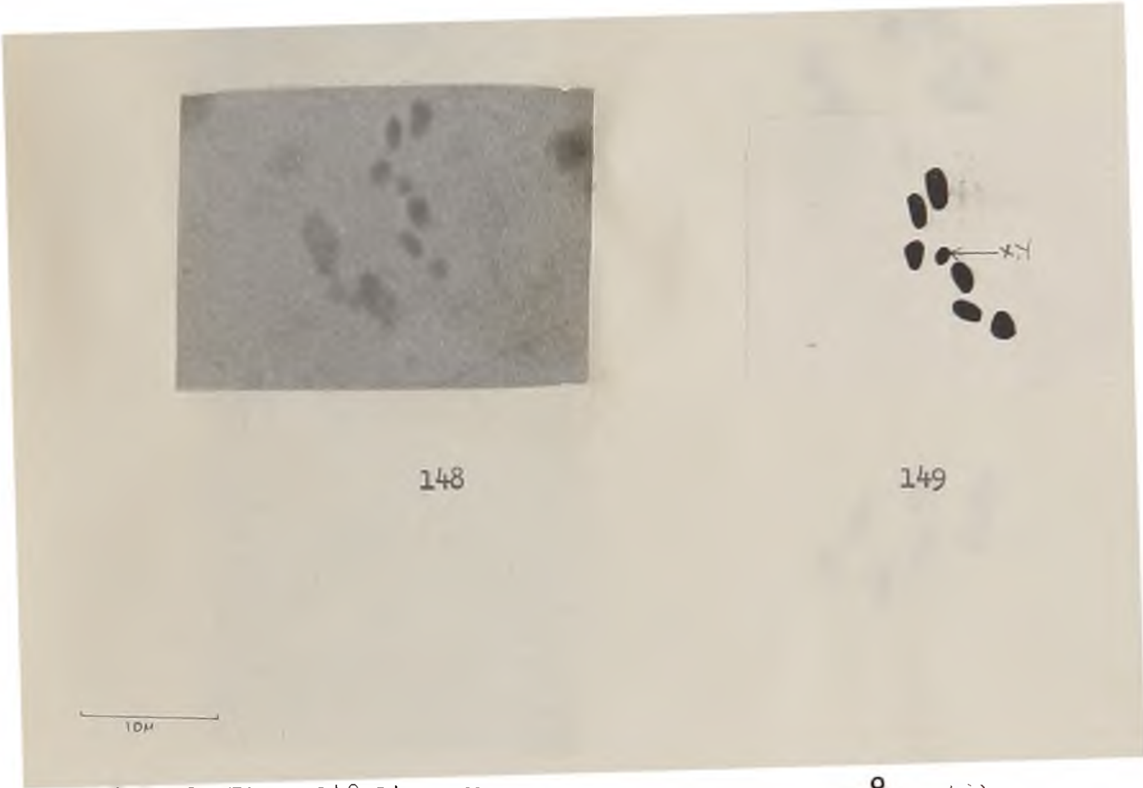
3.3.37 Figs. 144-145: *Sepontia misella* (Stål) 144) microphotograph, 145) tracing of Diakinesis.

146

147

10µ

3.3.38 Figs. 146-147: Tyoma verrucosa (Mont.) 146) microphotograph, 147) tracing of Metaphase II polar view.



3.3.39 Figs. 148-149: _Veterna sanguineirostris_ Stål 148) microphotograph, 149) tracing of Metaphase II polar view; chromosome elements irregular, arranged on equatorial plate.

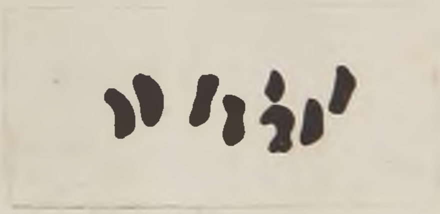
150

151

152

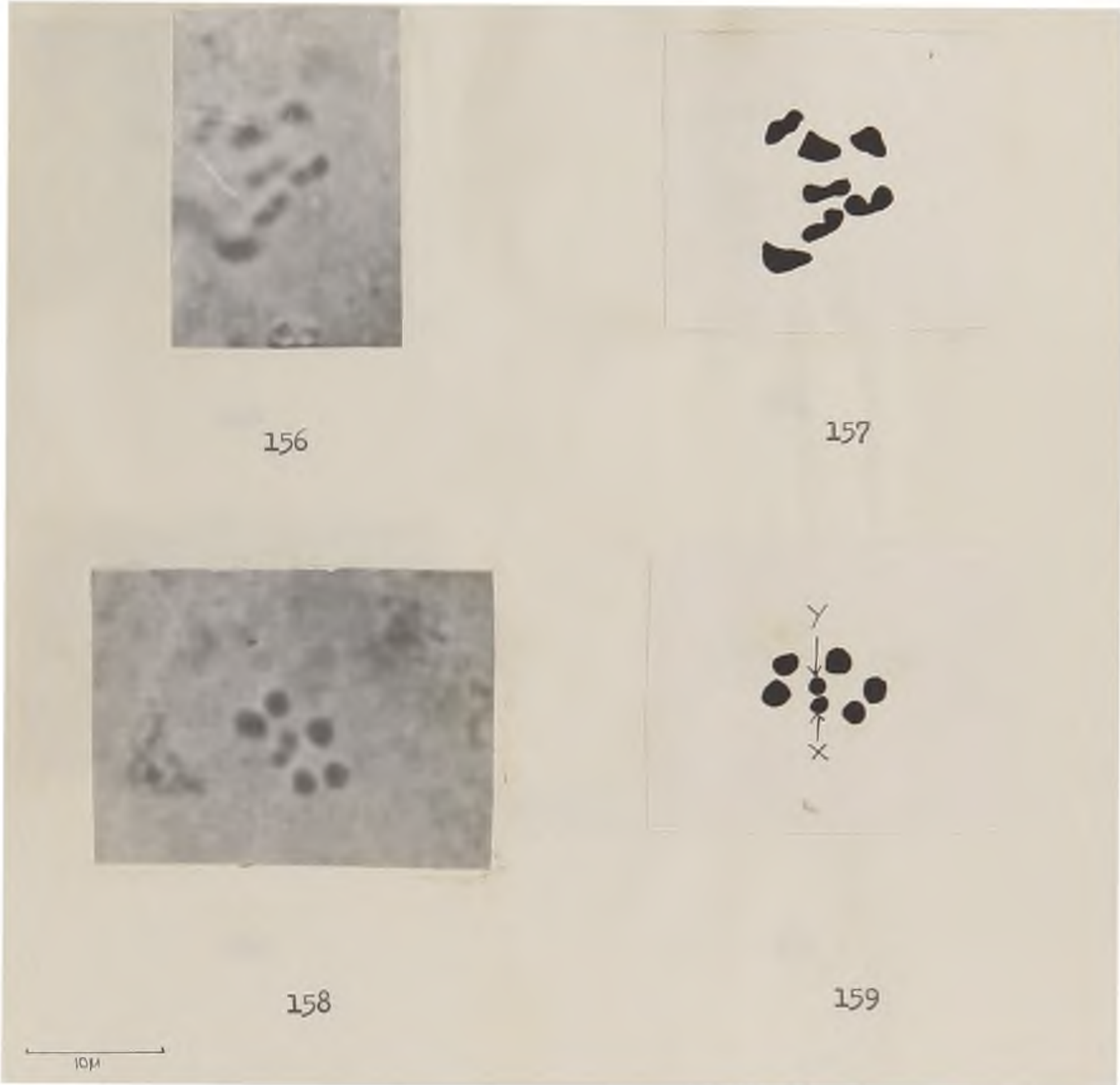
153

154



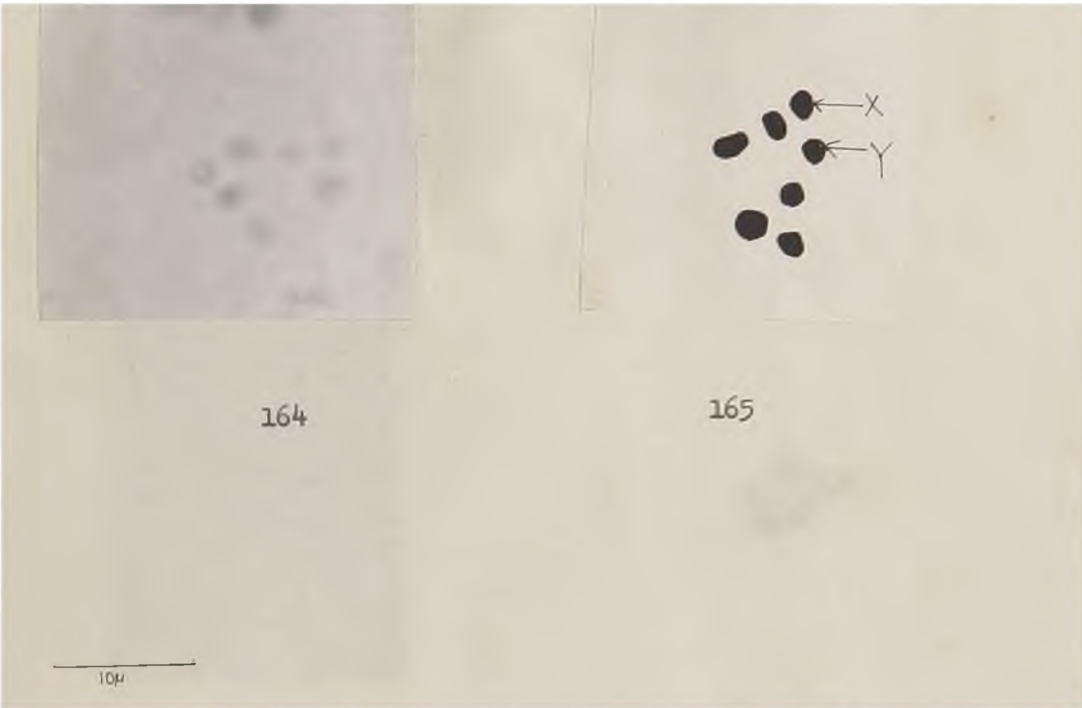
155

3.3.40 Figs. 150-155: Macrina juvenca (Burm.) 150) microphotograph, 151) tracing of Diakinesis, 152) microphotograph, 153) tracing of Metaphase I, 154) microphotograph, 155) tracing of Metaphase II side view.

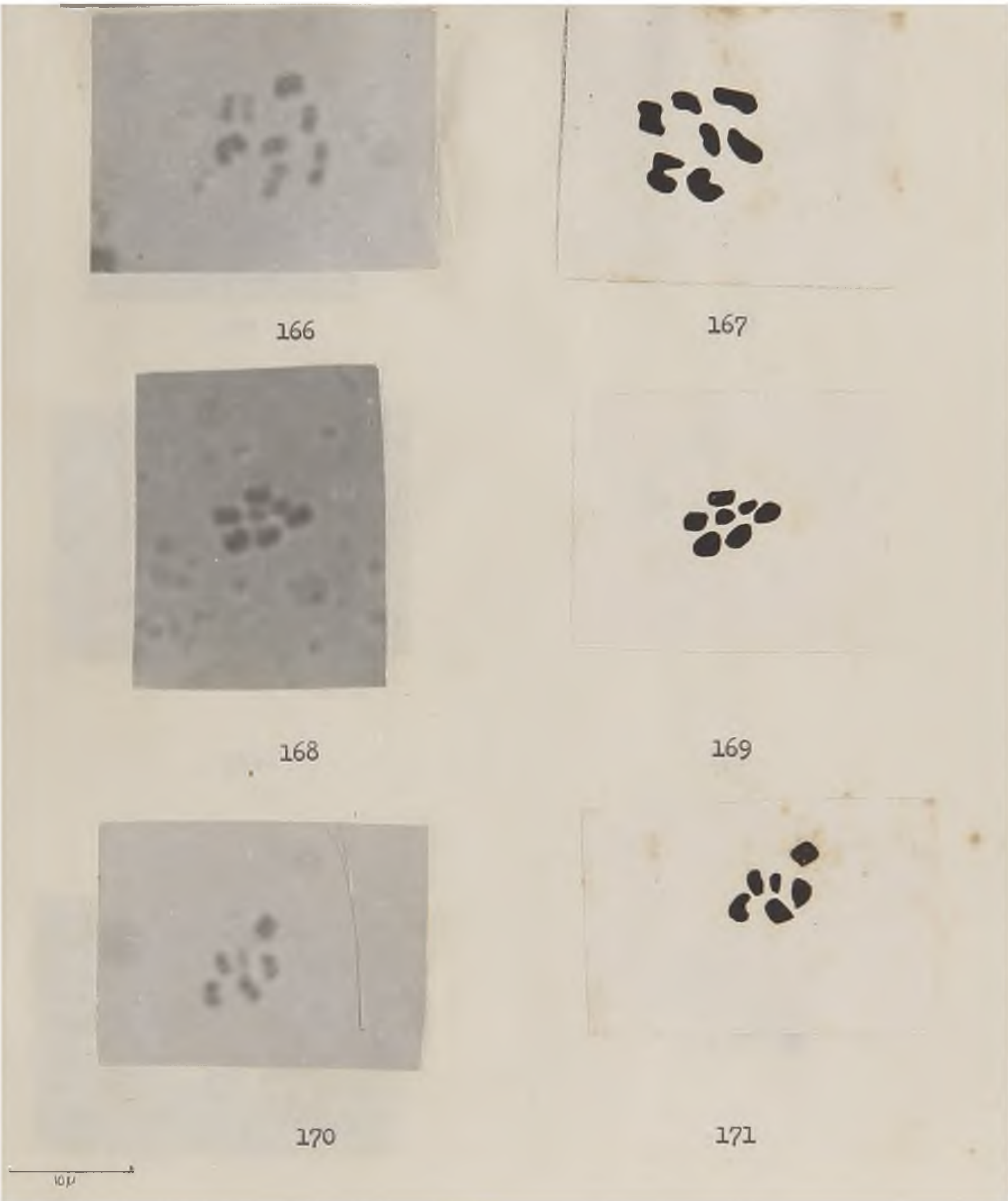


3.3.41 Figs. 156-159: Callidea duodecimpuntata Stål ♀ 156) microphotograph, 157) tracing of Diakinesis, 158) microphotograph, 159) tracing of Metaphase I.

