

A TAXONOMIC-MORPHOLOGICAL STUDY OF BOOPHILUS CURTICE, 1891
AND RHIPICEPHALUS KOCH, 1844 (ACARI: METASTIGMATA: IXODIDAE)

By

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Dedicated to my parents.

*"A man would do nothing if he wait until he
could do it so well, that no one would find
fault with what he has done".*

Cardinal Newman

*God skenk my die krag om te verander wat ek
kan, die gemoedskalmte om te aanvaar wat ek
nie kan verander nie en die wysheid om die
verskil te ken.*

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1. ABSTRACT

This investigation includes detailed morphological Scanning Electron Microscopic studies of both the immature and mature stages of *Rhipicephalus pravus*, *R. oculatus*, *R. appendiculatus*, *Boophilus decoloratus* and *B. microplus*.

A discussion on the methods and techniques employed for the preparation of tick specimens for Scanning Electron Microscopic studies is given.

A list of terms used in tick taxonomy is given and new terms, adopted for purposes of uniformity in acarine nomenclature, are incorporated.

Descriptions are given of the specimens as seen under the S.E.M. and these are compared with existing descriptions based on light microscopic and stereomicroscopic studies.

A brief discussion of several anatomical structures previously described is given.

A summary of selected variable characters of the immature and mature stages is given for use in future taxonomic studies.

Determinations of the similarities between the studied species based on conventional descriptions using the S.E.M., was undertaken. A computer is used to determine the similarity coefficients and work units for cluster analysis.

Information derived from dimensional analysis was subjected to a test of variances. A dendrogram was drawn up using an index of similarity.

It is concluded that there is greater similarity between *B. pravus* and *R. oculatus* than between either of these species and *R. appendiculatus*.

It is also concluded that there are no clear cut differences between the South African and Australian strains of *B. microplus*. The similarity between *B. decoloratus* and *B. microplus* are also measured.

From this investigation it is evident that the use of a combination of conventional and numerical methods is useful in taxonomic studies but with numerical taxonomy in the restrictedness as an expedient in taxonomy.

2. INTRODUCTION

According to Sokal & Sneath (1963), the science of taxonomy is one of the most neglected disciplines in biology. There is a great need in taxonomy today to develop an understanding of the methods by which classical taxonomists construct classifications. Although new developments are continually being made in techniques for studying species, finding new characters, describing new organisms and revising the systematics of previously known organisms little attention has been directed towards the theoretical basis of classification, i.e. taxonomy in the restricted sense of the theory of classification.

In the last few years there has been increased awareness of the problems in the aims and practice of taxonomy. In particular, there has been interest in the development of numerical methods in taxonomy as an aid to making systematics a quantitative science. Although in modern taxonomy, the purely morphological species definition has been replaced by a biological definition which takes ecological, geographical, genetic and other factors into consideration, the principle of similarity and divergence, in a comparative morphological sense, still takes precedence over all others. Many groups of animals (such as ticks) are still so poorly known in detail that the newer principles and techniques of taxonomy cannot be applied to any great extent. In such cases it is inevitable that the attention of the systematist is still almost entirely taken up with the description of new species, the construction of keys and similar preliminary tasks. The major portion of the work of the modern taxonomist still remains to be done.

Specimens which appear to be morphologically very similar and therefore possibly closely related may either be sibling species or subspecies of a polytypic species. The question as to whether the differences between two samples are sufficient to merit subspecific, specific or even generic separation frequently cannot easily be decided. In the past the question has often been too hastily answered in the affirmative with the result that at pre-

sent, the literature is almost flooded with synonyms.

It should be borne in mind that the most practical diagnostic characters of a taxonomic unit are those that relate to some easily visible structure with but slight variability. It is also necessary to emphasize the biological insignificance of many of the key characters or diagnostic characters, which may actually constitute the most unimportant differences between the two categories. The majority of the characters studied during this investigation may possibly be of no particular importance in the construction of keys, but merely serve as indicators to the taxonomist. The modern trend, however, is to assume that no character can become established in a population unless it has superior selective qualities. The adaptive significance of many taxonomic characters is obvious whereas in the others cases some of the morphological expressions of the phenotype may not be directly adaptive but merely represent the by-products of the physiological actions of a superior gene complex.

The lack of reliable diagnostic characters has been the most serious deterrent to a better understanding of the systematics of ticks, especially of the immature stages. In the present investigation additional characters to overcome this handicap were sought.

In studying the inter-relationships of ticks, Theiler (1948) stated that: "Ixodids have usually been recognised as the most primitive, although in some directions they show high specialization. Their primitive features are taken to be the long palps, the posterior position of the anus with the anal groove anterior; the scutum may sometimes only cover the first two pairs of legs, the skin sensory organs are more primitive, and Haller's organ shows very definite rather specialised division into two of the Rhipicephalinids; the presence in some species of definite sternal elements; the primitive coxae showing primitive chitinization of some parts and the positioning of these coxae". She furtherly stated: "The classification of ticks down to genera is relatively simple, but the

identification of species is difficult; for within the genus ticks are all built to the same plan, they are monotonous in their lack of initiative to find new variations of the fundamental generic structure". She stated also: "The classification of most ticks is a matter of personal opinion based on personal experience. Specific characters are instead of being equally stable, very unstable and most variable, and it is here, in this range of variability, that there is so much room for differences of opinion".

Most anatomical features observed with the light microscope are drawn by the observer rather than photographed because only one plane at a time can be viewed with this instrument. Ticks are quite rotund and microphotographs only show a small portion in clear detail. Successive levels of the specimen are viewed as the drawing is only the observer's interpretation of what was viewed through the microscope, even when a microprojector is used.

The role of the Scanning Electron Microscope (S.E.M.) in the study of acarine morphology has been discussed by Griffiths (1971), who considered it would enable investigators to reduce interpretive errors, to see external features more exactly, and to determine spatial relationships and details in three-dimensional micrographs with greater clarity than heretofore possible. Details of the morphology of many ticks are demonstrable through the use of the S.E.M., and magnified to great size for the study of details. It is often said that the introduction of the S.E.M. into biological research has revolutionized the possibilities for studying the surface structures of biological specimens. That is indeed so, but as resolution and magnification by microscopy increased, so more and more problems are encountered with interpretation. A major problem in interpretation is, of course, that produced by preparation artifacts. This necessitates the investigation, by whatever means can be contrived, of the effect of preparation on the structure of biological material.

3. PREPARATION TECHNIQUES FOR SCANNING ELECTRON MICROSCOPY

Physical and chemical changes in biological material occur continuously, since reaction to the environment is one of the characteristics of living material. After death post mortem changes immediately set in. As a general rule it is preferable to fix specimens from the living state, thereby avoiding post mortem deterioration, but this is not always practical, because living specimens are not always available.

For S.E.M. studies it is essential that the shape and surface topography of the specimen should be preserved in a state as close to life as possible.

The techniques for preparing specimens for the S.E.M. are as follows:

3.1 Preparing the surface of the specimen

The commonest interpretational errors arise from a lack of understanding of the limitations of the techniques for preparing biological specimens. It is often assumed that a "true" surface is being examined, when this surface is in fact covered with a contaminant such as mucus, tissue fluid, etc. These contaminants can often be washed away by iso-osmotic rinses, but other substances may be essential to digest a specific component.

Washing implies placing a specimen in a fluid and leaving it there for a relative long time, thus allowing the soluble material on the specimen to diffuse into the fluid surrounding it. Rinsing means a rather brief immersion of a specimen for the purpose of removing only superficial fluid or sediment that has adhered from a previous treatment. Rinsing is accomplished in a few seconds by dipping the specimen into the washing fluid or allowing fluid to run over it. Washing and rinsing, as steps in the process of preparing the surface structure of specimens, are used to remove substances which are likely to interfere with the successful operation of any succeeding step.

During this investigation several substances were evaluated as washing solutions, such as Potassium hydroxide, lactic acid, Nesbitts, Decon 75 and Extran flüssig. Of these Extran gave the best results. Specimens to be cleaned in Extran are left for 24 hours in a 25% solution. Increasing temperature of the washing fluid shortens the cleansing procedure. Exposure time depends on the degree of pollution. After washing in Extran the specimens are thoroughly washed in distilled water to prevent contamination of the fixing fluid. Better results can be obtained by rinsing or washing after fixation and post fixation because some of the fixatives left contaminants. Any traces of free permanganate, osmic acid or acrolein remaining in or on the specimen will leave an electron-opaque precipitate after dehydration in acetone. Sometimes they produce a granular precipitate or a general blackening of the specimens. The specimens can be rinsed in a buffer if the fixative was buffered, otherwise distilled water can be used. According to Davenport (1960) rinsing in water after fixation by picric acid should be avoided; specimens so fixed should be placed in an alcohol water mixture containing at least 50% alcohol. He also stated that water alone is believed to cause too much softening and maceration of tissues.

3.2 Fixation

Fixation of biological material prior to further preparation for the S.E.M. will nearly always be necessary. In some cases good results may be obtained without fixation, especially when the specimens have not been preserved for a long time, or when the specimens are well sclerotized.

Fixation is a process that is very difficult to describe. It is commonly said to be the preservation of structural and cellular elements in a condition near to the natural living state as possible. Generally speaking "a good fixative" is one that changes the cell chemistry the least and preserves the structure the best. (Davenport, 1960). Fixation on the whole is a contradictory process, consisting as it does of both the preservation

of some structures and the destruction of others. What one sees after fixation is always an entirely different picture from that seen during life, as it is at present utterly impossible to preserve anything in the exact condition in which it was when still alive.

The success or failure of fixation is judged by the quality of the final preparation. There are several problems associated with fixation. One is the degree of hardening of tissues needed to prevent the specimen collapsing when it is exposed to high vacuum pressures and in this respect fixatives differ considerably. Most fixatives are acid in reaction. According to Davenport (1960) the higher the concentration of hydrogen ions, the less perfect is the preservation of structural components. Formalin (not neutralized) has a pH of 3,4-3,6; a 1% solution of osmic acid ⁺ 6,1; a saturated solution of picric acid ⁺ 2,4 and a 10% solution of acrolein 7,6. Fixatives with small molecules, e.g. formalin, potassium permanganate and glutar aldehyde, usually penetrate more rapidly than those with large ones. The extent of penetration of picric acid, osmic acid and acrolein is limited because they have high molecular mass. There is, however, not a strict relationship between the molecular mass and the rate of penetration: some fixatives with a high molecular mass penetrate rather rapidly, e.g. mercuric chloride. (Davenport, 1960). The rate of penetration may also be influenced by the number of atoms or of reacting radicals; the fewer the atoms or reacting radicals, the more rapid the penetration. Rapid penetration of the fixative is very desirable. If it penetrates slowly changes may occur in the centre of the specimen before it is fixed. That, however, is not the case with preserved specimens.

During this investigation it was occasionally found that the outer layers of the specimen were overfixed and the topography of the specimen showed severe shrinkage and penetrating holes sometimes appeared. In other cases the innermost parts of the specimen were underfixed and the shape of the specimen distorted.

In some cases the larvae showed a tendency to be overfixed which was overcome by reducing the fixing time. Some adults were overfixed outside and underfixed inside, so a fixative with a stronger penetrative power was used. The remedy can also be obtained in the case of the adults by limiting the relative size of the specimen, by cutting it in parts, to allow prompt penetration.

The times required for different fixatives are very variable, depending partly on the specimen itself, and the correct time for a particular specimen must be determined by experiment.

Although many fixatives are in use for light microscopy, only a few are used in S.E.M. studies. In this investigation several fixatives were tested as follows:

3.2.1 Formaldehyde

This has a very low pH and a chemically pure buffered solution should be used. According to Davenport (1960), formalin penetrates tissue rapidly and is one of the best hardening agents. Several concentrations for several fixation times were tried during this investigation. The results obtained were unpredictable; some specimens were shrunken or overfixed, while others become swollen or vacuolized.

3.2.2 Picric acid

This fixative is invariably used in the form of a saturated solution in distilled water. The fixation times for tick specimens varied from 24-48 hours. According to Loots (1971), this is one of the best fixatives for preparing mites for the S.E.M. During this investigation it was found that the larvae shrank strongly, while the adults were quite well fixed.

3.2.3 Potassium permanganate

A stock solution of potassium permanganate (KMnO_4) is made up in distilled water to a 1% m/v and kept in a glass-stoppered bottle.

(This is necessary since KmNO_4 is slowly reduced on contact with air.) KmNO_4 was used because it is generally believed that it is a good hardening agent and penetrates rapidly. During this investigation it was used as a post fixative with reasonable success, the recommended time for post fixation being about six hours.

3.2.4 Gluteraldehyde

According to Davenport (1960) the concentration of gluteraldehyde used appears to be unimportant. During this investigation a 12% solution was employed with a fixing time of 24-48 hours. Good results were obtained with adult ticks but not with larvae and nymphae. The results were somewhat better when the specimens were post fixed in KmNO_4 and best when a buffered 2% solution (pH 7,4) was used, following by post fixation for six hours in either KmNO_4 or osmic acid.

3.2.5 Osmic acid

Osmic acid is the name commonly given to osmium tetroxide although this is not strictly speaking an acid. Although frequently used as a fixative, it is more often employed as a post fixative. It usually gives good results but has a number of serious disadvantages. It's vapour is lethal and it is extremely expensive. Solutions are very readily reduced by the presence of even minute quantities organic matter. Exposure of aqueous solutions to the light does not necessarily bring about reduction, as is commonly believed, provided that the water is absolutely pure and free from dust. Such a solution must be kept in a completely clean bottle. A fresh solution of osmic acid is a very pale straw colour. If any other colour (e.g. red, black or purple) is observed the sample has been reduced (Reimer, 1967).

Specimens must be transferred into osmium with a clean brush, not a metal instrument, because contact with metal reduces the osmium and the degree of fixation obtained is then minimal.

This substance should never be used in a solution stronger than 2%. During this investigation very good results were obtained with a 1% solution (pH 6,1) used for a post fixation time of about six hours for all ontogenetic stages. Fixation is completed when the material has become brown throughout.

3.2.6 Acrolein

Acrolein is used as a 10% concentration, pH about 7,6. The fixing times tried varied from 12-72 hours and the optimum for both larvae and adults was found to be about 12-24 hours. Better results were obtained when the specimens were post fixed with 1% osmium or 1% KmNO_4 solutions. Acrolein vapours are lethal.

3.3 Dehydration

Specimens for study with the S.E.M. must be freed of all volatile matter before they can be examined under high vacuum conditions. This factor has constituted a great limitation to the microscope's usefulness because it necessitates the removal of all water, which is so essential to biological structure and function. Several methods of dehydration were investigated, as follows:

3.3.1 Air drying

If either fixed or unfixed ticks are simply allowed to dry out in the air, severe shrinkage and deformation of larvae, nymphae and engorged adults is inevitable. Unengorged adults do not shrink quite so much.

3.3.2 Critical point drying

Critical point drying is used to dehydrate wet specimens without subjecting them to the distorting effects of surface tension as in air drying.

Specimens are passed through a graded series of increasingly concentrated dehydrating fluids, such as acetone. The specimens

are then placed in a pressure chamber. This is sealed and liquified gas (CO_2) is fed slowly through it to displace the intermediate fluid. The chamber is immersed in warm water to bring it above the critical temperature and pressure, changing the transitional fluid in and around the specimens to the gaseous phase. This takes place without surface tension distortion. The chamber is then opened and the dried specimens removed. This critical point drying process can be explained as follows: When a liquid in equilibrium with its own vapour is heated in a confined space, a critical temperature is reached at which all the liquid is converted into gas; above this temperature additional compression will force the gas to condense back to the liquid phase. As the pressure increases, the density of the vapour phase increases until at the critical point (critical temperature and pressure) it is equal to that of the liquid. Surface tension becomes zero, and the boundary between liquid and gas vanishes. Specimens immersed in pure liquid and carried through the critical point are thereby surrounded only by gas without any surface tension distortion. As the gas is bled off above the critical temperature the specimens remain unchanged and "dry". It is usually necessary to start by replacing the water in the specimen with a fluid mixable with a liquified gas. When using carbon dioxide (transitional fluid) the water is first replaced with 100% ethyl alcohol or acetone (dehydrating fluid), and then the alcohol or acetone with amyl acetate (intermediate fluid), by passing the specimens through a series of liquid mixtures and finally pure liquids. The transitional fluid must have a critical temperature higher than room temperature, but low enough to avoid damaging the specimens at the critical point. Carbon dioxide has a critical temperature of 31°C at a pressure of 72,9 atm. This method is summarized in a paper by Denton Vacuum Engineers (1973). It has only been investigated once and cannot therefore be evaluated with the other methods.

3.3.3 Freeze drying

Probably the commonest method employed at the moment for drying soft material is freeze drying. Properly done it is in general a sound method but difficulties are still encountered with very large specimens, e.g. engorged female ticks. It is perhaps the best way of preventing specimen distortion on drying, but under some circumstances it seems to be impossible to prevent the collapse of hydrated structures even by subliming the water off.

Fixation prior to freeze drying helps by producing surfaces that are as near as to ideal as possible. A technique described by Jooste (1971) in which freezing takes place extremely rapidly was used. The ticks were fixed in gluteraldehyde, picric acid, etc. for a specific time. After fixation they were thoroughly washed in Extran, placed on a small fine mesh sieve (22 mm in diameter, with 400 meshes/cm) and then immediately snap frozen by immersing the sieve into iso-pentane that had been cooled in liquid air to about -160°C for 5-10 minutes. Jooste (1971) estimated that this method produces a freezing rate of approximately $100^{\circ}\text{C}/\text{sec}$. and the water solidifies instantly without increasing in volume. This solidification process is so rapid that dissolved molecules, particularly at high dilution, have no time to aggregate as crystals. The sieve is then transferred immediately to the pre-cooled stage (-40°C) of a Edwards-Pearse tissue dryer. The water molecules were sublimed in a high vacuum while the specimen were maintained for a period at -40°C . As soon as the specimens were completely dehydrated the temperature was slowly increased to room temperature.

3.3.4 Drying in acetone

Specimens can be dried much better if their water content is replaced with a volatile solvent. The lower the surface tension of the liquid which is finally allowed to evaporate, the less the shrinkage and distorsion consequent upon drying (Pollister, 1966). However even the use of volatile solvents can't completely prevent distortion when specimens are air dried. Ticks were dehydrated in acetone, increasing concentrations of i.e. 25,

50, 75, 90 and 100%. They were left for about 30 minutes in each concentration and then placed on filterpaper in Petri dishes with the tops left halfway open to prevent the accumulation of dust and yet permit air circulation. They were left like this for about 80-96 hours, depending on the size of the specimen. Although freeze drying methods can give much quicker results, this old method of acetone-air drying still has its merits.