3.3.42 Figs. 160-163: <u>Hotea subfasciata</u> (Westw.) 160) microphotograph, 161) tracing of Metaphase I, 162) microphotograph, 163) tracing of Metaphase II side view.



3.3.43 Figs. 164-165: *Sphaerocoris testudogrisea* Stål 164) microphograph, 165) tracing of Metaphase I.



3.3.44 Figs. 166-171: _Steganocerus multipunctata_ (de Geer) 166) microphotograph, 167) tracing of Diakinesis, 168) microphotograph, 169) tracing of Metaphase I, 170) microphotograph, 171) tracing of Metaphase II polar view.

172

173

174

175

176

177

3.3.45 Figs. 172-177: Brachyplatys incertus (Walker) 172) microphotograph, 173) tracing of Diakinesis, 174) microphotograph, 175) tracing of Metaphase I, 176) microphotograph, 177) tracing of Metaphase II, side view.

3.3.46 Figs. 178-179: Brachyplatys testudonigra Stål 178) microphotograph, 179) tracing of Diakinesis.

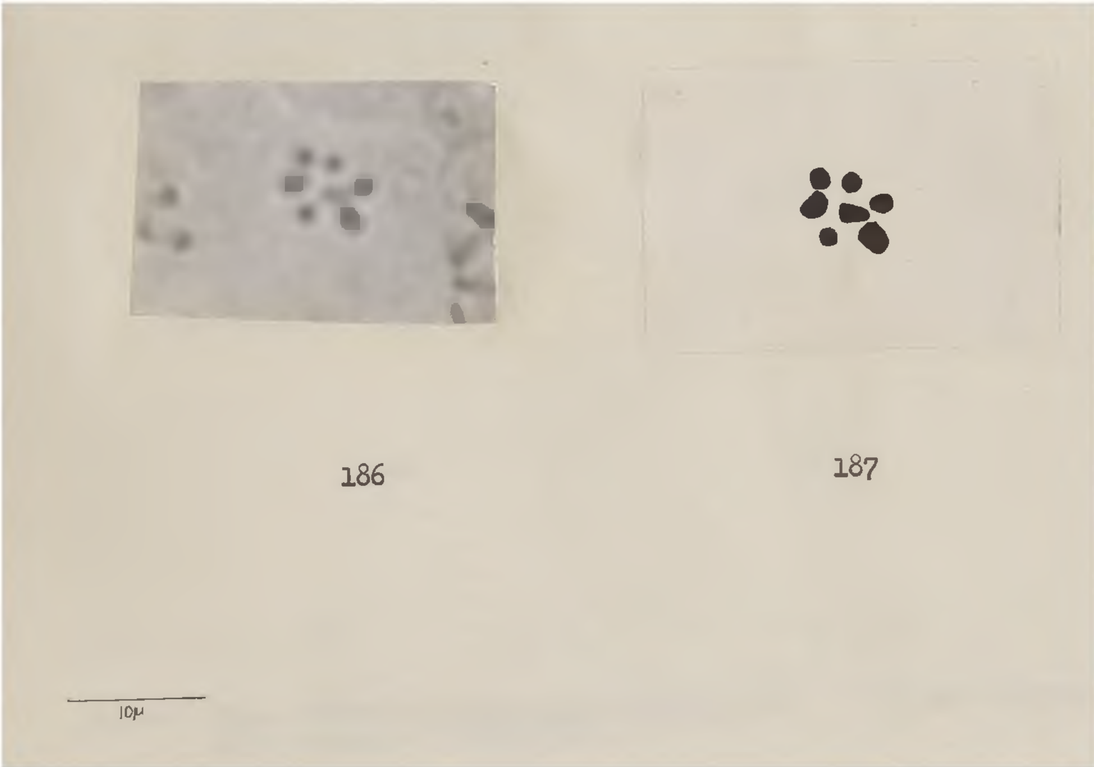
3.3.47 Figs. 180-183: <u>Coptosoma nubila</u> Germ. 180) microphotograph, 181) tracing of spermatogonial metaphase with 12 chromosomes (2 long, 8 medium and 2 small), 182) microphotograph, 183) tracing of Metaphase II polar view.

184

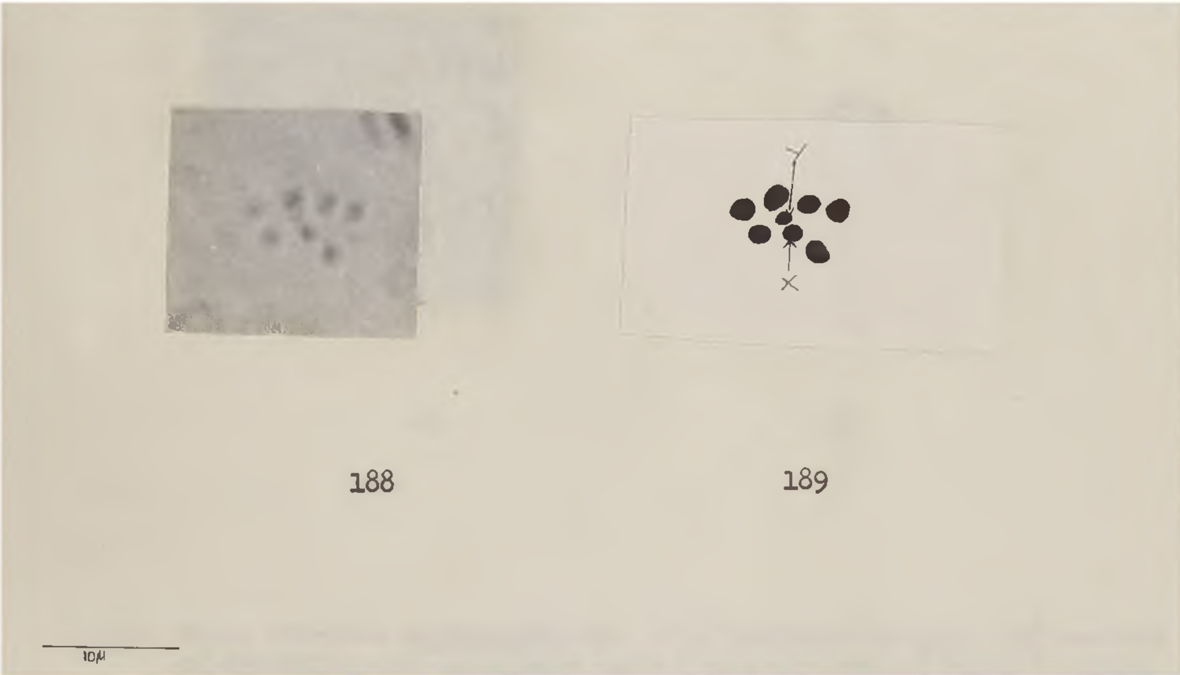
185

10μ

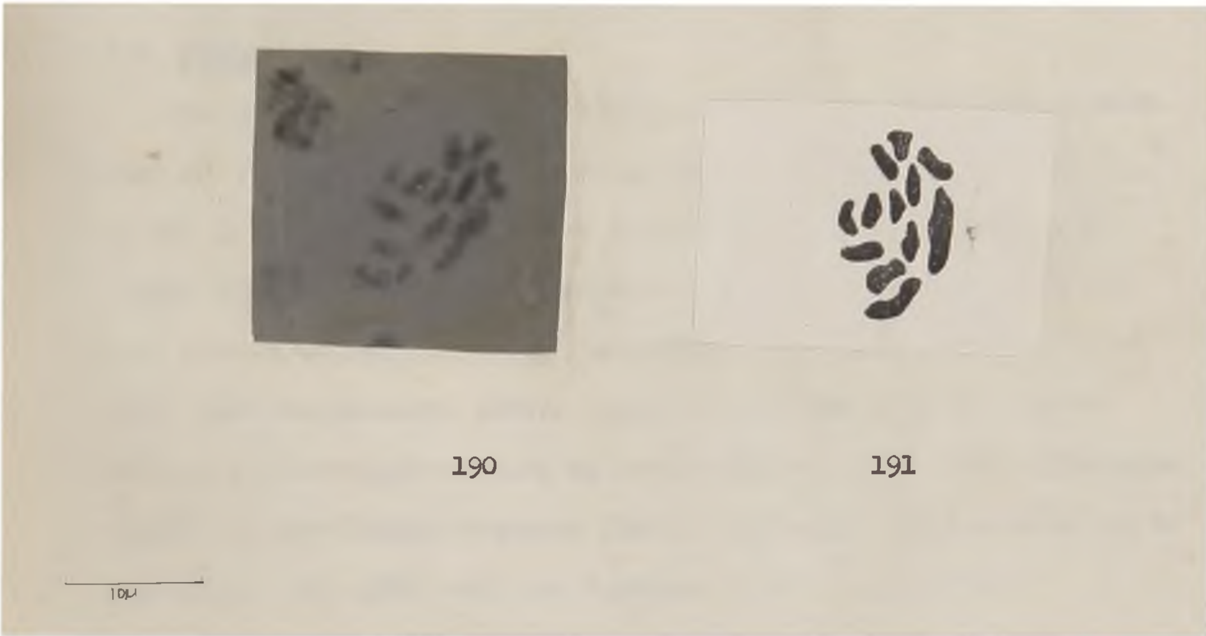
3.3.48 Figs. 184-185: Coptosoma stali Mont. 184) microphotograph, 185) tracing of Diakinesis.



3.3.49 Figs. 186-187: Coridius cuprifer (westw.) 186) microphotograph, 187) tracing of Metaphase II polar view.



3.3.50 Figs. 188-189: Piezosternum calidum Stål 188) microphotograph, 189) tracing of Metaphase I.



3.3.51 Figs. 190-191: Macroscytus sp. 190) microphotograph, 191) tracing of Spermatogonial metaphase with 12 chromosomes (2 long, 8 medium and 2 small).

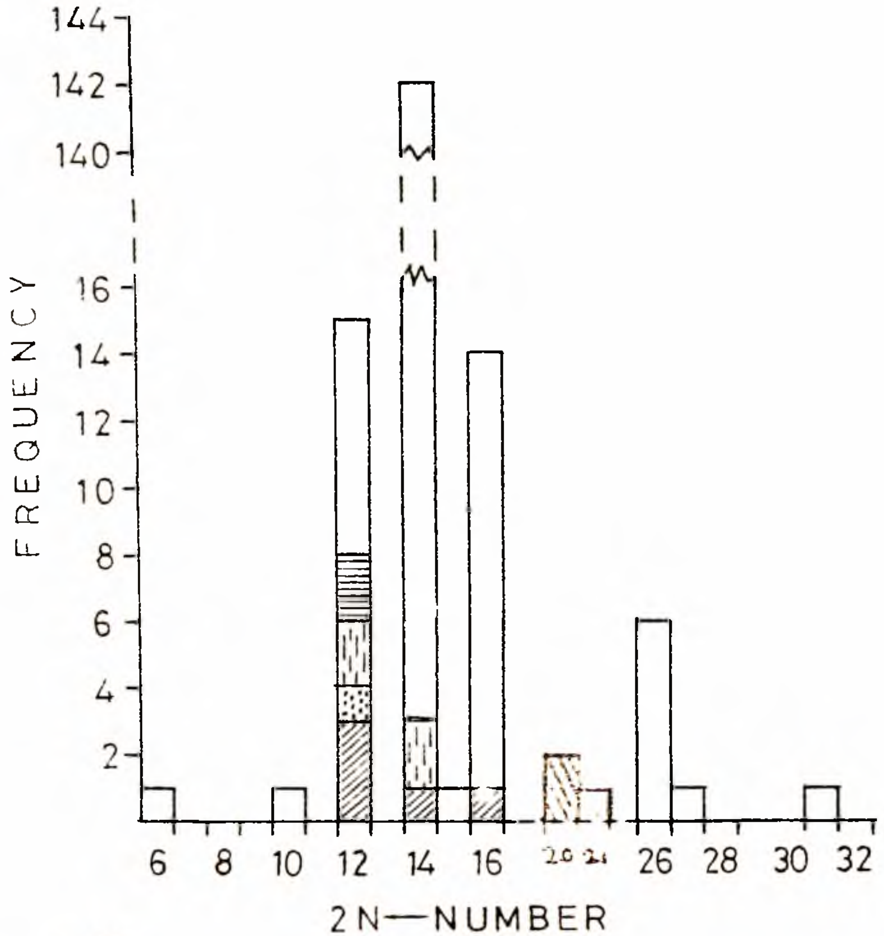
SECTION 4

DISCUSSION

4.1 SYSTEMATICS:

The Pentatomoidea are essentially tropical or subtropical insects. They are mostly phytophagous although some are predacious. There is as yet no general agreement as on their higher classification. Some groups which are regarded as distinct families by some authors have been treated as subfamilies of Pentatomidae by others (e.g Schouteden, 1905, 1910 and Kirkaldy, 1909). Recently, however with the results of work by investigators, such as Leston (1954a, 1954b, 1955), Southwood (1956), Scudder (1959), Miyameto (1961), Kumar(1962, 1965 , 1968a and b) and Cobben 1968, 1978) etc. the families formerly treated as subfamilies under Pentatomidae have been elevated to family status.