3.4 Mounting of specimens

Tick specimens were attached to specimen stubs with nail varnish, "Aquadac", or "Silverdac". One of the difficulties in using either "Aquadac" or "Silverdac" is that it dries very quickly and the transfer of objects as small as the larvae must be done rapidly before the surface hardens and loses its adhesive qualities. Nail varnish is easier to handle because it hardens relatively slowly and allows sufficient time for correct orientation of the specimen. According to Wooley (1970) acetone causes some artifacts on the surface of the specimen when the nail varnish is diluted with acetone. He mentioned that residues of the glue were carried by capillary forces onto the surface of the specimen and occluded some of the structural details there.

Sufficient specimens of ticks of the different life stages were mounted on stubs to give a selection of two study positions: ventral and dorsal.

3.5 Metal coating

The mounted specimens were coated in a Balzers vacuum plant with a 60:40% gold-palladium alloy or aluminium under a high vacuum (10^{-5} torr). According to Loots (1971) better results are obtained from two or more light coatings than from one or two relatively heavy coatings. Coatings were done at different angles to permit an overall covering of the specimen. Coating ensures electrical conductivity from the specimen surface to the holder and also creates a layer which will emit ample secondary electrons following bombardment by electrons. When the coating is inadequate to ensure good electrical conductivity on the specimen's

surface, the image produced is severely disturbed by undesirable charging effects.

The specimens were then transferred to the specimen chamber of the S.E.M. for observation. The microscope used was a Cambridge Instrument's Stereoscan Mk II Scanning Electron Microscope.

4. RESEARCH MATERIAL

This investigation was based on 997 specimens of the following tick species (L = larvae; N = nymphae; F = females; M = males).

Rhipicephalus pravus Donitz, 1910: 41 L; 36 N; 42 F and 42 M. The strain originated from a female collected from an eland, Sunningdale, Private Nature Reserve, Potgietersrus, R.S.A. and was provided by the Veterinary Research Institute, Onderstepoort, R.S.A.

Rhipicephalus oculatus Neuman, 1901: 36 L; 37 N; 40 F and 45 M. The strain originated from "Kosos", Bethanie District, South West Africa and was provided by the Veterinary Research Institute, Onderstepoort, R.S.A.

Rhipicephalus appendiculatus Neuman, 1901: 50 L; 49 N; 29 F and 21 M. The strain originated from the Veterinary Research Laboratory, Kabete, Kenya.

Boophilus decoloratus Canestrini, 1887: 68 L from the Veterinary Research Laboratory, Kabete, Kenya and 20 L; 23 N; 30 F and 22 M from Lesotho, provided by the Veterinary Research Institute, Onderstepoort, R.S.A. Another 71 L; 44 N; 16 F and 17 M were provided by the Tick Research Unit, Rhodes University, R.S.A.

Boophilus microplus Koch, 1844:- South African strains: 120 L; 49 N; 37 F and 66 M provided by the Veterinary Research Institute, Onderstepoort, R.S.A; Australian strains: 105 L and 5 N from Biar=

ra via Esk; 126 L; 8 N; 24 F and 90 M from Mt. Alford; 70 L; 16 N; 24 F and 21 M from Gracemere via Rockhampton; 96 N; 35 F and 11 M from Mackay; 95 L from Mena Creek, Innisfail, Qld; 8 N; 24 F and 29 M from Mt Alford; 94 L; 31 F and 20 M from Ridgeland via Rockhampton; 43 L and 11 M from Wandura via Mackay, all of which were provided by the Department of Parasitology, University of Queensland and the Animal Research Institute, Australia.

Experiments to improve fixation techniques were based on larvae, nymphae and adults of *Hyalomma marginatum rufipes*, *Rhipicephalus capensis* and *Hyalomma turanicum*, provided by the Veterinary Research Institute, Onderstepoort, R.S.A.

4. METHODS OF CALCULATING DIMENSIONS OF THE TICKS STUDIED

No descriptions of a tick species can be regarded as complete without reference to its dimensions and it seems unlikely that it will ever be justifiable to disregard this aspect in taxonomical studies. Simpson et al. (1960) point out that when numerical observations are to be made it should be decided in advance what is to be measured and how. The most important criteria of good numerical observations are that they should be logical, related to a definite problem, adequate, well delimited, comparable and standardized.

A re-evaluation of the ratios employed in morphometric studies is a necessity. Any ratio when used as a tool in taxonomic studies must fulfil certain basic requirements. These are, according to Oberholzer (1970), the following:

1. The choice of ratios must be made on the basis of advanced knowledge of the type of variation.
2. They must represent essential morphological characters and must be suitable for comparison between different populations.
3. They should vary little within a random population sample and also between different populations of the same species.
4. Any sign of allometry should be looked for because, if it does

exist in a certain ratio, different sizes should be compared, taking the necessary precaution.

Many measurements have to be made in a morphological study of this kind. These proved useful as the degree of variability at any stage of tick development could be determined, and in addition the mean growth rate from stage to stage, together with changes in form, could be ascertained.

Measurements were made from stereo-micrographs by means of sliding callipers calibrated to the third decimal. These data are convertible by reference to the magnification of the structure concerned to give its real dimensions. While overall length or breadth may vary in population, the proportions of the various parts to each other may remain fairly constant. For comparison within and between samples, taxonomists therefore use ratios rather than linear measurements.

In the case of the gnathotectum the length was measured from the base of the external sheaths of the chelicerae dorsally and from the post hypostomal setae ventrally, to the posterior margin excluding both the cornua (when present) and the socket-like structure posterior to the gnathothecum. The length of the palpal segments was measured along the dorsal surface from the mid-dorsal base of one segment to its junction with the adjacent segment. The length of a specimen was calculated excluding the gnathosoma, because the latter and the idiosoma were not always on the same level. The length was obtained mid-dorsally from the base of the emargination to the posterior margin of the body. The length of the scutum was obtained from the mid-dorsal base of the emargination to the posterior margin and the length of the alloscutum from the posterior margin of the scutum to the posterior margin of the body. The maximum breadth of all these parts of the body were also measured and the ratios between their lengths and breadths were obtained. Measurements of other structures are given in the descriptions. The lengths of the setae on the tibia-tarsus complex and that of Haller's organ were obtained from micrographs ta-

ken from a lateral view to obtain accurate length. In cases where the setae were bent, a rotarmeter was employed to calculate their lengths.

6. EXPLANATIONS OF TERMS USED IN DESCRIPTIONS AND ABBREVIATIONS USED IN FIGURES AND PLATES

- Accessory shields (ac sh): Paired ventral shields external to the adanal shields in the males.
- Acetabulum (a): The cotoloid cavity of the condylophores of the ambulacra.
- Adanal shields (ad sh): Paired ventral shields near the anus in the males.
- Alae (al): Lateral wing-like projections of the gnathothecum.
- Alloscutum (alsc): Dorsal area of idiosoma behind the scutum in the larvae, nymphae and females.
- Ambulacrum (am): Locomotor limbs on the distally parts of the legs.
- Ambulacrum spurs (am s): Spurs between the claws on the distal dorsal part of the pulvillus.
- Anal aperture (a a): Slit-like opening of the alimentary tract.
- Anal groove (an gr): A groove round the anus behind; in the majority of cases it runs forwards and outwards towards the genital grooves, which it may attain. Sometimes this groove is continuously with a post-anal median groove.
- Anal valves (an v): Semi-lunar structures lateral to the slit-like aperture of the anus.
- Annulus (an a): Ring-like structure round the anus.
- Anus (an): The postero-ventral opening of the alimentary tract on the opisthogaster.
- Basilar piece (b p): Possibly a remnant of the apotele in the ambulacra as in the Acari.
- Camerostome (c): Hollow excavation in the anterior part of the idiosoma for reception of the gnathosoma.
- Caudal appendage (c a): Ventral tail-like caudal appendage in the males.