Kirkaldy (1909) lists over 3,400 species of the Pentatomidae and includes them under subfamilies. Brues, Melander and Capenter (1954) erect a superfamily the Scutelleroidea/Pentatomoidea, with the following families under it: Cydnidae, Corimelaenidae, Plataspidae, Scutelleridae, Podopidae, and Pentatomidae. China and Miller (1959) raised the Aphylidae and Phloeidae to family status, thus further reducing the subfamilies under Pentatomidae as listed by Kirkaldy (1909). Leston (1958) represented the central group of Pentatomoidea families with the series: Tessaratomidae, Scutelleridae, Cydnidae, Aphylidae,

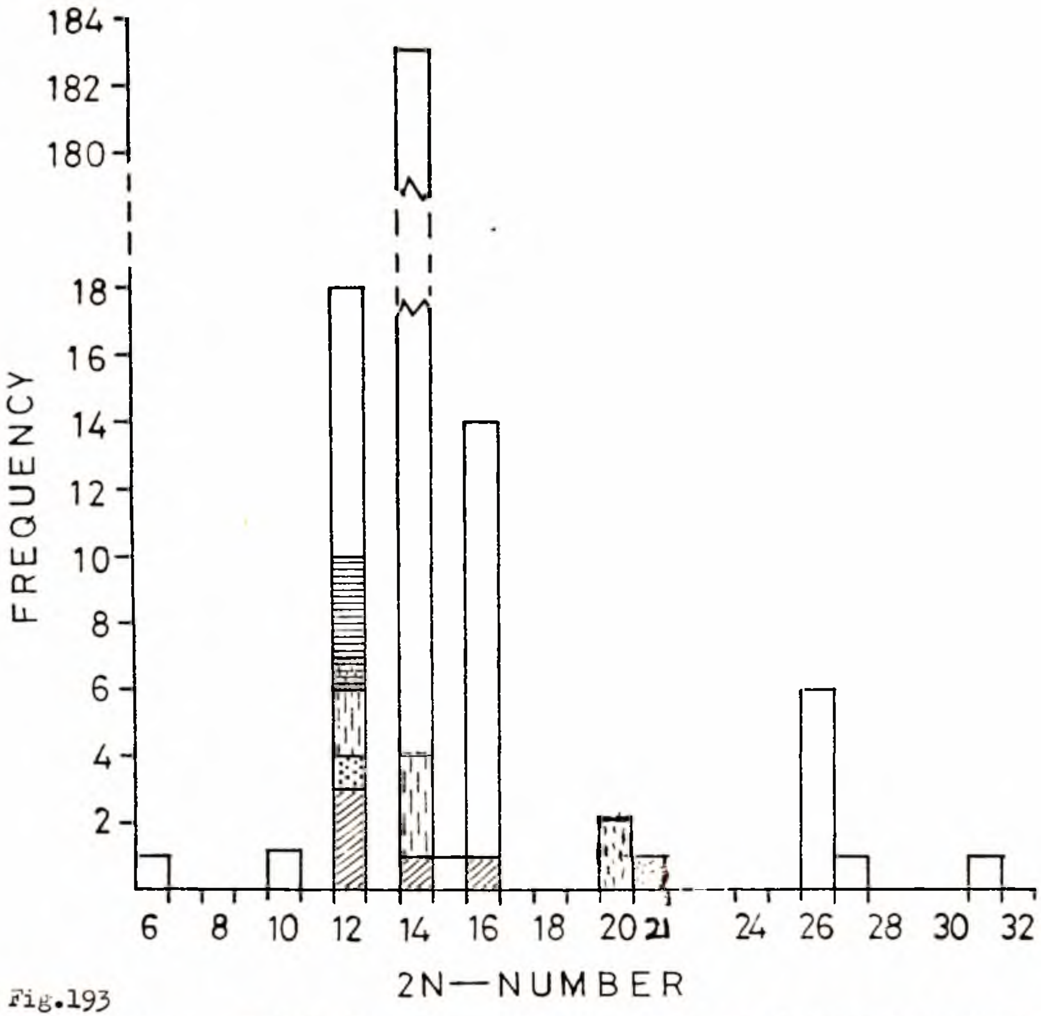


KEY

FAMILY	2N-No	FREQ
Pentatomidae	6 10 12 14 15 16 26 27	1 1 4 142 1 14 6 1
Tessaratomidae	12	3
Cydnidae	12 31	6 1
Acanthosomatidae	12	6
Scutelleridae	12	15
Brachyplatidae	12	8
Dinidoridae	14 20 21	3 2 1
Eumenotidae	14	1
Urostylidae	16	1

Fig.192

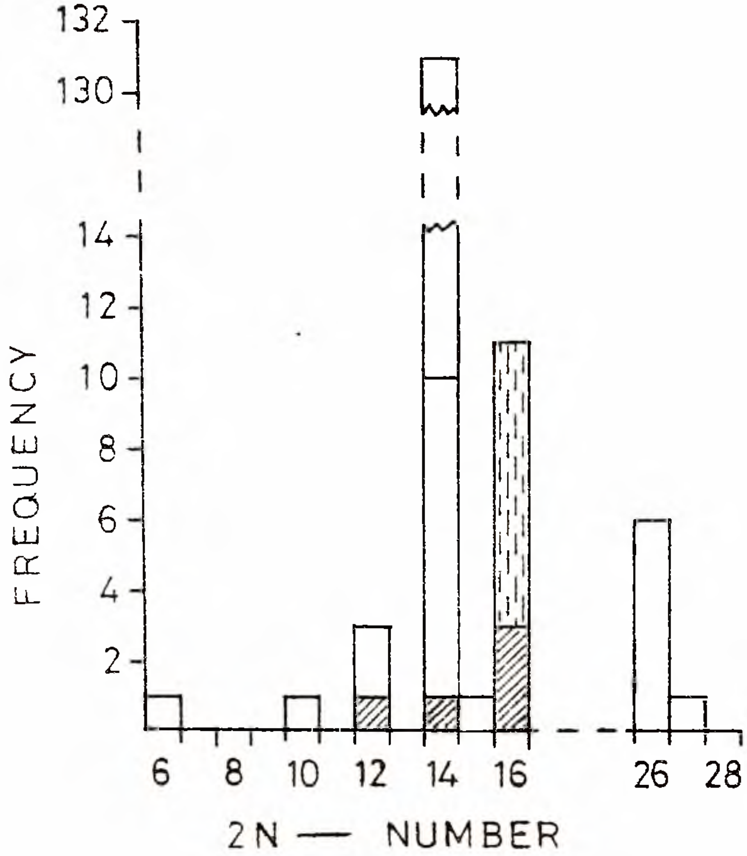
Distribution of 2N-Numbers in families of Pentatomoidea Cytologically studied and already published.



KEY

FAMILY	2N-No	FREQ.
Pentatomidae	6 10 12 14 15 16 26 27	1 1 4 183 1 14 6 1
Tessaratomidae	12 14	3 1
Cydnidae	12 31	7 1
Acanthosomatidae	12	6
Scutelleridae	12	18
Brachyplatidae	12	10
Dinidoridae	21 14 20	4 2
Eumenotidae	14	1
Urostylidae	16	1

Fig.193
Distribution of 2N–Numbers in families of Pentatomoidea Cytologically studied to date

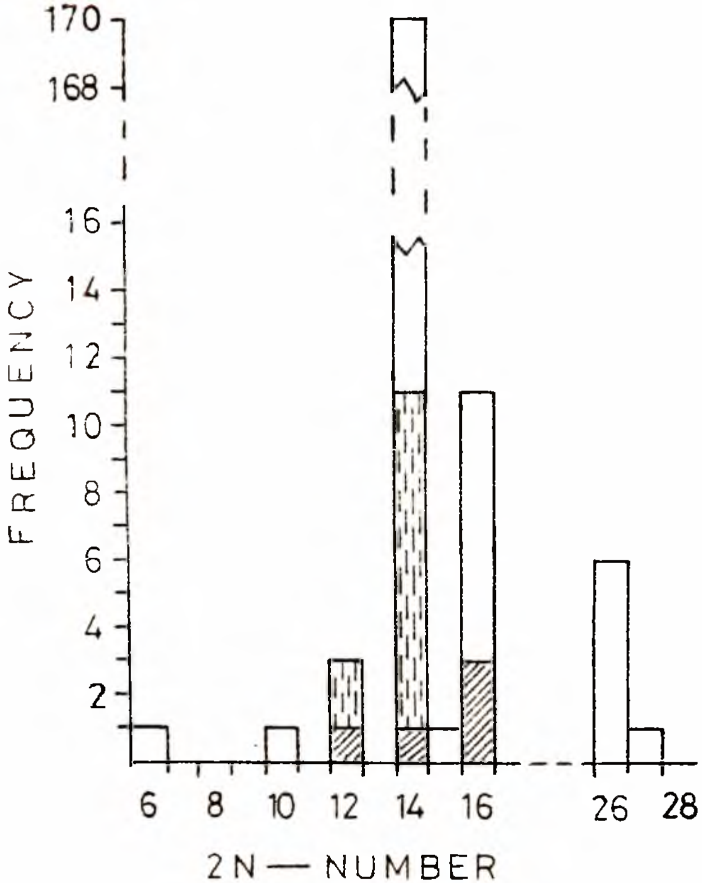


KEY

SUB FAMILY	2N-No	FREQ
Pentatominae	6	1
	10	1
	12	3
	14	131
	15	1
	16	11
	26	6
	27	1
Amyoteinae	12	1
	14	10
	16	3
Podopinae	14	1

Fig.194

Distribution of 2N-Numbers in 170 species of Pentatomidae Cytologically studied and already published.



KEY

SUB FAMILY	2N–No	FREQ
Pentatominae	6	1
	10	1
	12	3
	14	170
	15	1
	16	11
	26	6
	27	1
Podopinae	14	1
Phyllocephalinae	14	1
Amyoteinae	12	1
	14	11
	16	3

Fig.195

Distribution of 2N-Numbers in 211 species of Pentatomidae Cytologically studied up to date.

Plataspidae, Pentatomidae, Dinidoridae, Urostylidae and Acanthosomatidae, with Phloeidae as an early off shoot of Tessaratomidae. Recently, the book entitled, "The Insects of Australia" (Mackerras, 1970) includes the following families occurring in Australia under the superfamily Pentatomoidea: Tessaratomidae, Dinidoridae, Scutelleridae, Plataspidae, Aphylidae, Lestoniidae, Urostylidae, Cydnidae, Acanthosomatidae, and Pentatomidae. A new family, Thaumastellidae Štys has recently been erected by Štys (1964) on account of its primitive chorionic structure, as revealed by the eggs of <u>Thausmastella aradoides</u>. Štys' (1964) conclusion that Thausmastellidae must be regarded as an early offshoot of the pentatomoid stock is confirmed by Cobben (1968).

4.2 KARYOTYPES AND CLASSIFICATION:

From the literature, the chromosome number of only 217 species of Pentatomoidea is known (Fig. 192, Appendix Tables 3, 6-11). There may be a few errors of omission which may be attributed to the limited library facilities available to me. The present work has examined forty-nine (49) species where chromosome number had never been worked out earlier. In all fifty-five (55) species belonging to six families of Pentatomoidea were examined, out of this only six species had previously been examined. This brings the number of species of Pentatomoidea with known chromosome number to 266 (Fig. 193).

4.3 FAMILY PENTATOMIDAE (Figs. 1 - 155):

This is the largest family among the group Pentatomoidea, and probably presents the most common species among its members. Until recently almost all the other families of the Pentatomoidea were placed under the Pentatomidae as subfamilies, but following morpho-taxonomical studies on genitalia, alimentary canal, salivary glands, and wing venation, etc. the Cydnidae, Tessaratomidae, Dinidoridae, Brachyplatidae, Scutelleridae, Acanthosomatidae and Urostylidae, were all raised to family status.

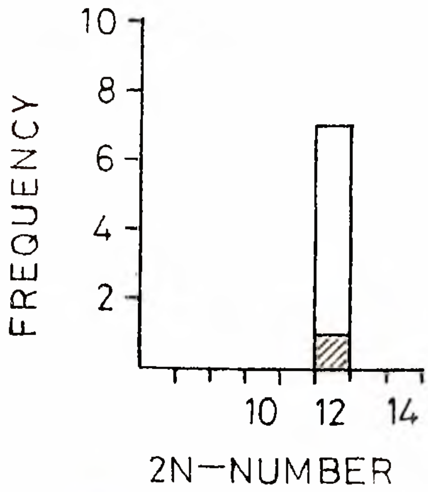
The Pentatomid bugs, being easily available, have had their cytological data relatively well extended. However, since the review of Manna (1958), little work seems to have been published on their chromosomes. The Pentatomidae is more or less uniform with regard to chromosome number with the elevation of the subfamilies Brachyplatinae, Cydninae, Tessaratominae, Scutellerinae, and Dinidorinae raised to family status. This family is characterised by 14 chromosomes (modal number), XX:XY type of sex determination, absence of m chromosomes in the species so far studied, a characteristic disposition of the first and second metaphase chromosomes, in which the autosomes are arranged in the form of a ring around the periphery of the spindle, and the sex-chromosomes usually lie at the centre (Manna, 1958).

Two hundred and eleven species (211) of four subfamilies of Pentatomidae are so far known cytologically (Appendix Table 4). The Amyoteinae (Asopinae) are known cytologically through the study of fifteen species (Fig. 195). In the males, three diploid numbers of

12, 14 and 16 have been reported, of which 14 seems to be the original (Manna, 1951, 1958, Makino 1951). Manna (1958) explains this by the fact that most of the species so far studied (11 out of 15) possess this number, one species Oechalia patruelis has 12 chromosomes. The number 16 is found in three species of Apateticus (Podisus). Manna (1958) suggests that since two species of Apateticus and one of Oechalia have 14 chromosomes, it can be concluded that the 16 chromosome species in the latter are derived from the basic 14 in Amyoteinae.

A species each of Podopinae and Phyllocephalinae (from this study) is known, and in each case the chromosome number is 14.

Pentatominae possess the most diversified chromosome numbers, ranging from six to twenty-seven among the one hundred and ninety-four (194) species studied up to date (Appendix Table 4, Fig. 195). As Manna (1958) puts it "it is apparent from the cytological data that this subfamily includes heterogenous groups". Whilst all the species in the tribes of Pentatominae, namely, Discocephalini, Edessini, Halyini and Sciocorini, examined have 14 chromosomes (Manna, 1958). The tribe Pentatomini evinces a marked conservatism as to changes in the number and behaviour of its chromosomes. Of the one hundred and ninety-four (194) species examined, one hundred and seventy (170) have chromosome number of 14, eleven possess 16, in six the complement is 26, in three the number is 12 each, and one

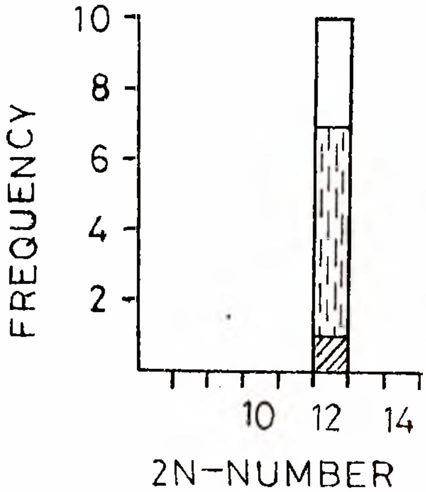


KEY

SUB FAMILY	2N-No	FREQ.
Scutellerinae	12	7
Pachycorinae	12	1
Eurygastrinae	12	7

Fig.196

Distribution of 2N-Numbers in 15 species of Scutelleridae Cytologically studied and already published.



KEY

SUB FAMILY	2N-No	FREQ.
Scutellerinae	12	10
Pachycorinae	12	1
Eurygastrinae	12	7

Fig.197 /

Distribution of 2N-Numbers of Scutelleridae Cytologically studied to date.

species each contains 6, 10, 15 and 27 chromosomes (Fig. 195). So far as our evidence goes, the few deviations from the characteristic chromosome of 14, may be due primarily to processes involving fusion and fragmentation (Schrader, 1947, Schrader and Hughes-Schrader, 1956). In all Pentatomini (except Thyanta calceata) the males have a XY sex determining mechanism and in all it is in the second meiotic division that the X and Y segregate from each other and enter separate spermatids. It should be mentioned here that the ways in which the cytological changes here described have come about are still a matter of conjecture (Hughes-Schrader and Schrader, 1956). There is nearly always a rather even gradation in size from the largest to the smallest chromosomes in a complement. This suggests that extensive rearrangements have not been common in the chromosomal evolution of the Pentatomini. Since species with less than 14 chromosomes are even rarer, it would appear that factors additional to fragmentation and fusion are at work to make such changes permanent, and that these are not often present (Schrader, 1947).

4.4 FAMILY SCUTELLERIDAE (Figs. 196 and 197):

There is considerable disagreement over the status of this group. Reuter (1912), van Duzee (1917), Scudder (1959), Cobben (1968) and several others assign it a family status, while others like Kirkaldy (1909), Pruthi (1925), Southwood (1956) and Miyamoto (1961) have considered it to be of subfamily rank. Southwood (1956), in dealing with the eggs of Pentatomoidea, treated this group as a subfamily, but Cobben (1968) points out that "scutellerid eggs, can be distinguished from Pentatomid eggs by the persistence of some long internal micropylar canal" and that "clear familial dichotomy is suggested since some Pentatomid species have the same low anagenetic level for their egg structures (arrangement of micropyles and incomplete pseudoperculum) as scutelleridae but lack the internal canal", thus the scutelleridae cannot be placed under the Pentatomidae. Kumar (1962, 1964, 1965), working on the genitalia and salivary glands of this group and reviewing other evidence confirmed that the scutelleridae, indeed deserves a family status within the superfamily Pentatomoidea.

Chromosome number of eighteen species, belonging to eleven genera, including the three species, Callidea duodecimpunctata (Stål), Hotea subfasciata (Westw) and Steganocarus multipunctata(de Geer) examined in this study (Figs. 156 - 171) is known. All the species possess 12 chromosomes (Figs 196-197), which can therefore be taken as the characteristic number for the Scutelleridae. However, according to Manna (1958), of the four or five species of Eurygaster, E. maurus is reported by Geitler (1938) to have individuals with 14 chromosomes (Appendix Table 8). All the species of the Scutelleridae are said to have the same general plan of meiosis with a XY:XX type of sex determination comparable with that of the pentatomid bugs (Manna, 1958).

4.5 FAMILY BRACHYPLATIDAE (PLATASPIDAE):

It is usual to give it a family status these days. From morpho-taxonomical studies on the genitalia and salivary glands, Kumar (1962), observed that the Brachyplatidae are a specialized group exhibiting close resemblances to Cydnidae, but the differences in the two are sufficient enough to create different families for each of the two. Recent authors like Brues, Melander and Capenter (1954), Manna (1958), China and Miller (1959), Mackerras (1970) in the "Insects of Australia", and Cobben (1978), all make reference to the Plataspidae.

The cytological knowledge of ten species is known, four of *Brachyplatys* and six of *Coptosoma*. This includes the two species *Brachyplatys incertus* (walker) and *Coptosoma nubila* Germ where chromosome numbers have been added on from this study (Figs. 172-185). The Brachyplatidae is characterized by having 12 chromosomes (Fig. 192) with the usual XY:XX sex determination. The behaviour of the sex chromosomes during meiosis follows the usual pentatomid pattern. Manna (1958) reports that the meiotic cells are smaller than those of pentatomid bugs, however this study found them to be about the same, except in *Coptosoma ståli* (Mont), where the cells appear larger. The significance of these observations would perhaps be better appreciated when lot more work has been done on this family. It is suggested that more serious thought be given to devising a project on the Plataspidae alone, so that more information on their chromosomes would be known for more substantive cytological deductions to be made on the systematic status of this family.

4.6 DINIDORIDAE

Since 1870, the Dinidoridae has been considered a distinct group possessing certain special features (Sinnadurai, 1979). Lethierry et Severin (1893), in their catalogue of Hemiptera classified it as a "subfamily Dinidorinae". Distant (1881), called it Dinidorinae and the group was classified under this name until the middle of this century. More recent authors, such as Leston (1955), Pendergrast (1957), Scudder (1959), Miyamoto (1961), Kumar (1962, 1965), Cobben (1968, 1978) etc. have on a variety of grounds accorded this group a family status.

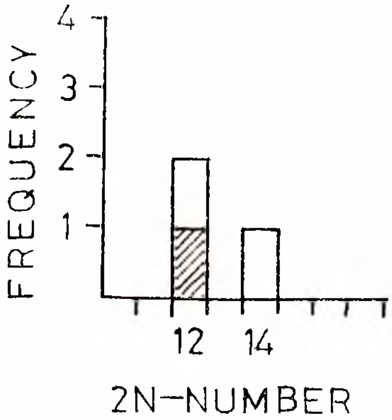
The family Dinidoridae is now divided into two subfamilies, the Dinidorinae and the Megyminae, each of which is further subdivided into two tribes (Sinnadurai, 1979). The Dinidorinae includes Dinidorini and Thalmini, and the Megyminae has Megymini and Eumenotini. Coridius, the largest genus with 39 species and Dinidor come under Dinidorini. The common genus under Megyminae, Megymenum is also placed under the tribe Megymini while Eumenotini is represented by the monotypic genus Eumenotes. Coridius seems to be the most advanced and highly successful group.

According to Sinnadurai (1979), the Subfamily Megyiminae is supposed to show primitive characters in external features such as the anteocular processes, pronotal tuberosities and the lobed or tubercled connexiva. The male genitalia has a poorly developed conducting chamber and a single pair of conjunctival processes which are quite elongated in the genus Megymenum. The sack-like spermatheca seen in this genus is more primitive than the genus Eumenotes which has less elaborate external features.

As has rightly been pointed out by Sinnadurai (1979), the evidence for the affinities of the Dinidoridae to other families of the Pentatomoidea have been drawn mostly from work carried out on the single species Coridius ianus or the genus Coridius and occassionally on the genus Megymenum. Close similarities to the family Pentatomidae have been shown by the work of several authors. The trichobothrial arrangement in the abdomen of Dinidoridae is similar to Pentatomidae (Schaeffer, 1966). Work on the chromosomes by Leston (1955) leads to a similar conclusion. However, according to Kumar (1962) the genitalia and salivary glands of Dinidoridae differ considerably from the Pentatomidae. There is also to some lesser extent some similarity of Dinidoridae to Tessaratomidae, Scutelleridae and Acanthosomatidae (Sinnadurai, 1979). Cobben (1968) suggests that such overlap means no mutual relationship but parallelism. Sinnadurai concludes her treatise by saying that the Dinidoridae is probably a family that differentiated from the Pentatomid stock at an early stage and became a specialised group.

Cytologically, only seven species (including the one of this study, Coridius cuprifer (Figs. 186 - 187), belonging to three genera, Coridius (Aspongopus), Dinidor and Megymenum have been studied. These three genera have different diploid numbers (Fig. 192), 14 in four species of Coridius, 20 in two species of Megymenum and 21 in Dinidor rufocinctus. Of these three genera, two of them (Coridius and Dinidor) belong to the subfamily, Dinidorinae, whilst Megymenum is in the subfamily Megyminae created by Sinnadurai (1979). The fact that the two species of Megymenum examined have the same chromosome number of 20, and the four species of Coridius also possess a chromosome number of 14, seems to support the creation of the second subfamily. However, there is the question as to why the Dinidor also of the same subfamily and tribe as the Coridius has a different chromosome number of 21, and not 14 as Coridius? Does it suggests the creation of another subfamily?

It is to be noted however that D. rufocinctus is of different genus though of the same subfamily and tribe as Coridius. Further according to Schrader (1947) D. rufocinctus is supposed to have a multiple sex chromosome mechanism, hence it should not be strange for it (D. rufocinctus) to exhibit a different chromosome number. Since it is possible for one tribe of a subfamily to possess diversified chromosome numbers, as is found in the Pentatomini of Pentatominae. The differences in chromomosome numbers of Megymenum and Coridius confirm the morpho-taxonomical studies by Sinnadurai (1979), which led her to create two subfamilies, Dinidoridae and Megyininae. The present cytological data are however rather meagre. It is hoped that future work will concentrate more on the Dinidoridae, to provide adequate cytological information to supplement the morpho-taxonomical

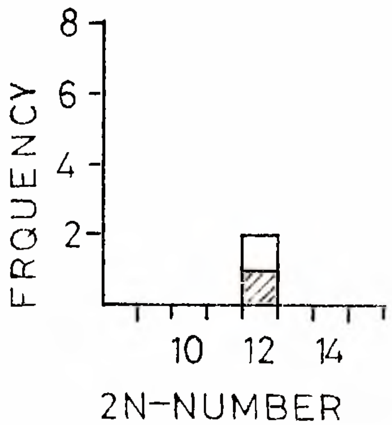


KEY

SUB FAMILY	2N-No	FREQ
Tessaratominae	12	2
Oncomerinae	14 12	1 1

Fig.198

Distribution of 2N-Number in 4 species of Tessaratomidae Cytologically studied to date.