- Cervical grooves (c gr): A pair of grooves or depressions on the antero-median part of the scutum of larvae, nymphae & females and conscutum of males, starting at the cervical pits and extending backwards.
- Cervical pits (c p): A pair of pits adjacent to the inner angles of the scapulae.
- Chelicerae (ch): Paired structures lying dorsally to the hypostome each bearing an internal article with a fixed dorsal process and an external article which articulates with the outer side of the internal article.
- Cheliceral Sheaths (ch sh): Double-walled tubular folds of the gnathosoma integument surrounding the individual cheliceral shafts.
- Cheliceral shafts (ch s): Shafts bearing the chelicerae terminally.
- Claws (cl): Parts of the ambulacra for attachment on the host.
- Collar (c): Crescent-shaped cuticular folds just posterior to the gnathothecum ventrally.
- Condylophores (cond): A pair of anterior projections of the pretarsus which articulate with a pair of acetabula on either side of the basilar piece.
- Conscutum (con): A chitinized shield covering the dorsal surface in the males.
- Corona (cora): The apical portion of the hypostome which bears numerous very small denticles.
- Cornua (Corn): Spur-like projections from the postero-lateral margins of the gnathotectum.
- Coxae (cox): The proximal immovable sclerotized plates on the venter of the podosoma to which the legs are attached.
- Coxal spurs (cox sp): Spur-like or spine-like projections from the posterior margin of the coxae; the one on the median side is the internal spur and that on the outer side is the external spur.
- Denticles (d): Recurved tooth-like processes on the ventral surface of the hypostome.
- Digits (di): Distal moveable parts of the chelicerae.
- Emargination (em): The hollowed-out portion of the scutum between

- the scapulae in which the gnathosoma is articulated.
- Eyes (e): Light sensitive areas on the antero-lateral margins of the scutum or conscutum.
- Femur (f): Third segment of the palps and legs, counting from the proximal end.
- Festoons (fe): More or less rectangular areas, separated by grooves, into which the posterior margin of the body is divided in most Ixodidae.
- Fovea (fo): Pair of small, circular pits often observable near the middle of the conscutum in males and posterior to the scutum in females.
- Gene's organ (G o): Membranous bilobed organ just posterior to the camerostome, concerned with waxing of the eggs during oviposition.
- Genital orifice (g or): The external aperture of the reproductive organs opening mid-ventrally, posterior to the gnathothecum. Absent in the immature stages.
- Genital apron (g a): A light sclerotized flap attached in front of and covering the genital orifice.
- Genital grooves (g g): Grooves which start at the genital orifice, run backwards between the coxae and external to the anal grooves towards the posterior margin of the body.
- Genu (g): Segment between the femur and the tibia.
- Gnathotectum (gnatht): Roof of the gnathosoma (the tectum, basis capitulum, episton or tegulum of other authors).
- Gnathosoma (gnath): Comprises the precheliceral, cheliceral and pedipalpal segments, anterior to the idiosoma.
- Gnathothecum (gnathth): Sclerotized frame surrounding the chelicerae and forming the attachment site for the cheliceral sheaths.
- Haller's capsule (H c): Partially isolated chamber containing sensillae on the dorsal surface of the tarsus of leg I.
- Haller's pit (H p): Depression containing sensillae on the dorsal surface of the tarsus of leg I, anterior to the capsule.
- Hypognathum (hyp): For infra or subcapitulum; referring to the region of the gnathosoma ventral to the chelicerae and divided into the coxal region and the hypostome.

- Hypopharyngx (hy): A median, ventral, anterior extension of the gnathosoma, armed with longitudinal files of denticles ventrally and grooved dorsally.
- Idiosoma (id): The body excluding the gnathosoma.
- Lateral grooves (l g): A pair of grooves originating at the cervical pits and extending backwards, lateral to the cervical grooves.
- Macula (m): A more or less centrally placed sclerotized area on the spiracle.
- Marginal grooves (m g): Grooves commencing posterior to the eyes and running backwards along the sides of the body to the festoons.
- Opisthogaster (op): Ventral aspect of the idiosoma, lacking legs and bearing the anus, spiracles and festoons.
- Palps (p): Moveable appendages, articulated antero-laterally with the gnathosoma.
- Para-median grooves (pm g): Grooves lying one on each side of the postero-median groove.
- Podogaster (po): Ventral region of the idiosoma bearing the legs.
- Post anal median grooves (pa m g): Median groove posterior to the anus, running backwards.
- Porose areas (p a): Two more or less depressed areas on the gnathotectum of the female.
- Postero-median groove (po m g): Mid-dorsal longitudinal groove near the posterior margin of the body.
- Pre-tarsus (pr): Proximal parts of the condylophores, connecting the ambulacra to the tarsus of the legs.
- Pulvillus (pu): A soft pad on the ventral side of the ambulacra on which the tick walks.
- Punctations (punc): Small pits of various sizes, frequently bearing setae, scattered over the integument.
- Scapulae (sca): The anterior angles of the scutum projecting forward on either side of the emargination.
- Scutum (sc): A dorsal sclerotized shield, covering the anterior part of the idiosoma in females nymphae and larvae.
- Sensillae sagittiformia (ss): Sensory structures on various parts of the body.

Sensillae. The following are present on the gnathosoma and idiosoma.

- Palpal sensillae: Mesial series (M)
: Sub median series (SM)
: Lateral series (L)
: Mid-ventral (MV)
: Sub-mesial (VSM)
: Sub-dorsal series on tibia-tarsus complex (SD)
: Dorsal series (D)
: Supra ventral series (SV)
: Ventral series (V)
- Scutal setae : Sc-series
- Allosutae setae : Marginal dorsal (Md)
: Centro-dorsal (Cd)
: Centro-sub-dorsal (Csd)
: Sternal (St)
: Premarginal (Pm)
: Ventral marginam (VM)
: Spiracular (Sp)
: Pre-anal (Pa)
- Anal setae (an s)
- Genital setae : Antero-lateral complex. (Ga)
: Lateral complex (Gl)
- Coxal setae : Cox s
- Gnathothecal setae (G)
- Setae on Haller's organ: Pre-halleral (p H)
: Halleral (H)
- Tarsal setae : (t s)
- Sensory pits (se p) Pits on the gnathotectum.
- Socket (so): Posterior part of the gnathosoma which fits into the emargination.
- Spiracles (sp): Paired respiratory plates ventro-laterally on the opisthogaster and posterior to the fourth coxae in the nymphae and adults
- Sternum (Ste): Mid-ventral part of the idiosoma between the coxae.
- Sub-anal shields (s an sh): A pair of plates posterior to the accessory and adanal plates.

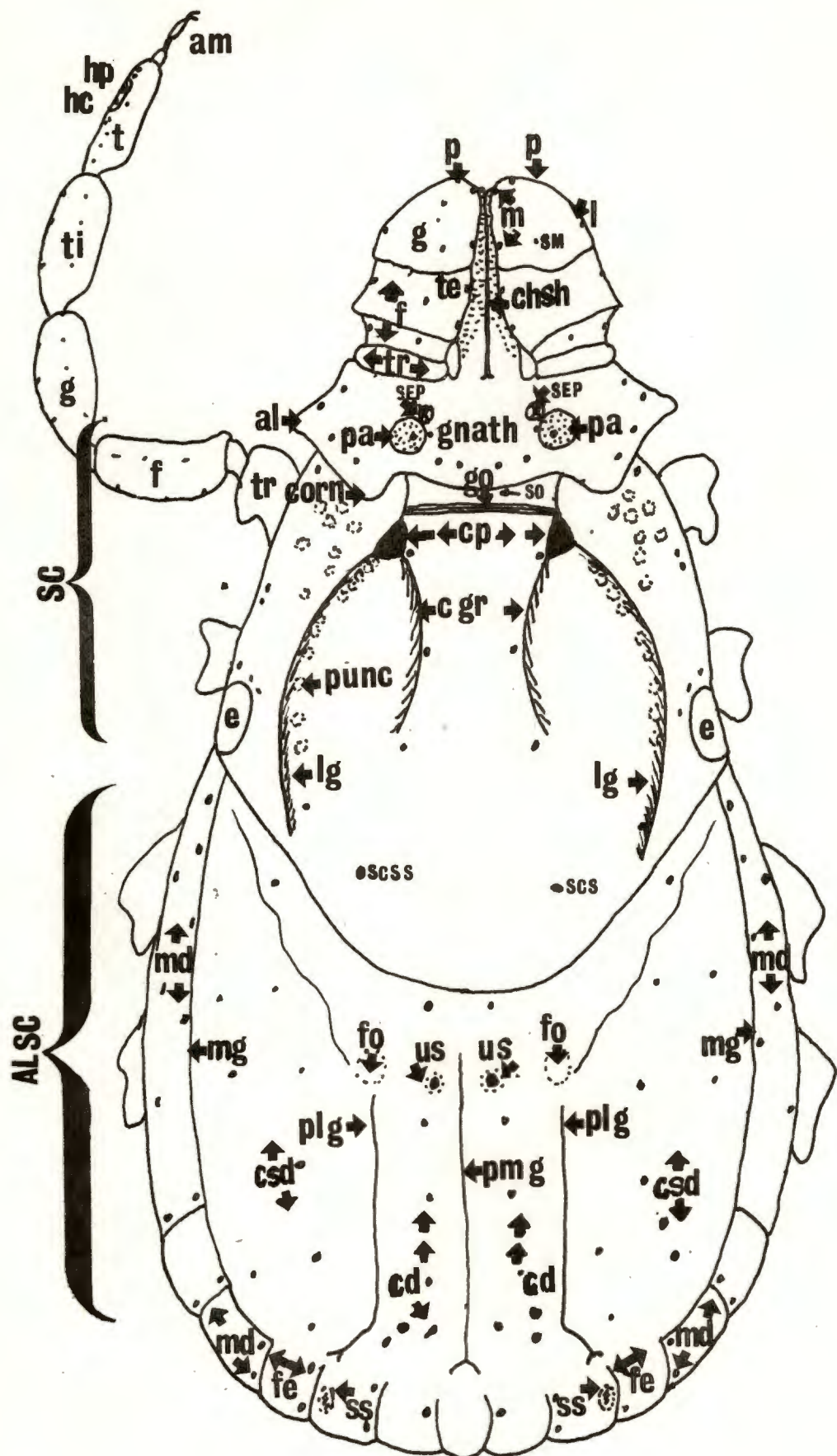


FIGURE 1

FIGURE I

Key morphological characters; Dorsal aspect of a hypothetical female tick.

(Additional characters used in fuller descriptions of individual species are explained where they first occur.)

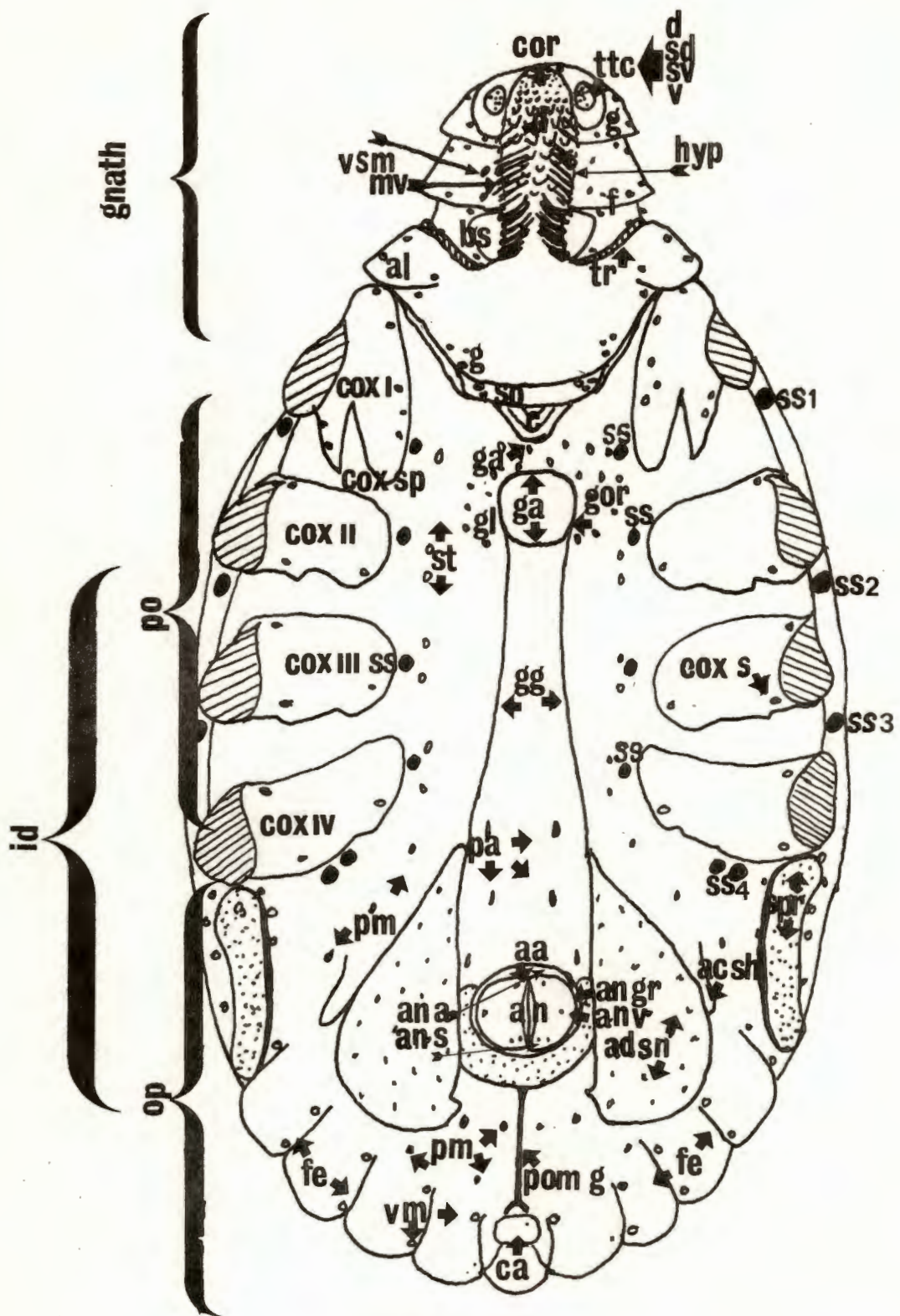


FIGURE 2

FIGURE II

Key morphological characters: Ventral aspect of a hypothetical male tick.

(Additional characters used in fuller descriptions of individual species are explained where they first occur.)

Tarsus (t): Segment distal to the tibia.

Teeth (te): Dorsal plates of the outer cheliceral sheaths.

Tibia (ti): Second distal segment of the legs.

Tibia-tarsus complex (ttc): Distal segment of the palps, formed by fusion of the tibia and tarsus and articulated ventrally with the genu.

Trochanter (tr): The second proximal segment of the legs between the coxa and the femur.

7. DESCRIPTIONS

It is well known that ticks are important transmitters of various diseases of man and animals. To understand the role they play in this respect under natural conditions it is essential that all stages of their life cycle should be identified accurately.

Today there are still many gaps in our knowledge of the systematics of ticks. This can be attributed to a number of factors; e.g., the small number of known reliable characters available for inclusion in keys and the inadequacy of some descriptions and illustrations especially of the larvae and nymphae. However the re-editing, recapitulation and rearrangement of known facts can lead to an increase in our knowledge.

Information obtained through S.E.M. studies can be used to assist in the solution of taxonomic problems by confirming, modifying or rejecting previous decisions arrived at on general morphological grounds. How this information is handled, depends largely on the purpose of the investigation. It also relates to many of the problems regarding the nature, handling and selection of characters, classificatory procedures, information processing and computer methods, which have become central issues in the relatively new field of numerical taxonomy. S.E.M. information can be handled either like conventional characters or character-complexes or simply as "pure" information without broken down and the characters interpreted individually using computer processing.

Today there are many synonyms amongst tick names, because there are relatively few reliable taxonomic characters for ticks been discovered. For example, Minning (1934), divided the genus *Boophilus* into three subgenera: *Boophilus*, *Uroboophilus* and *Palpoboophilus* and described a number of new species. These subgenera, according to Hoogstraal (1956) have been given the status of genera in many published papers, probably because Minning himself, curiously enough, failed to place a generic designation before them in his discussion of the species. Several later workers (Cooley, 1946; Anastos, 1950; Hoogstraal, 1956 and others) have questioned the worth of these findings and in the present instance Minnings reports have been little value. His method, according to Hoogstraal (1956), "appears to have been to hastily examine a few specimens from widely scattered areas, to describe and illustrate them inadequately, and whenever possible to apply names based on assumed, uncritically assessed, slight morphological variations". Anastos (1950), followed by Hoogstraal (1956), reduced the multiplicity of forms described by Minning (1934), to three species, all belonging to the one genus *Boophilus*. "A pains-taking study of extensive, world wide series of specimens will be necessary before any final judgement on all subspecies and related species can be given". (Hoogstraal, 1956.)

"Speciation in this genus has been extremely conservative and retracted geographical species do not appear to have evolved (Hoogstraal, 1956). He stated that many morphological variations are manifestations of the degree of engorgement, method of preservation, or angle of examination. Boophilids are difficult to study owing to their superficial variability and size.

Boophilus decoloratus is distributed throughout most of the Ethiopian Faunal Region, barring the northern and southern periphery of this region on continental Africa. According to Theiler (1962) it is present in South Africa throughout all types of forest, grasslands and parklands, except the desert shrub of the Karoo veld, the thorn country and desert shrub of the North Western Cape and in the desert grasses and desert succulents of Bush=

manland, Namaqualand and from the Namib desert from South West Africa. According to Anastos (1956), *B. microplus* is found in Central America, South America, Australia, the Oriental Region, in the Southern part of Florida and in parts of Africa.

B. decoloratus is a one-host tick and cattle are the chief host. Among wild animals antelopes are important hosts but few others are infested. Wild carnivores are almost never parasitized by this tick. There is evidence that it transmits boutonneuse fever, Q fever, redwater or Texas fever, Spirochaetosis, gallsickness, piroplasmosis and possibly porcine babesiosis (Hoogstraal, 1956). *B. microplus* is also a one-host tick and the hosts are as in *decoloratus*. This tick transmits redwater or Texas fever, Babesiosis anaplasmosis or gallsickness and biliary fever.

According to Walker (1961) the genus *Rhipicephalus* is taxonomically a difficult one. She further stated that "although the adults of some species are easy to recognise others are extremely variable morphologically and consequently may be anything but easy to assign to a definite species. The immature stages are even more troublesome". According to Hoogstraal (1956): "Problems of morphological and biological criteria in the rhipicephalids are unlikely to be solved until more extensive field research and patient laboratory investigation have been devoted to them." According to Hoogstraal (1956) distinguishing characters in many specimens tend to become so generalized that diagnosis is difficult. He stated that this is especially true for the females. He also commented that the question of biological races remains to be explored and that many data suggest that this phenomenon may occur in certain groups of rhipicephalids.

Walker (1961) stated that the rhipicephalids can probably be divided into five groups, e.g., the *R. sanguineus* group, *R. kochi* group, *R. pravus* group, *R. appendiculatus* group and the *R. evertsi* group.

The *R. pravus* group contains *R. pravus* itself, *R. oculatus* and

probably *R. arnoldi* (Walker, 1961). *R. pravus* occurs in the drier areas of East Africa and extends to the more southernly parts of the continent. In South Africa "it shows a preference for Bushveld or dry Parklands and avoids open grasslands and the more humid parklands" (Theiler, 1962). "*R. pravus* is rather more indiscriminate in choice of hosts than most other rhipicephalids, being common on domestic cattle, antelopes, carnivores and hares. Immature stages utilize rodent and insectivores as hosts" (Hoogstraal, 1956). According to Theiler (1962) it has been proved that *R. pravus* transmits *Theileria parva*, which causes East Coast fever. "*R. oculatus* is present in most of the drier areas of the R.S.A. and is found in other parts of Southern Africa" (Theiler, 1962). "*R. oculatus* adults are parasitic essentially on wild hares; the immature stages may also be found on hares, but seem to prefer elephant shrews, shrews and hares in the same habitats and field mice, domestic animals and wild animals" (Theiler & Robinson, 1953).