KEY

SUB FAMILY	2N-No	FREQ
Oncomerinae	12	1
Tessaratominae	12	2

Fig.199

Distribution of 2N-Numbers in 3 species of Tessaratomidae.

studies of Sinnadurai (1979) for the establishment and creation of the two subfamilies.

4.7 FAMILY TESSARATOMIDAE (Figs 198 and 199)

The status of this group within the Pentatomoidea is undecided. Leston (1954a) and Dupius (1949) have raised it to family status, with three constituent subfamilies: the Oncomerinae, Natalicolinae and the Tessaratominae. In Leston's (1955) opinion, one of its genera Piezosternum, displays certain features, "very suggestive" of coreoid affinities. Kumar (1968b) however, observed that the Oncomerinae shows more similarities to Tessaratomini than to any other group of Pentatomorpha and is thus placed close to Tessaratomini in the Tessaratomidae. He further observed that the Oncomerinae is a homogenous group and bears no relationship whatsoever to Coreoidea, noting that similarities between Tessaratomidae and Coreoidea, emphasised by certain authors are superficial and based on an inadequate investigation of far too few representatives of the groups concerned.

Cytologically, very little work has been done on this family. Until this study, only three species were known cytologically with a chromosome number of 12 (Appendix Tables 3). The species are Eusthenes saevus (Stål), Tessaratoma javanica (Thunberg), and Piezosternum subulatum (Stål). The species examined in this study, Piezosternum calidum, has a chromosome number of 14 (Figs 188-189) with an XY:XX type of sex determination. If the basic chromosome number of the Tessaratomidae is 12, then they can be placed in the same category as the Plataspidae, Scutelleridae and Cydnidae etc. and may thus have some similarity of these, however the 14 chromosome number of Piezosternum places it close to the Pentatomidae. The present data, however, is too scanty to be able to predict any basic chromosome number of this group. A cytological investigation of the rich Australian Oncomerine fauna is especially desirable.

4.8 FAMILY CYDNIDAE

The family now consists of Sehirinae, Cydninae and Coriomelaeinae. Kumar (1962) suggested that Cydninae and Coriomelaeinae should be raised to family level, having treated Sehirinae as one of the Cydninae. The Cydnidae is observed to possess three pairs of conjunctival processes, and in this respect, show affinities to Scutelleridae, Dinidoridae, and Tessaratomidae (Leston, 1954a). Male reproductive organs however tend to indicate its affinities to Plataspidae (Kumar, 1962), while Scudder (1959) on ovipositor of Coriomelaeinae observed its affinities to certain Tessaratomidae and Pentatomidae. However, both Scudder (1959) and Pendergrast (1957) noted that Thyreocoris does not show affinities to Cydninae, which clearly indicates that Thyreocoris is placed in a wrong subfamily as suggested by Scudder (1959).

We have cytological knowledge of eight species, seven have chromosome number of 12, and one Stibaropus molginus has 31. Whilst those with the 12 chromosomes number have XY:XX type of sex mechanism.

S. molginus, has X_1X_2Y sex chromosomes in the males (Appendix Table 7). The only species, *Macroscytus* sp. worked on in this study has a chromosome complement of 12 (Figs 190-191). The basic chromosome number of Cydnidae is 12, and this places the family closer to Plataspidae and Tessaratomidae, as the morpho-taxonomical studies of Leston (1954b) and Kumar (1962) have already revealed and this fact is further confirmed by the available cytological information.

4.9 OTHER FAMILIES OF PENTATOMOIDEA

Three other families in literature where cytological information is known, but specimens of which could not be examined in this study, because of unavailability are: Acanthosomatidae (Appendix Table 6), Eumenotidae and Urostylidae. Six species belong to three genera of Acanthosomatidae namely, *Acanthosoma*, *Plasmostethyus* and *Elasmucha* have been examined cytologically, with chromosome number of 12, some individuals of *Elasmucha* are however said to have 18 chromosomes (Parshad, 1957a). Manna (1958) observes that Acanthosomatidae are distinct cytologically from the Pentatomidae, and are characterised by 12 chromosomes. On the basis of this, the Acanthosomatidae can be said to show affinities to the other groups also with diploid members of 12, like the Brachyplatidae and the Scutelleridae. This is in agreement with Leston (1958), who placed these groups close together with the Tessaratomatidae. Kumar's (1962) observation from studies of salivary glands also suggests that the Acanthosomatidae may have affinities with Scutelleridae. Some authors (Pendergrast, 1957;

Kumar, 1962) stressed that Urostylidae, Acanthosomatidae and Dinidoridae have several genital features in common with Pyrrhocoridae, but Cobben (1968) thinks such overlap means no mutual relation, but merely parallelism. Eumenotidae until now based on a single genus Eumenotes is accorded a tribal status by Sinnadurai (1979).

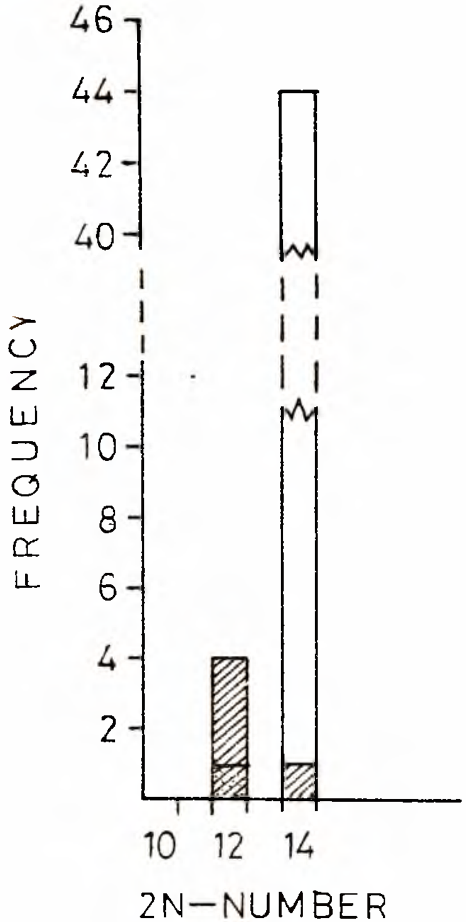
The other family Urostylidae is known cytologically by only one species Urostylis pallida of Urostylidae has 16 chromosomes. In a study based on diploid numbers, Leston (1958) kept Urostylidae as family perhaps related to his 2n = 12 group (Tessaratomidae, Scutelleridae, etc). Until Parshad (1957), found that 2n = 16 in Urostylidae, Leston took this family off his more primitive pentatomoid stock at a point later than differentiation of the Acanthosomatidae. According to Kumar (1971), Urostylidae seem to have differentiated at a much earlier stage. It appears that Urostylidae and Pyrrhocoridae diverged from a Pentatomoid-Pyrrhocoroid stock at an early stage in the evolution of Pentatomomorpha, possibly close to a point where Aradoidea branched off. As Kumar (1971) admitted, the above explanation is not fully satisfactory, however in the groups discussed above, there are common features which are the result of parallel evolution in response to functional demands. There is far more room for further work cytologically to provide supplementary ideas on affinities of most of the groups here discussed.

From the preceding discussions of individual families, the following karyotype groups appear to emerge, namely: 14 and 12. Under the group 14 is the family Pentatomidae, whilst the families Scutelleridae, Cydnidae and Plataspidae fall under the karyotype group 12. These agree with results of morpho-taxonomical studies of workers such as Southwood (1956), Pendergrast (1957), Scudder (1959), Miyamoto (1961), Kumar (1962, 1964, 1965, 1968 etc) and Cobben (1968, 1978) that these later groups show affinities to each other. No basic chromosome number can however be cited for the other families of Pentatomoidea, that is Dinidoridae, Tessaratomidae, Acanthosomatidae and Urostylidae because the cytological data for each of these are too scanty, for any sound conclusions to be arrived at. Generally, however, it appears that the Pentatomoidea is characterized XY:XX sex determining mechanism. The males invariably possess a single Y-chromosome, but species with more than one X-chromosome are not uncommon.

It has been suggested that the 12+XY chromosome mechanisms, may be regarded as representing the ancestral pentatomoid stock, perhaps before its divergence into the various subfamilies and families (Manna, 1958; Leston, 1958; Parshad, 1957b). However whilst both Manna (1958), and Leston (1958) put 2n = 14 as the point of origin, Leston considers 12 as the modal number of origin.

Generally, from the results and discussions, it is found out that the cytological information gathered from this work was in agreement with most of the results of morpho-taxonomical studies in determining the affinities of the families of the Pentatomoidea to one another.

There were no obvious contradictions of the cytological data presented and information obtained from the results of work already known from morphological studies. Even at places where the cytological information was too little and dispersed, there were indications that with further work more light could be thrown on the problems considered in this discussions.



KEY

FAMILY	2N–No	FREQ.
Pentatomidae	14	44
Scutelleridae	12	4
Tessaratomidae	14	1
Dinidoridae	14	1
Brachyplatidae	12	4
Cydnidae	12	1

Fig.200

Distribution of 2N-Numbers in the 6 families of Tropical Pentatomoidea worked on in this study.

SECTION 5

SUMMARY

1. 55 species of male Ghanaian Pentatomoidea belonging to six families were cytologically investigated, 49 of them being reported for the first time. The spermatogonial chromosome numbers (2n), and sex determining mechanisms of all the species were elucidated.

2. Microphotographs and tracings of karyotypes observed for each species were presented as figures (1 - 191). Histograms of 2n-numbers of the various families were also constructed.

3. Information gathered was pooled with the information in literature, analysed and discussed. In all 217 species of Pentatomoidea are known cytologically from the literature. The present work has increased this number to 266 species.

4. Course of meiosis, was found to be typically heteropteran in all the species examined. The family Pentatomidae was found to exhibit diploid numbers ranging from 6-27 with 14 as the modal number. It has an XY:XX type of sex determining mechanism. 211 species of Pentatomidae belonging to 4 subfamilies are so far known, 41 of these being contribution from this study.

5. The Scutelleridae and Plataspidae are characterised by 12 chromosomes, with an XY:XX type of sex determining mechanism, and a general plan of meiosis comparable with that of the Pentatomid bugs. 18 species of Scutelleridae including the three species, Callidea duodecim

punctata (Stål), Hotea subfasciata (Westwood), and Steganocerus multipunctata (de Geer) were examined in this study, and 10 species of Plataspidae also including the two species, Brachyplatys incertus (Walker), and Coptosoma nubila Germ from this study are known cytologically.

6. The basic chromosome number of 12 for both the Plataspidae and the Scutelleridae, were found to confirm results of morpho-taxonomical studies which suggests some affinities between the two.

7. The Dinidoridae is known cytologically from only seven species with chromosome number of 14, 20 and 21. The difference in chromosome numbers of Coridius (14), Dinidor (21) and Megymenum (20), seem to support the creation of a new subfamily Megyiminae, by Sinnadurai (1979). Dinidor rufocinctus is said to have a multiple sex chromosome mechanism. Eumenotis obscura now placed under the newly created subfamily Megyiminae by Sinnadurai (1979) has a chromosome number of 14 and a XY:XX sex determining mechanism.

8. 4 species of Tessaratomidae are known cytologically with a chromosome number of 12 for three species and 14 for one species, Piezosternum calidum (Stål) examined in this study. The later has a XY:XX sex determining mechanism.

9. 8 species of Cydnidae including the lone one of this study (Macroscytus sp) are known cytologically with a diploid complement of 12 for seven species, and one species Stibaropus molgimus (Schiodte) has a complement of 31. It has a XY:XX sex determining mechanism.

10. The Acanthosomatidae is characterized by 2n=12 chromosomes with a XY:XX sex determining mechanism. Six species are known cytologically belonging to three genera: <u>Acanthosoma</u>, <u>Elasmucha</u> and the <u>Elasmostethus</u>. The possession of 12 chromosomes as a basic number may indicate itsaffinity to the Plataspidae, Scutelleridae and probably Cydnidae, as morpho-taxonomical studies have suggested.

11. Urostylidae which was considered by Leston (1958) as a family related perhaps to his 2n=12 group (Tessaratomidae, Scutelleridae etc) is known to have 16 chromosomes by Parshad (1957a) in <u>Urostylis</u> <u>pallida</u>. More work is therefore needed to clarify the correct affinities of Urostylidae.

12. There is still more room for lot more work cytologically to provide more light on ideas on affinities of Pentatomoid families and sub-families.

SECTION 6

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* original not seen

APPENDIX TABLE 1

LIST OF SPECIES OF PENTATOMOIDEA USED AS MATERIAL

SPECEIS	LOCALITY	DATE OF COLLECTION
Acrosternum heegeri Fieb.	Legon (UV).(S), Weija(S)	May, June, July, August, 1979
Aeliomorpha sp. griseoflava Stål	Aburi(S), Legon(S), Weija(S)	May-August, 1979
Aeptus singularis (Dall.)	Legon(S)	September, 1979
Aethemenes chloris (Westw.)	Legon (UV)	March, 1979
Aspavia acuminata Mont.	Legon(S), Tafo(S)	July, December 1979
Aspavia armigera (Fabr.)	Legon(S), Kumasi(S), Kade(S), Weija(S) Tafo(S)	May, July-September, December, 1979
Aspavia hastator (Fabr.)	Kade(S), Aburi(S), Kibi(S), Mampong(S) Tafo(S), Suhum(S)	February, May-Oct. 1979
Atelocera serrata (Fabr.)	Tafo(S)	December, 1979
Bathycoelia rodhaini Schout.	Kade(UV), Tafo(HP)	February, June 1979
Bathycoelia thalassina (H.-S)	Legon(UV), Tafo(HP),	February-June, 1979 January, 1980
Benia sp. A	Aburi(S)	October, 1979
Carbula capito Stål	Suhum(S), Aburi(S)	May, June, July, September, 1979
Carbula carbula (Dist.)	Aburi(S), Mampong(S)	January, 1980
Carbula marginella Stål	Aburi(S), Kade(S), Legon(S)	July-December, 1979
Carbula melacantha Stål	Amonokrom(S), Kibi(S) Tafo(S)	July-October, 1979
Carbula sp. nr. sjostedti Schout.	Aburi(S), Kumasi(S) Tafo(S)	October, December 1979
Caura pugillater (Fabr.)	Kade(S), Tafo(S)	October, December 1979

APPENDIX TABLE 1 (cont'd)

LIST OF SPECIES OF PENTATOMOIDEA USED AS MATERIAL

SPECIES	LOCALITY	DATE OF COLLECTION
Diploxys bipunctata (Amyot et Serville)	Legon(UV),(S)	June, August, 1979
Amaxosana punctata Dist.	Legon(S)(UV)	June, 1979
Durmia haedula Stål	Legon(S)(UV), Tafo(S)	April, May, 1979
Durmia lutulenta Stål	Kade(S), Legon(S), Tafo(S)	July, August, 1979
Durmia sp.	Legon (UV)(S)	June, 1979
Dymantis grisea Jen-Haar	Legon (UV), Kumasi(S)	August, September, 1979
Eysarcoris inconspicuus (H.-S)	Legon (S)	August, September,1979
Halyomorpha annalicornis (Sign.)	Tafo(S), Kade (S)	November, 1979 January, 1980
Halyomorpha retlexa (Sign.)	Bunso(S), Tafo(S)	December, 1979
Halyomorpha picus Dist.	Suhum(S)	May, 1979
Lenda punctata (Palisot-Beauvois)	Aburi(S), Kade(S) Kibi(S), Tafo(S) Suhum(S)	February, June-Octber, January, 1980
Macrina juvenca (Burm.)	Kade(S), Tafo(S), Kibi(S)	February-September, 1979
Macrorhaphis acuta (Dall.)	Legon(S), Kade(S)	July-September, 1979
Nezara viridula Linnr.	Dodowa(S), Legon(S) Kade(S)	July-December, 1979 January, 1980
Nezara viridula var smaragdula (Fabr.)	Dodowa(S), Legon(S)	July, December, 1979 January, 1980
Nezara viridula var torquata Puton.	Dodowa(S), Legon(S),	February, July, December, 1979
Antestia sp.	Legon (UV)	May-July, 1979
Antestia sp.S.1	Legon (UV)	May-July, 1979
Antestia sp. ? immunda Linnr.	Legon (UV)	May, June, 1979
Antestiopsis sp. S.1	Legon (UV)	May, 1979

APPENDIX TABLE 1 (cont'd)

LIST OF SPECIES OF PENTATOMOIDEA USED AS MATERIAL

SPECEIS	LOCALITY	DATE OF COLLECTION
Piezodorus hybneri (Gmelin)	Legon(S), Dodowa(S)	July-September, 1979
Scotinaphara fibulata Schout.	Kade(S)	November, 1979
Sepontia misella Stål	Aburi(S), Kade(S), Suhum(S), Tafo(S)	February-December, 1979
Tyoma verrucosa Mont.	Aburi(S), Tafo(S)	September, October, 1979
Veterna sanquineirostris Stål	Kade(S), Tafo(S)	February, 1979 January, 1980
Afrius purpureus (Westw.)	Legon(S), Tafo(S)	September, December 1979
FAMILY SCUTTELLERIDAE		
Callidea duodecimpunctata Stål	Asutuare (HP), Legon(HP)	February-December,1979 January-April, 1980
Hotea subfasciata (Westwood)	Aburi(S), Kibi(S), Suhum(S)	September, November 1979
Sphaeracoris testudogrisea Stål	Legon(S)	September, 1979
Steganocerus multipunctata (de Geer)	Kade(S), Tafo(S)	November, December 1979
FAMILY BRACHYPLATIDAE		
Brachyplatys incertus (Walker)	Tafo(S), Kade(S)	November, December 1979, January, 1980
Brachyplatys testudonigra (De Geer)	Kade(S), Tafo(S) Kumasi(S)	November, December, January, 1980
Coptosoma nubila (Germ.)	Legon(S), Tafo(S)	August-September,1979 November, 1979

APPENDIX TABLE 1 (cont'd)

LIST OF SPECIES OF PENTATOMOIDEA USED AS MATERIAL

SPECEIS	LOCALITY	DATE OF COLLECTION
Coptosoma stali Mont.	Legon(S), Aburi(S), Tafo(S), Kade(S)	August-November, 1979 January, 1980
FAMILY DINIDORIDAE		
Coridius cuprifer (Westw.)	Tafo(S), Kade(S), Aburi(S)	September, 1979, January, 1980
FAMILY TESSARATOMIDAE		
Piezosternum calidum (Stål)	Tafo(S), Kade(S), Aburi(S)	September-December, 1979 January, March, 1980
FAMILY CYDNIDAE		
Macroscytus sp.	Legon(HP)(UV)	February-July, 1979 September-November 1979 May, 1980

(S) = Sweeping (HP) = Hand picking (UV) = Ultra violet trap

APPENDIX TABLE 2

SUMMARY OF RESULTS

NAME	MALE 2N NUMBER	KARYOTYPE
FAMILY PENTATOMIDAE		
Acrosternum heegeri Fieb.	14	12A+X+Y
Aeliomorpha sp.? *griseoflava* Stål	14	12A+X+Y
Aeptus singularis (Dall.)	14	12A+X+Y
Aethemenes chloris (Westw.)	14	12A+X+Y
Afrius purpureus (Westw.)	14	12A+X+Y
Aspavia hastator (Fabr.)	14	12A+X+Y
Aspavia armigera (Fabr.)	14	12A+X+Y
Aspavia acuminata Mont.	14	12A+X+Y
Atelocera serrata (Fabr.)	14	12A+X+Y
Bathycoelia thalassina (.-S)	14	12A+X+Y
Bathycoelia rodhaini Schout	14	12A+X+Y
Benia sp.A	14	12A+X+Y
Carbula capita Stål	14	12A+X+Y
Carbula carbula (Dist.)	14	12A+X+Y
Carbula marginella Stål	14	12A+X+Y
Carbula melacantha Stål	14	12A+X+Y
Carbula sp. nr. *sjostedti* Schout.	14	12A+X+Y
Caura pugilator (Fabr.)	14	12A+X+Y
Diploxys bipunctata (Amyot et Serville)	14	12A+X+Y
Amaxosana punctata Dist.	14	12A+X+Y
Durmia haedula Stål	14	12A+X+Y
Durmia lutulenta Stål	14	12A+X+Y
Durmia sp.	14	12A+X+Y
Dymantis grisea Jen-Haar	14	12A+X+Y
Eysarcoris inconspicuus (H.-S)	14	12A+X+Y
Farnya vessicolor (Fabr.)	14	12A+X+Y
Halyomorpha annulicornis (Sign.)	14	12A+X+Y

APPENDIX TABLE 2

SUMMARY OF RESULTS (cont'd)

NAME	MALE 2N NUMBER	KARYOTYPE
Halyomorpha picus (Dist.)	14	12A+X+Y
Halyomorpha reflexa (Sign.)	14	12A+X+Y
Lerida punctata (Palisot Beauvois)	14	12A+X+Y
Macrina juvenca (Burm.)	14	12A+X+Y
Macroshaphis acuta (Dall.)	14	12A+X+Y
Nezara viridula (L.)	14	12A+X+Y
Nezara viridula var *smaragdula* (Fabr.)	14	12A+X+Y
Nezara viridula var *torquata* (Puton)	14	12A+X+Y
Antestia sp.	14	12A+X+Y
Antestiopsis sp. S. I	14	12A+X+Y
Antestia sp. S. I	14	12A+X+Y
Antestia sp. ? *immunda* Linnr.	14	12A+X+Y
Piezordorus hybneri (Gmelin)	14	12A+X+Y
Scotinophora fibulata (Schouteden)	14	12A+X+Y
Sepontia misella Stål	14	12A+X+Y
Tyoma verrucosa (Mont.)	14	12A+X+Y
Veterna sanquineirostris Stål	14	12A+X+Y
FAMILY SCUTELLERIDAE		
Callidea duodecimpunctata (Stål)	12	10A+X+Y
Hotea subfasciata (Westw.)	12	10A+X+Y
Sphaeracoris testudogrisea Stål	12	10A+X+Y
Steganocerus multipunctata (de Geer)	12	10A+X+Y

TABLE 2

SUMMARY OF RESULTS (cont'd)

NAME	MALE 2N NUMBER	KARYOTYPE
FAMILY BRACHYPLATIDAE (PLATASPIDAE)		
Brachyplatys incertus (Walker)	12	10A+X+Y
Brachyplatys testudo nigra Stål	12	10A+X+Y
Coptosoma nubila Germ	12	10A+X+Y
Coptosoma stali (Mont.)	12	10A+X+Y
FAMILY DINIDORIDAE		
Coridius cuprifer (Westw.)	14	12A+X+Y
FAMILY TESSARATOMIDAE		
Piezosternum calidum Stål	14	12A+X+Y
FAMILY CYNIDAE		
Macroscytus sp.	12	10A+X+Y

APPENDIX TABLE 3

CYTOLOGICAL WORK ON PENTATOMOIDEA FROM LITERATURE

Family	Subfamily	No of Species with known 2n	2n number
ACANTHOSOMATIDAE		6	10A+X+Y = 12
TESSARATOMIDAE		3	10A+X+Y = 12
	Tessaratominae	2	10A+X+Y = 12
	Natalicolinae	-	-
	Oncomerinae	1	10A+X+Y = 12
CYDNIDAE	Shirinae	7	6 = 10A+X+Y = 12 1 = 21A+X+Y = 31
SCUTELLERIDAE		15	10A+X+Y = 12
	Scutellerinae	7	10A+X+Y = 12
	Pachycorinae	1	10A+X+Y = 12
	Eurygastrinae	7	10A+X+Y = 12
BRACHYPLATIDAE	Coptosominae	8	10A+X+Y = 12
DINIDORIDAE	Dinidorinae	6	3 = 12A+X+Y = 14 1 = 18A+X+Y = 21 2 = 18A+X+Y = 20
EUMENOTIDAE		1	12A+X+Y = 14
UROSTYLIDAE		2	14A+X+Y = 16

APPENDIX TABLE 3 (cont'd)

Family	Subfamily	No of Species with known 2n	2n number
PENTATOMIDAE		170	1 = 4A+X+Y = 6 1 = 8A+X+Y = 10 4 =10A+X+Y = 12 142 =12A+X+Y = 14 1 =12A+2X+Y= 15 14 =14A+X+Y = 16 6 =24A+X+Y = 26 1 =24A+2X+Y=27
	PODOPINAE	1	12A+X+Y = 14
	PHYLLOCEPHALINAE	-	-
	AMYOTEINAE	14	10 = 12A+X+Y = 14 3 = 14A+X+Y = 16 1 = 10A+X+Y = 12
	PENTATOMINAE	155	1 = 4A+X+Y = 6 1 = 8A+X+Y = 10 3 =10A+X+Y = 12 131 =12A+X+Y = 14 1 =12A+X+Y = 15 11 =14A+X+Y = 26 6 =24A+X+Y = 26 1 =24A+X+Y = 27