According to Theiler (1962) "It is not until recently that the taxonomic limits of *R. pravus* and *R. oculatus* have been fixed; so that many of the older records, and of immatures, need to be rechecked against present-day definitions of these two species". According to Theiler & Robinson (1953): "(Dönitz, 1910 gave a very brief description of *R. pravus*. Warburton (1912) agreed that this species corresponded with his newly described *R. neavei* var *punctatus*. Bequaert (1960) suspects that Warburton re-described *R. capensis* var *compositus* as *R. neavei* *punctatus*. Zumpt (1950) shows this record to be *R. longus*. Zumpt (1942) re-described *R. pravus* from Tanganyika; he gives the eyes as "leicht gewölbt und etwas vertieft stehend"; and considered both *R. neavei* and *R. neavei* *punctatus* as synonyms of *R. appendiculatus*. In 1950 he re-established *R. neavei* var. *punctatus* is according to the description but a deeply punctate *R. appendiculatus*. Zumpt (1950) show in his drawing and descriptions that the eyes for *R. pravus* as being surrounded by a groove and resembling that of *R. oculatus*, except that it is not so distinctly hemispherical. Santos Dias (1950) shows that *R. reavei* *punctuosa* is a valid species,

and not a synonym of *R. appendiculatus*; he also lifts it from a variety of *R. neavei* and gives it specific status as *R. punctatus*". In the meantime Theiler & Robinson (1953) draw clear-cut differences between *R. oculatus* and *R. pravus*.

According to Walker (1961) the *R. appendiculatus* group is a large one, consisting of *R. appendiculatus*, *R. mühlensi* and three ornate species, *R. humeralis*, *R. pulchellus* and *R. maculatus*. She furtherly stated that *R. appendiculatus* "is certainly the most important species in the genus from the veterinary point of view and is widely distributed in East, parts of Central and South Africa, usually in areas with 625 mm of rain or more per year". *R. appendiculatus* is the chief vector of East Coast Fever. "Most prominently listed as hosts are cattle, but antelopes and buffalo are also frequently reported" (Hoogstraal, 1956). "Larvae and sometimes nymphs feed on medium small animals such as hares and cane rats; is furtherly a vector of boutonneuse fever, pseudo East Coast fever, redwater, louping-ill and Nairobi sheep disease" (Hoogstraal, 1956). "It appears, however, that no matter how variable this species may be, it is seldom difficult to distinguish from other species" (Hoogstraal, 1956).

It was with a view to throwing a little more light on the morphology of ticks; seeking additional diagnostic characters and re-evaluating those that are commonly used, that this investigation was undertaken. Comparative studies were made therefore of *R. pravus* and *R. oculatus* in an attempt to find additional characters for the differentiation of those two species, particularly in the larval stage. They in turn were compared with *R. appendiculatus* as a representative of another group within the same genus. The morphology of *B. decoloratus* and *B. microplus* was also compared and contrasted. In addition, in view of suggestions that there are certain differences, mainly biological and ecological, between the South African and Australian forms of *B. microplus*, the morphology of specimens of this species from both areas were compared.

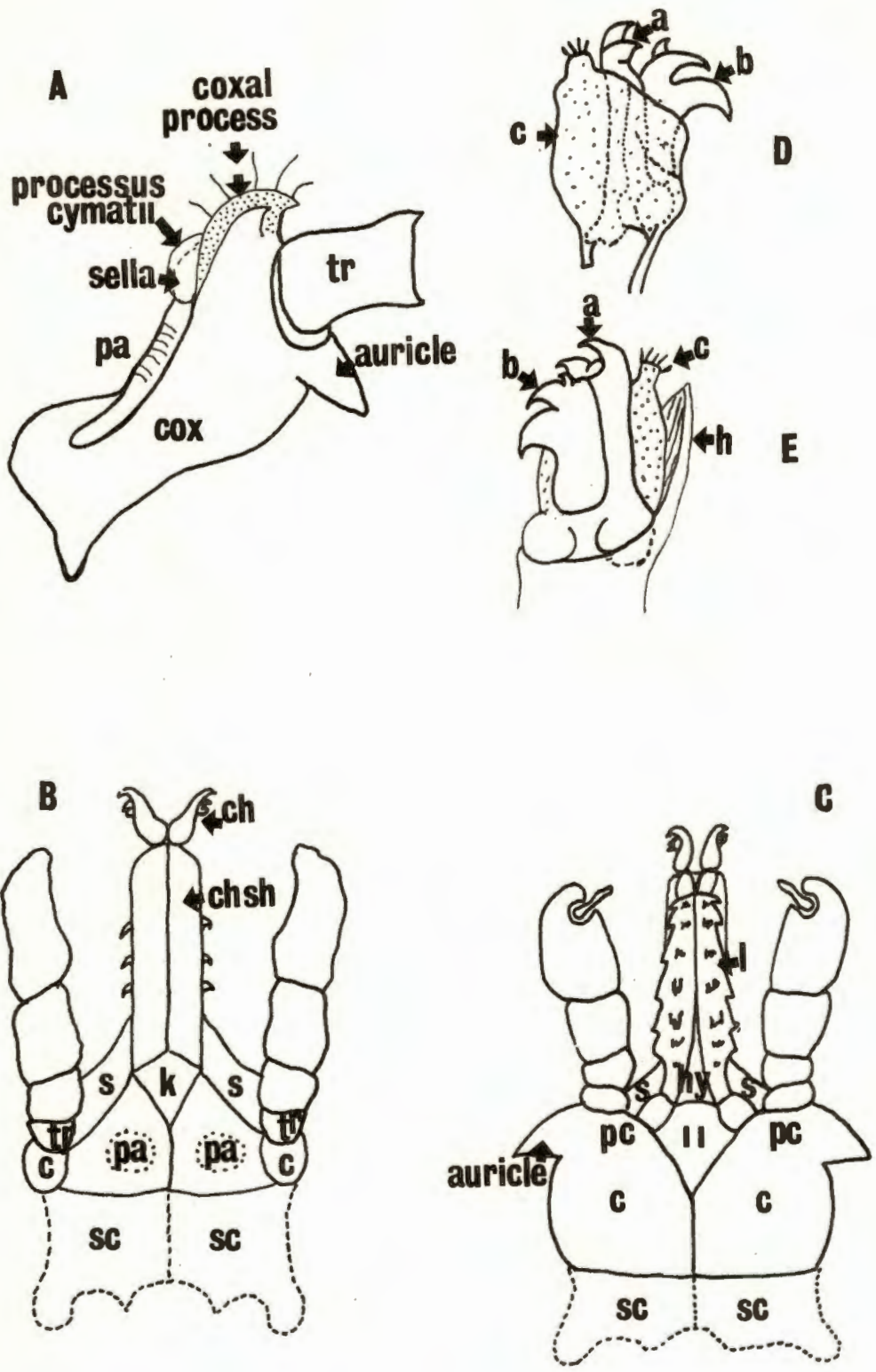


FIGURE 3

Figure 3*

- A. Diagram of a primitive ixodid coxa, showing parts that may enter into the formation of the gnathosoma.
- B & C. Composition of the gnathosoma, dorsal and ventral.
- D. *Amblyomma maculatum* Koch, right cheliceral digit, dorsal.
- E. *Dermacentor variabilis* (Say), end of right chelicera, ventral

- a = main shaft of cheliceral digit
b = toothed lateral lobe of digit
c = membranous dorsal lobe of digit
h = protective extension (hood) from shaft of chelicera
II = sternum
k = part of primary cephalic lobe
Sc = subcoxa
S = sella
pc = processus cymatii
l = coxal process

Other lettering as described in list of abbreviations.

* After Snodgrass, 1948.

There is still an immense amount of work to be done on this subject, and it is hoped that this thesis will arouse greater interest in S.E.M. studies and consequently advance the work.

7.1 Gnathosoma

The distinctive feature relating to the feeding apparatus of ticks is the presence of a discrete head structure carrying the mouthparts known as the gnathosoma, capitulum or capitellum. The first term is adopted in this thesis for purposes of uniformity in acarine nomenclature.

The gnathosoma of ixodid ticks has been studied by numerous workers, principally by Nuttall (1920), Sen (1934, 1935), Schulze (1938), Yalvac (1939), Bertram (1939), Snodgrass (1948, 1952), Arthur (1946, 1951, 1953c and 1956a,b), Lavoipierre (1955), Moorhouse & Tatchell (1966) and Schuntner & Tatchell (1970).

Ticks have a well-developed, sclerotized gnathosoma which is formed, as in other Acari, out of three segments, the precheliceral, cheliceral and pedipalp segments. The gnathosoma fits into a excavation between the scapulae of the scutum, the so called camerostome.

Ventrally the gnathosoma consist of the hypognathum which is divided into two basic regions - a posterior coxal region and an anterior hypostomal region or hypostome.