APPENDIX TABLE 4

DISTRIBUTION OF 2N-NUMBERS IN THE FAMILIES OF PENTATOMOIDEA STUDIED CYTOLOGICALLY TO DATE

Family	Subfamily	No of Species with known 2n	2n number
ACANTHOSOMATIDAE		6	6 = 10A+X+Y = 12
TESSARATOMIDAE		4	3 = 10A+X+Y = 12 1 = 12A+X+Y = 14
	Tessaratominae Natalicolinae Oncomerinae	2 - 2	2 = 10A+X+Y = 12 - 1 = 10A+X+Y = 12 1 = 12A+X+Y = 14
CYDNIDAE	Sehirinae	8	7 = 10A+X+Y = 12 1 = 28A+2X+Y= 31
SCUTELLERIDAE		18	18 = 10A+X+Y = 12
	Scutellerinae Pachycorinae Eurygastrinae	10 1 7	10A+X+Y = 12 10A+X+Y = 12 10A+X+Y = 12
BRACHYPLATIDAE	COPTOSOMINAE	10	10A+X+Y = 12
DINIDORIDAE	DINIDORINAE	7	4 = 12A+X+Y = 14 1 = 18A+2X+Y= 21 2 = 18A+X+Y = 20
EUMENOTIDAE		1	12A+X+Y = 14
UROSTYLIDAE		1	14A+X+Y = 16
PENTATOMIDAE		211	1 = 4A+X+Y = 6 1 = 8A+X+Y = 10 4 =10A+X+Y = 12 183=10A+X+Y = 14 1 = 12A=2X+Y = 15

APPENDIX TABLE 4 (cont')

Family	Subfamily	No of Species with known 2n	2n number
PENTATOMIDAE			14 = 14A+X+Y = 16 6 = 24A+X+Y = 26 1 = 24A+2X+Y= 27
	PODOPINAE	1	1 = 12A+X+Y = 14
	PHYLLOCEPHALINAE	1	1 = 12A+X+Y = 14
	AMYOTEINAE	15	1 = 10A+X+Y = 12 11 = 12A+X+Y = 14 3 = 14A+X+Y = 16
	PENTATOMINAE	194	1 = 4A+X+Y = 6 1 = 8A+X+Y = 10 3 = 10A+X+Y= 12 170 = 12A+X+Y= 14 1 = 12A+2X+Y=15 11 = 14A+X+Y =16 6 = 24A+X+Y = 26 1 = 24A+X+Y = 27

APPENDIX TABLE 5

DISTRIBUTION OF 2N NUMBERS IN THE SIX FAMILIES OF PENTATOMOIDEA WORKED ON THIS STUDY

Family	Subfamily	Frequency	2n Number
Tessaratomidae	Oncomerinae	1	12A+X+Y = 14
Scutelleridae	Scutellerinae	4	10A+X+Y = 12
Dinidoridae	Dinidorinae	1	12A+X+Y = 14
Brachyplatidae	Coptosominae	4	10A+X+Y = 12
Pentatomidae	Amyoteinae	1	12A+X+Y = 14
	Phyllocephalinae	1	12A+X+Y = 14
	Pentatominae	42	12A+X+Y = 14
CYDNIDAE	Sehirinae	1	10A+X+Y = 12

APPENDIX TABLE 6

Cytological work on Acanthosomatidae from Literature

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL*
Acanthosomatidae	Acanthosoma denticoada Yakoulev	10A+X+Y	Miyamoto 1957, Japan
"	Acanthosoma haemorrhoidale (Lin)	10A+X+Y	Woodward 1950, England
"	Acanthosoma labiduroides Yakouleve	10A+X+Y	Yosida 1956, Japan
"	Elasmastethus humeralis Yakoulev	10A+X+Y	Yosida 1956, Japan
"	Elasmostethus interstinctus (Linn.)	10A+X+Y	Halkka 1956, Finland
"	Elasmucha securvum Dallas	10A+X+Y	Parshad 1957b, India

* Locality of material underlined.

APPENDIX TABLE 7

Cytological work on Tessaratomidae, Cydnidae from Literature

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL *
Tessaratomidae Tessaratominae	Eusthenes saevus Stål	10A+X+Y	Parshad 1957b, India
"	Tessaratoma jauanica Thunberg	10A+X+Y	Parshad 1957b,
Subfamily Oncomerinae	Piezosternum subulatum Stål	10A+X+Y	Schrader 1947, Brazil
Family Cynidae Sehirinae	Sehirus bicolor (Linn.)	10A+X+Y	Leston 1954b, U.K.
"	Stibaropus molgimus Stål	28A+X+Y	Parshad 1957b, India
"	Aethus maurus Dallas	10A+X+Y	Jande 1959b, India
"	Aethus varians (Fabr.)	10A+X+Y	Jande 1959b, India
"	Aethus nigritus (Fabr.)	10A+X+Y	Jande 1959b, India
"	Macroscytus brunneus Stål	10A+X+Y	Kumar (Unpublished) Ghana
"	Macroscytus subaenus (Fabr.)	10A+X+Y	Parshad 1957b, India

* Locality of material underline.

APPENDIX TABLE 8

Cytological work on Scutelleridae from Literature

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL *
SCUTELLERIDAE Subfam. Scutellerinae	Cantao ocellatus Thungberg	10A+X+Y	Banerjee 1958, India
"	Chrysocoris eques Distant	10A+X+Y	Jande 1959b, India
"	Chrysocoris stollii Wolft	10A+X+Y	Singh and Singh Japan
"	Scutellera nobilis Distant	10A+X+Y	Jande 1959b, India
"	Scutellera perplexa (Westw.)	10A+X+Y	Manna 1958b, India
"	Solenostethnim rubropunctatum Distant	10A+X+Y	Jande 1959b, India
"	Sphaerocoris testudogrisea (de Geer)	10A+X+Y	Kumar (Unpublished) Ghana
Subfamily Pachycorinae	Hotea curculioneides Vollenhoven	10A+X+Y	Manna, 1958, India
Subfamily Eurygastrinae	Eurygaster austriacus Schrank	10A+X+Y	Montgomery, 1901, 1906, U.S.A.
"	Eurygaster alternatus Uhler	10A+X+Y	Schachow 1932, Germany
"	Eurygaster hotlentota Jakoulev	10A+X+Y	Schachow 1932, Australia
"	Eurygaster maura Saunders	12A+X+Y	Geitler 1938, Australia, Germany
"	Eurygaster maura Saunders	10A+X+Y	Schachow 1932, Australia
"	Odontatarsus caudatus Horvath	10A+X+Y	Schachow 1932, Germany

* Locality of material underlined.

APPENDIX TABLE 8 (cont'd)

Cytological work on Scutelleridae, Brachyplatidae from Literature

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL*
Scutelleridae Eurygastrinae	Odontotarsus purpureo-lineatus Horvath	10A+X+Y	Schachow 1932, Germany
"	Odontotarsus robustus Jakoulev	10A+X+Y	Schachow 1932, Germany
BRACHYPLATIDAE	Brachyplatys pauper (Vollenhoven)	10A+X+Y	Rao 1954, India
"	Brachyplatys subaeneus (Westw.)	10A+X+Y	Manna 1958, India, Banerjer 1958, India
"	Brachyplatys testudonigra Stål	10A+X+Y	Kumar (Unpublished), Germany
"	Coptosoma biguttula (Motschlsky)	10A+X+Y	Yosida 1956, Japan
"	Coptosoma cribarium (Fabr.)	10A+X+Y	Banerjee 1958, India
"	Coptosoma punctissimum (Mont.)	10A+X+Y	Yosida 1956, Japan
"	Coptosoma stali (Mont.)	10A+X+Y	Kumar (Unpublished) Ghana
"	Coptosoma variegata (H.-S)	10A+X+Y	Jande 1959b, India

* Locality of material under-lined.

APPENDIX TABLE 9

Cytological work on Dinidoridae from Literature

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL *
Dinidoridae	Coridius janus (Aspongopus) Fab.	12A+X+Y	Manna 1958, India
"	Coridius orientalis (Aspongopus) Kirkaldy	12A+X+Y	Manna 1951, India
"	Coridius sp	12A+X+Y	Jande 1959b, India
"	Dinidor ruficocinctus (Stål)	18A+X+Y	Schrader F. 1947, India
"	Megymenum brevicorne (Dallas)	18A+X+Y	Banerjee 1958, India
"	Megymenum gracilicorne	18A+X+Y	Schrader 1960, Costa Rica

* Locality of material underlined.

APPENDIX TABLE 10

Cytological work on Pentatomidae from Literature

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL*
Pentatomidae Pentatominae	Ablaptus amazonus Stål	12A+X+Y	Schrader 1960, Costa Rica
"	Acrosternum hilasis Say	12A+X+Y	Montgomery, 1901 U.S.A.
"	Acrosternum marginatum(P&B)	12A+X+Y	Hughes-Schrader and Schrader, 1950 Panama
"	Acrosternum sp	12A+X+Y	Hughes-Schrader and Schrader, 1957 Trinidad
"	Acrosternum pennsylvanicum (P. and B.)	12A+X+Y	Hughes-Schrader and Schrader, 1957, USA
"	Acrosternum scutellatum Distant	12A+X+Y	Hughes-Schrader and Schrader, 1957 Costa Rica
"	Adria parvula Bergroth	12A+X+Y	Jande 1959, India
"	Aelia acuminata (Linnaeus)	12A+X+Y	Schachow 1932, Germany
"	Aelia fieberi Scott	12A+X+Y	Miyamoto 1957, Japan
"	Aelia rostrata Boheman	12A+X+Y	Yosida 1956, Japan
"	Aelionorpha griseoflava Stål	12A+X+Y	Kumar, unpublished Ghana
"	Aenoria lewisi (Scott)	12A+X+Y	Jande 1959b, India
"	Agachitus dromedanius Stål	12A+X+Y	Schrader 1960, Costa Rica

* Locality of material underlined.

APPENDIX TABLE 10 (CONT'D)

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL*
Pentatomidae			
Sub Pentatominae	Agonoscelis nobilus (Fab.)	12A+X+Y	Manna 1951, India
"	Alitocoris parvus (Distant)	12A+X+Y	Schrader 1960, Panama
"	Alitocoris schraderi (Sailer)	12A+X+Y	Schrader 1960, Costa Rica
"	Ancyrosoma alliolineata	12A+X+Y	Schachow 1932, Germany
"	Antestiopsis cruciata (Antestia)	12A+X+Y	Manna 1951, India
"	Architas pudeus (Dist.)	12A+X+Y	Schrader 1960, Panama
"	Arveluis albopunctata (de Geer)	12A+X+Y	Hughes-Schrader and Schrader 1956, Costa Rica
"	Aspavia ingens Distant	12A+X+Y	Leston unpbl., Ghana
"	Bagrada picta (Fabr)	12A+X+Y	Rao 1955, Dutt. India
"	Banaso bidens schraderi Sailer	24A+X+Y	Schrader and Hughes-Schrader 1956, Costa Rica, Panama
"	Banasa celva (Say)	24A+X+Y	Wilson, 1905, 1907, Schrader and Hughes-Schrader 1956, U.S.A
"	Banasa centralis Sailer	24A+X+Y	Schrader and Hughes-Schrader, 1956 Costa Rica
"	Banasa dimidiata (Say)	14A+X+Y	Wilson 1907; Schrader and Hughes-Schrader 1956, USA
"	Banasa enchlora (Stal)	14A+X+Y	Schrader and Hughes-Schrader 1956, U.S.A.