The exact composition of the gnathosoma is perhaps more complex than is indicated above. Analyzing the gnathosoma structure on the basis of comparative anatomy, Schulze (1938) stated that various elements besides the palpal coxae and the cephalic lobe enter into its composition. First, from a general study of the leg coxae of the Ixodidae, Schulze puts forward the concept of a primitive ixodid coxa (Fig. 3A) with an auricular lobe (au) on the outer angle. Along the anterior margin of the coxa a "process cymantii" (pc) projects distally at the base of the anterior lobe. On the part of the cymantium on the coxa is a po=

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rose area (p.a.) of sense organs like those on the areae porosae of the gnathotectum. A small accessory fold (s) lies above the cymatial process. The composition of the gnathosoma is as follows: (Fig. 3B,C). The pedipalp coxae form the major part of the gnathosoma, but the trochantors may usually be included, since in certain ticks they appear as distinct basal segments of the palps. Schulze (1938) stated that the areae porosae (p.a) on the dorsal surface of the gnathotectum, are derived from the dorso-mesal extensions of the porose areas of the coxal cymatia (Fig. 3A, pa) united along the midline of the gnathosoma (Fig. 3B) while the small triangle (K) between their divergent anterior ends is formed from the primary cephalic lobe. On the ventral surface (Fig. 3C), the coxae (c.c) are united with each other proximally and distally embrace a plate (II) representing the deutosternum, which characteristically bears a pair of setae and forms the median basal part of the hypostome. The lateral toothed parts of the hypostome (l) are the anterior lobes of the primitive coxae (Fig. 3C, l) united with each distally and with the sternal tongue between their bases. At the base of each coxal lobe of the hypostome appears the processus cymantii (Fig. 3C, pc) and laterad of this is a saddlelike piece, the "sella" (s), representing the small fold above the cymatium of the primitive coxa (Fig. 3C, s). Finally, a subcoxal component is present as an invaginated extension from the gnathotectum (Fig. 3C, Sc).

7.1.2 Gnathothecum

Both the shape and the measurements of the gnathotectum can easily be misinterpreted if there is a slight error of orientation under the S.E.M. There are two reasons for this: firstly, the dorsal surfaces of the body and the gnathosoma are usually on slightly different planes, so that when the body is horizontal the gnathosoma is depressed and foreshortened. Secondly, the antero-lateral borders of the gnathotectum viewed dorsally are rounded surfaces, not sharp edges, a faulty impression of the degree of salience and of the precise position of the lateral angle is obtained unless the gnathosoma is placed in an accurately horizontal position. To solve this problem the tick is viewed from an an=

TABLE I

The influence of the angle at which the gnathotectum is viewed on measurements of its length and breadth

No. of degrees from the horizontal level	Length mm	Breadth mm
8	0,045	0,112
13	0,048	0,114
18	0,051	0,114
23	0,052	0,114
28	0,055	0,114
33	0,058	0,114
38	0,060	0,114
43	0,065	0,114
48	0,065	0,114
53	0,065	0,112
58	0,065	0,112
63	0,066	0,111
68	0,066	0,111
73	0,065	0,113
83	0,062	0,112
Variance	0,00001	0,00000
Standard deviation	0,000724	0,000116
Standard fault	0,000187	0,00003
Average length	0,059	0,1129
Variance coefficient	12,234	1,0297

terior direction. As shown in Table I the breadth of the gnathotectum is not influenced to the same extent as the length. Correct interpretation of the length seemed to be when the specimen is orientated between 43-48° to the electron beam and for the breadth between 12-48°. A fourth problem to which measurements are subjective, is the accuracy of the investigator in obtaining the necessary dimensions. Fifty measurements of both the length and the breadth of the gnathotectum of a particular specimen were undertaken at different time intervals. The results were as follow.

Results	Length	Breadth
Variance	0,000000	0,000000
Standard deviation	0,000149	0,000191
Standard fault	0,000047	0,000060
Variance coefficient	2,360900	1,646800

According to Arthur (1953c) the front margin of the gnathotectum in the British Prostriata varies in shape and provides a basis for broad classification. The shape itself is also of diagnostic value. A socket-like structure which is the articulation of the gnathosoma with the idiosoma, is visible dorsally. This structure was investigated although in some cases it was rather difficult to see because it was covered in the retracted position by the head.

LARVAE

Rhipicephalus pravus (Plates I, 1d, II, 9. Fig. 4, A1.)

Dimensions:= Dorsal aspect:- length: 0,054-0,058 mm;
breadth: 0,093-0,107 mm; Breadth socket: 0,071-0,086 mm.

Sensory pits:- from each other 0,046-0,064 mm; from lateral margins: 0,022-0,028 mm; from antero-lateral margins: 0,017-0,026 mm and from posterior margin 0,022-0,028 mm.

Ratio between the length and breadth dorsally about 0,557. Postero-lateral margins continuous through smooth curves with the straight posterior margin. Surface flattened except for a triangular depression immediately behind palpal insertion (Plate I, 1.) Socket rectangular (Plate I, 1). Shape of gnathotectum as in Fig. 4, A1. Ventral surface of gnathothecum curved antero-posteriorly (Plate II, 9.), sloping more gently to the hypostomal base than to the posterior edge. Two elevations occur mesial from the junction with the palps. Two basal median depressions in line with two widely separated, short post hypostomal setae (Plate II, 9.).

Rhipicephalus oculatus (Plates I, 2 & II, 10. Fig. 4, A1).

Dimensions:= Dorsal aspect:- length: 0,055-0,068 mm; breadth: 0,110-0,118 mm; Breadth socket: 0,087-0,094 mm; Sensory pits:- from each other: 0,049-0,060 mm; from lateral margins 0,026-0,035 mm; from antero-lateral margins: 0,019-0,031 mm and from posterior margin 0,023-0,033 mm.

Ratio between the length and breadth dorsally about 0,541. Shape of gnathotectum corresponds with that of *pravus* (fig. 4, A1). Triangular depressions as in *pravus* (Plate I, 2) Socket resembles that of *pravus* (Plate I, 2).

Ventrally the gnathothecum resembles that of *pravus* (Plate 10).

Rhipicephalus appendiculatus (Plates I, 3 & II, 11. Fig. 4, A2).

Dimensions:= Dorsal aspect:- length: 0,062-0,073 mm; breadth: 0,120-0,139 mm. Breadth socket: 0,081-0,095 mm; Sensory pits:- from each other: 0,057-0,063 mm; from lateral margins: 0,027-0,037 mm; from antero-lateral margins: 0,028-0,037 mm and from posterior margin: 0,025-0,034 mm.

Ratio between the length and the breadth dorsally about 0,524. Lateral margins continuous through smooth curves with the straight posterior margin. Lateral margins bluntly angular (Plate I, 3.) Shape of gnathotectum as in fig. 4, A2. Socket not very prominent because it is mostly covered with the gnathotectum (Plate I,

3.)

Ventrally the gnathothecum resembles that of *pravus* (Plate II, 11), except that the post hypostomal setae longer than in *pravus* and *oculatus*.

Boophilus decoloratus (Plates I, 4 & II, 12. Fig. 4, B3)

Dimensions:= Dorsal aspect:- length: 0,060-0,064; breadth: 0,130-0,135 mm. Breadth socket: 0,064-0,076 mm. Sensory pits:- from each other: 0,056-0,060 mm; from lateral margins: 0,027-0,038 mm; from antero-lateral margins: 0,027-0,038 mm and from posterior margin 0,025-0,032 mm.

Ratio between the length and breadth dorsally about 0,466. According to Gothe (1967), the length varied from 0,084-0,092 mm while the breadth varied from 0,136-0,144 mm. Posterior margin straight. Antero-lateral margins concave. (Plate I, 4.) Surface generally flattened except for an antero-lateral elevation immediately behind palpal insertion (Plate I, 4.) Shape of gnathothectum as in fig. 4, B3. Socket narrowly rounded posteriorly. (Plate I, 4.).

Ventrally the gnathothecum is curved from the anterior to the posterior margin, sloping relatively gently to the hypostomal base and relatively strongly posteriorly (Plate II, 12.) Broad oblique depressions situated antero-laterally; beyond them the surface becomes slightly elevated to the posterior and lateral margins. Depressions between post hypostomal setae and post hypostomal setae as in *pravus*, except that they are longer. (Plate II, 12.)

Boophilus microplus (Plates I, 5 & III, 1. Fig. 4, B4).

Dimensions:= Dorsal aspect:- length: 0,068-0,085 mm; breadth: 0,130-0,160 mm. Breadth socket: 0,071-0,091 mm. Sensory pits:- from each other: 0,060-0,078 mm; from lateral margins: 0,032-0,051 mm; from antero-lateral margins: 0,028-0,042 mm and from the posterior margin 0,030-0,042 mm.

Ratio between the length and breadth dorsally about 0,523. According to Gothe (1967) the length ranges from 0,084-0,092 mm, while the breadth ranges from 0,168-0,176 mm. According to both Arthur (1960) and Roberts (1965) the average length is 0,15 mm. The average length obtained during this investigation was 0,078 mm. The average breadth is 0,18 mm according to Arthur (1960) and 0,17 mm according to Roberts (1965). An average breadth of 0,16 mm was obtained during this investigation. The shape of the gnathotectum nearly corresponds with that of *decoloratus* (fig. 4, B4). Surface as in *decoloratus* (Plate I,5.) Socket broadly rounded posteriorly.(Plate I, 5.)

Ventrally the gnathothecum is broadly rounded posteriorly and almost corresponds in shape and topography with that of *decoloratus*. (Plate III, 1.) Depressions and post hypostomal setae as in *decoloratus*, except that the setae are longer. (Plate III, 1.)