APPENDIX TABLE 10 (cont'd)

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL*
Pentatominae	Banasa lenticularis Uhler	14A+X+Y	Schrader and Hughes-Schrader 1956, USA
"	Banasa minor Sailer	24A+X+Y	Schrader and Hughes-Schrader 1956, USA
"	Banasa panamensis Sailer	12A+X+Y	Hughes-Schrader and Schrader, 1956, 1958 Panama
"	Banasa rufifrons Sailer	24A+X+Y	Schrader and Hughes-Schrader 1956 Panama
"	Banasa zeteki Sailer	24A+X+Y	Schrader and Hughes-Schrader 1956, Panama
"	Brachystethus rubromaculatus Dallas	12A+X+Y	Schrader 1960, Costa Rica
"	Carbula biguttata Distant	12A+X+Y	Yosida 1956, Japan
"	Carbula aspavia Distant	12A+X+Y	Parshad, 1957b India
"	Carbula socia Distant	12A+X+Y	Manna 1958, India
"	Carbula sp.	12A+X+Y	Manna 1958, India
"	Carpocoris melanocerus Mulsant et Rey	12A+X+Y	Geitler 1938, Australia
"	Carpocoris pudicus (Poda)	12A+X+Y	Schachow 1932, Germany
"	Captus pallipes (Neodius)	14A+X+Y	Parshad 1957a,b, India
"	Chlorochroa juniperina (Pentatoma)	12A+X+Y	Wilson 1905a, USA
"	Codophila varia (Fab.)	12A+X+Y	Schachow 1932, Germany
"	Coenus delius (Say)	12A+X+Y	Montgomery 1901,

APPENDIX TABLE 10 (cont'd)

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL*
Pentatomidae Subfam. Penta	*Cosmopepla lintneriana* (Kirkaldy)	14A+X+Y	Montgomery 1901, 1906, U.S.A.
"	*Dalpada confusa* Distant	12A+X+Y	Parshad 1957a, India
"	*Dalpada concinna* (Westwood)	12A+X+Y	Parshad 1957a, "
"	*Dalpada versicolor* Distant	12A+X+Y	Rao 1955, India
"	*Dinocoris baccarum* (Pentatoma)	12A+X+Y	Schachow 1932, Germany
"	*Dolycoris indicus* Stål	12A+X+Y	Manna 1951, India
"	*Edessa caldaria* Distant	12A+X+Y	Schrader 1945a, Panama
"	*Edessa celsa* Distant	12A+X+Y	Schrader 1945a, Panama
"	*Edessa costae* Bergroth	12A+X+Y	Schrader 1945a, Panama
"	*Edessa fuscidorsata* (Fabr.)	12A+X+Y	Schrader 1945a, Panama
"	*Edessa irlorata* Dallas	12A+X+Y	Schrader 1945a, Panama
"	*Edessa laticornis* Stål	12A+X+Y	Schrader 1945a, Panama
"	*Edessa pictiventris* Stål	12A+X+Y	Schrader 1945a, "
"	*Edessa rufomarginata* Stål	12A+X+Y	Schrader 1945a, Panama
"	*Edessa vinula* Stål	12A+X+Y	Schrader 1945a, Panama
"	*Edessa* sp I	12A+X+Y	Schrader 1945a, Panama
"	*Edessa* sp II	12A+X+Y	Schrader 1945a, Panama
"	*Edessa* sp III	12A+X+Y	Schrader 1960, Panama

APPENDIX TABLE 10 (cont'd)

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL*
Pentatominae	Eurydema dominulus Reuter	12A+X+Y	Geitler 1938, Australia
"	Eurydema festiva Hovarth	12A+X+Y	Schachow 1932, Germany
"	Eurydema fieberi Fieber	12A+X+Y	Parshad 1957a, India
"	Eurydema liturifera Distant	12A+X+Y	Parshad 1957, "
"	Eurydema oleracea Hovarth	12A+X+Y	Schachow 1932, Germany
"	Eurydema ornata Hovarth	12A+X+Y	Schachow 1932, Germany
"	Eurydema pulchra Distant	12A+X+Y	Parshad 1957a, India
"	Eurydema rugosa Motschulsky	12A+X+Y	Parshad 1957a, "
"	Eurydema ventralis Kolenati	12A+X+Y	Geitler 1938, Australia
"	Euschistus crassus Dallas	10A+X+Y	Hughes-Schrader and Schrader 1956, USA
"	Euschistus fissilis Uhler	12A+X+Y	Wilson 1905, 1906, USA
"	Euschistus ictericus Stål	12A+X+Y	Wilson 1906, U.S.A
"	Euschistus obscurus Dallas	12A+X+Y	Hughes-Schrader and Schrader 1956, USA
"	Eurchistus servus Stål	12A+X+Y	Wilson 1906, U.S.A
"	Euschistus tristigmus Stål	12A+X+Y	Montgomery 1906, Wilson 1906, U.S.A
"	Euschistus variolarius Stål	12A+X+Y	Montgomery 1906, Wilson 1906 U.S.A
"	Euschitus sp	12A+X+Y	Montgomery 1906, U.S.A.
"	Eysarcoris aenus (stollia)	14A+X+Y	Schachow 1932, Germany

APPENDIX TABLE 10 (cont'd)

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL*
Pentatominae	Eysarcoris capitatus Distant	12A+X+Y	Manna 1951, India
"	Eysarcoris guttiger Thunberg	12A+X+Y	Manna 1951, "
"	Eysarcoris inconspicuus (H.S)	12A+X+Y	Parshad 1957a,"
"	Eysarcoris fabricii Hahn	14A+X+Y	Schachow 1932, Germany
"	Eysarcoris montivagus Distant	12A+X+Y	Parshad 1957a, India
"	Eysarcoris parvus Uhler	12A+X+Y	Miyamoto 1957a, India
"	Eysarcoris ventralis (Westwood)	12A+X+Y	Miyamoto 1957, India
"	Eysarcoris sp	12A+X+Y	Miyamoto 1957, "
"	Graphosoma italicuus (Muller)	12A+X+Y	Geitler 1938, Australia
"	Graphosoma rubrolineata (Westwood)	12A+X+Y	Yosida 1956, Japan
"	Graphosoma semipunctata (Fabr.)	12A+X+Y	Schachow 1932, Germany
"	Halyomorpha picus (Fabr.)	12A+X+Y	Parshad 1957a,b, India
"	Halys dentatus Distant	12A+X+Y	Sharma and Parshad 1955, India
"	Halys sulcatus Thungberg	12A+X+Y	Manna 1958, India
"	Holcostethus limbolarius Stål	12A+X+Y	Hughes-Schrader and Schrader 1956, USA
"	Lerida punctata (Palisot Beauvois)	12A+X+Y	Leston Unpbl., Ghana
"	Loxa flavicollis (Drusy)	12A+X+Y	Schrader 1945b, Costa Rica
"	Loxa florida (van Duzee)	14A+X+Y	Schrader 1945b, USA

APPENDIX TABLE 10 (cont'd)

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL *
Pentatominae	Macropygium reticulare	12A+X+Y	Schrader 1960, Costa Rica
"	Mayrinia variegata (Distant)	12A+X+Y	Schrader 1945a, 1960, Costa Rica
"	Menida bengalensis (Westw.)	12A+X+Y	Banerjee 1958, India
"	Menida violacea (Notschulsky)	12A+X+Y	Yosida 1956, India
"	Melanoderma apicifera Distant	12A+X+Y	Schrader 1960, Costa Rica
"	Mecistorhinus tripterus (Fab.)	12A+X+Y	Schrader 1960, Costa Rica
"	Mecistorhinus sepulcralis Stål	12A+X+Y	Schrader 1960, Brazil
"	Mecistor hinus panamensis Ruckes	12A+X+Y	Schrader 1960, 1946 Panama
"	Moncus obscurus Dallas	12A+X+Y	Schrader 1960a, Panama
"	Mormidea lugens Stål	12A+X+Y	Montgomery 1901, 1906, U.S.A.
"	Murgantia histrionica Stål	12A+X+Y	Hughes-Schrader and Schrader 1956, USA
"	Neodine macraspis Perty	12A+X+Y	Schrader 1946, 1960 Costa Rica
"	Neottiglossa leporina Putor	12A+X+Y	Schrader 1946, Costa Rica
"	Neottiglossa pusilla Jakovlev	12A+X+Y	Schrader 1960, Costa Rica
"	Nezara antennate Scott	12A+X+Y	Miyamoto 1957, Japan

APPENDIX TABLE 10 (cont'd)

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL*
Pentatominae	Nezara viridula Stål	12A+X+Y	=Yosida 1956, Japan
"	Pentatoma smaragula (Amyotet serville)	12A+X+Y	Wilson 1906, U.S.A
"	Niphe subferruginea Distant	14A+X+Y	Parshad 1957a, India
"	Ochrophara montana (Dist.)	12A+X+Y	Manna 1951, India
"	Palomena angulosa (Montschusky)	14A+X+Y	Yosida 1956, Japan
"	Palomena prasina Saunders	14A+X+Y	Schachow 1932, Germany
"	Palomena reuteri (Dist.)	12A+X+Y	Parshad 1957b, India
"	Palomena viridissima (Poda)	14A+X+Y	Schachow 1932, Germany
"	Pellaea stictica Berg.	12A+X+Y	Hughes-Schrader and Schrader 1957, USA
"	Pentatoma japonica (Dist.)	12A+X+Y	Parshad 1957a, India
"	Pentatoma rufipes Brulle	12A+X+Y	Parshad, 1957a, Japan
"	Peromatus notatus (Amyotet Serville)	12A+X+Y	Schrader 1945a, Costa Rica
"	Piezodorus lituratus (Fab.)	12A+X+Y	Schachow 1932, Germany
"	Piezodorus rubrofasciatus (Fab.)	12A+X+Y	Manna 1951, India
"	Placosternum urus	12A+X+Y	Parshad 1957a, India
"	Platycarenus notulatus	12A+X+Y	Schrader 1946b, Costa Rica
"	Plantia frinbriata	12A+X+Y	Manna, 1958 India

APPENDIX TABLE 10 (cont'd)

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL[x]
Pentatominae	Priossus exemptus (Stål)	12A+X+Y	Parshad, 1957 India
"	Pseudovoplitus longicornis (Ruckes)	12A+X+Y	Schrader 1960b, Costa Rica
"	Rhytidolomia saucia	12A+X+Y	Schrader 1960, U.S.A
"	Rhytidolomia senilis (Pentatoma)	14A+X+Y	Schrader 1960 "
"	Schraderia cinctus (Ruckes)	12A+X+Y	Schrader 1960, Costa Rica
"	Schraderia hugheseae (Ruckes)	12A+X+Y	Schrader 1960, Costa Rica
"	Sciocoris curritans	12A+X+Y	Parshad 1957, India
"	Sciocoris helferii Fieber	12A+X+Y	Jande 1959b, India
"	Sciocoris sulcatus Fieber	12A+X+Y	Miyamoto 1957, Japan
"	Scotinophora sp.	10A+X+Y	Jande 1959b, India
"	Scotinophora sp. A	12A+X+Y	Jande 1959b, India
"	Scotinophora sp. B	12A+X+Y	Jande 1959b, India
"	Scotinophora horvathi (Dist.)	12A+X+Y	Jande 1959b, India
"	Solubea pugnax Stål	8A+X+Y	Wilson 1906, USA
"	Spermatodes sp.	14A+X+Y	Manna, 1951, India
"	Stagonomus bipunctata Linneus	10A+X+Y	Miyamoto 1957, Japan
"	Staria lunata Puton	12A+X+Y	Miyamoto 1957, Japan
"	Stenozygum colaratum Klug	12A+X+Y	Leston and Wahrman, Unpbl. Israel
"	Thyanta antiquensis (Westwood)	12A+X+Y	Schrader and Hughes-Schrader 1956, Haiti
"	Thyanta calceata (Say)	24A+X+Y	Wilson 1906, Schrader and Hughes-Schrader 1956, USA
"	Thyanta castator (Fab.)	14A+X+Y	Schrader and Hughes-Schrader 1956, USA

APPENDIX TABLE 10 (cont'd)

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL *
Pentatominae	Thyanta pallidovirens (Stål)	14A+X+Y	Schrader and Hughes-Schrader 1956, USA
"	Thyanta pallidovirens (Stål)	12A+X+Y	Schrader and Hughes-Schrader 1946, USA
"			Ueshima 1963, Japan
"	Thyanta perditor (Fab.)	12A+X+Y	Schrader and Hughes-Schrader 1956, USA
"	Thyanta pseudocasta	12A+X+Y	Montgomery 1901, 1906; Wilson 1906, U.S.A.
"	Trichopepla semivittata (Say)	12A+X+Y	Kumar (Unpbl.) Japan
Subfamily Phylocephalinae	Podops inuncta (Fab.)	12A+X+Y	Woodward 1950; Pendergrast 1957, England
Subfamily Amyoteinae	Arma elector (Fabr.)	12A+X+Y	Miyamoto 1957, Japan
Pentatomidae Amyoteinae	Oechalia grisea (Burm.)	12A+X+Y	Heizer 1951, Hawai
"	Oechalia pacifica Stål	12A+X+Y	Heizer 1951, "
"	Oechalia patruelis Stål	10A+X+Y	Heizer 1951, "
"	Perillus bioculatus (Mineus)	12A+X+Y	Wilson 1906, U.S.A

APPENDIX TABLE 10 (cont'd)

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL *
Pentatomidae			
Amyoteinae	Perillus confluens Stål	12A+X+Y	Montgomery 1901, USA
"	Picromerus bidens (Amyot et Serville)	12A+X+Y	Yosida 1956, Japan
"	Picromerus nigridens Puton	12A+X+Y	Miyamoto 1957, Japan
"	Podisus bracteatus (Fitch)	12A+X+Y	Wilson 1906b, U.S.A.
"	Podisus macuventris (Say)	12A+X+Y	Montgomery 1901, U.S.A.
"	Podisus modestus (Say)	14A+X+Y	Wilson 1906b, U.S.A
"	Podisus placidus Uhler	14A+X+Y	Wilson 1906, U.S.A.
"	Stiretcus anchorago (Fabr.)	12A+X+Y	Parshad 1957a, India
"	Troilus huridus (Fabr.)	12A+X+Y	Miyamoto 1957, Japan

* Locality of material underlined

APPENDIX TABLE 11

Cytological work on Eumenotidae, Urostylidae from Literature

FAMILY	SPECIES	2n	REFERENCE AND LOCALITY OF MATERIAL*
Eumenotidae	Eumenotis obscura (Westwood)	12A+X+Y	Manna 1951, India
Urostylidae	Urostylis pallida Scott	14A+X+Y	Parshad, 1957a, India

* Locality of material underlined.