NYMPHAE

Rhipicephalus pravus (Plates I, 6. & III, 2. Figg. 4, B 1 & 5, C1.)

Dimensions:= Dorsal aspect:- length: 0,097-0,108 mm; breadth: 0,264-0,272 mm. Sensory pits:- from each other: 0,093-0,109 mm; from lateral margins: 0,065-0,088 mm; from antero-lateral margins: 0,047-0,057 mm and from posterior margin: 0,030-0,035 mm. Socket: breadth: 0,113-0,117 mm. Ventral aspect:- length 0,099-0,108 mm; breadth: 0,245-0,269 mm.

Ratio between the length and breadth dorsally about 0,379. Theiler & Robinson (1953) stated that the gnathotectum is at least two and a half times as broad as long, while Walker (1956) stated that it is three times as broad as long. Lateral angles blunt. Anterior margin concave; antero-lateral margins almost straight and shorter than the straight to slightly concave postero-lateral margins. Posterior margin straight. (Plate I, 6.) Shape of gnathotectum as in fig. 4, B1. The junction of the posterior margins rounded and protruding slightly, forming very small cornua. Two sensory pits occur in the positions indicated in the dimensions.



PLATE I

PLATE I⁺

Dorsal aspect of gnathosoma of larvae:-

1. *Rhipicephalus pravus*;
2. *R. oculatus*;
3. *R. appendiculatus*;
4. *Boophilus decoloratus*;
5. *B. microplus*.

Dorsal aspect of gnathosoma of nymphae:-

6. *R. pravus*;
7. *R. oculatus*;
8. *R. appendiculatus*;
9. * *B. decoloratus*;
10. *B. microplus*.

Dorsal aspect of gnathosoma of males:-

11. *R. pravus*;
12. *R. oculatus*.

+ Scale lines in μm .

* After Arthur & Londt (1973).

Surface smooth with triangular depressions as in the larvae, but not so markedly defined. The socket rectangular and covered posteriorly with a membranous structure. (Plate I, 6.)

Ratio between the length and breadth ventrally about 0,402. Posterior margin broadly convex, continuous through blunt angles with the slightly convex postero-lateral margins (plate III, 2). Shape of the gnathothecum ventrally as in fig. 5, C1. Postero-lateral margins form a sharp angle with the antero-lateral margins which are slightly convex. The latter two constitute the alae of the gnathothecum. Surface smooth sloping more slightly to the hypostomal base than to the posterior edge. A pair of setae occurs postero-mesial to the alae. Post hypostomal setae are relatively short with two deep depressions between it. Two setae occur ventrally at the sides of the socket. (Plate III, 2.)

Rhipicephalus oculatus (Plates I, 7 & XIV, 4. Figg. 4, B1 & 5, C1.)

Dimensions:= Dorsal aspect:- length: 0,097-0,101mm; breadth: 0,282-0,314 mm. Sensory pits:- from each other: 0,100-0,118 mm; from lateral margins: 0,086-0,098; from antero-lateral margins: 0,032-0,041 mm; from posterior margin 0,044-0,052 mm. Socket: breadth: 0,121-0,139 mm. Ventral aspect:- length: 0,128-0,134 mm; breadth: 0,282-0,318 mm.

Ratio between the length and breadth dorsally about 0,328. Theiler & Robinson (1953) stated that the gnathotectum is about three times as broad as long. This corresponds fairly well with the results obtained during this investigation. The shape of the gnathotectum corresponds with that of *pravus*. (Plate I, 7 & fig. 4, B1.)

Theiler & Robinson (1953) stated that the cornua is feebly developed, and this also correspond with our findings. Two sensory pits occur as indicated by the dimensions. Surface as in *pravus*.

Socket as in *pravus*.

Ratio between the length and breadth ventrally about 0,427. Ventrally the gnathothecum resembles that of *pravus*. (Plate XIV, 4 and fig. 4, B1.) Post hypostomal setae, depressions, setae next to the alae and setae on the socket ventrally resemble that of

pravus.

Rhipicephalus appendiculatus (Plates I, 8 & III, 3. Figg. 4, B2 & 5, C2.)

Dimensions:= Dorsal aspect:- length: 0,094-0,121 mm; breadth: 0,288-0,320 mm. Sensory pits:- from each other: 0,155-0,167 mm; from lateral margins: 0,038-0,089 mm; from antero-lateral margins: 0,038-0,055 mm; from posterior margin: 0,032-0,046 mm. Socket:- breadth: 0,154-0,168 mm. Ventral aspect:- length: 0,120-0,127 mm; breadth: 0,262-0,302 mm.

Ratio between the length and breadth dorsally about 0,364. Lateral angles blunt; antero-lateral margins straight and continuous through smooth curves with the concave postero-lateral margins. (Plate I, 8.) The latter continuous through smooth curves with the straight to concave posterior margin. Very slight indications of cornua occur. Shape of gnathotectum as in fig. 4, B2. Two sensory pits occur positionally as indicated by the dimensions. Surface smooth except for a vague triangular depression which extends over the whole length of the gnathotectum. Socket resembles that of *pravus*. (Plate I, 8.)

Ratio between the length and breadth ventrally about 0,428. The shape, surface and setae ventrally as in *pravus* except for two well-defined sub-triangular spurs which occur on the posterior margin. (Plate III, 3, fig. 5, C2.) Post. hypostomal, setae and setae on the socket ventrally as in *pravus*. (Plate III, 3.)

Boophilus decoloratus (Plates I, 9 & III, 4, Figg. 4, B3 & 5, C3.)

Dimensions:= Dorsal aspect:- length: 0,141-0,161 mm; breadth: 0,334-0,369 mm. Sensory pits:- Anterior pair:- from each other: 0,206-0,222 mm; from lateral margins: 0,056-0,059 mm; from antero-lateral margins: 0,070-0,077 mm; from posterior margin: 0,068-0,077 mm. Posterior pair:- from each other: 0,141-0,153 mm; from lateral margins: 0,050-0,055 mm; from antero-lateral margins: 0,075-0,085 mm; from posterior margin: 0,048-0,053 mm. Socket:- breadth: 0,198-0,226 mm. Ventral aspect:- length: 0,138-0,144 mm; breadth 0,267-0,278 mm.

Ratio between the length and breadth dorsally about 0,468. According to Gothe (1967) the length of the gnathotectum varies from 0,152-0,160 mm. According to Arthur (1960) the breadth varies from 0,32-0,37 mm, while Gothe (1967) stated that it is about 0,332-0,342 mm. Posterior margin nearly straight. (Plate I, 9.) Cornua lacking: Posterior margin merging by way of strongly divergent, postero-lateral "angles" with mildly sinuous postero-lateral margins to maximum breadth, thence through almost a right angle to straight convergent antero-lateral margins to furrowed region, adjacent to insertion of palps. Shape of gnathotectum as in fig. 4, B3. Surface smooth and curving gently to the periphery, except antero-laterally where it is elevated and longitudinally furrowed. Two pairs of widely situated sensory pits, slightly behind level of greatest breadth. Posterior margin of socket almost straight and continuous through widely rounded curves with the anterior margin. (Plate I, 9.)

Ratio between the length and breadth ventrally about 0,511. Posterior and postero-lateral margins markedly convex diverging to greatest breadth, thence sharply angled to short straight convergent antero-lateral margins, interrupted only by a shallow depression, associated with a short transverse furrow. (Plate III, 4.) Shape of gnathothecum ventrally as in fig. 5, C3. Region adjacent to palpal insertion bears short, shallow depressions. (Plate III, 4.)

At greatest breadth surface sharply ridged for a distance transversely. At this level a pair of widely separated setae occur. A pair of closely set post hypostomal setae of similar length, with two deep depressions them. A pair of setae on the sides of the socket ventrally. (Plate III, 4.)

Boophilus microplus (Plates I, 10 & III, 5. Figg. 4, B4 & 5, C4.)

Dimensions:= Dorsal aspect:- length: 0,108-0,147 mm; breadth: 0,322-0,389 mm. Sensory pits:- Anterior pair: from each other= 0,220-0,227 mm; from lateral margins: 0,060-0,061 mm; from antero-lateral margins: 0,042-0,048 mm; from posterior margin: 0,047-0,051 mm. Posterior pair: from each other: 0,160-0,164 mm; from

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lateral margins: 0,043-0,045 mm; from antero-lateral margins: 0,056-0,067 mm; from posterior margin: 0,056-0,075 mm. Socket:- breadth: 0,198-0,217 mm. Ventral aspect:- length: 0,130-0,145 mm; breadth: 0,351-0,370 mm.

Ratio between the length and breadth dorsally about 0,379. According to Arthur (1960) the breadth of the gnathotectum is from 0,28-0,31 mm; Roberts (1964) gives 0,30-0,35 and Gothe (1967) 0,351-0,370 mm. According to Gothe (1967) the length is 0,136-0,144 mm. Posterior margin convex; postero-lateral margins slightly concave. (Plate I, 10, fig. 4, B4). Cornua well-developed. Postero-lateral margins straight to mildly concave with the lateral angles usually pointed. Antero-lateral margins straight to mildly concave (fig. 4, B4). Shape of gnathotectum as in fig. 4, B4. Surface as in *decoloratus*. Two pairs of sensory pits, slightly behind level of greatest breadth (Plate I, 10).

Ratio between the length and breadth ventrally about 0,385. Posterior and postero-lateral margins more widely rounded than in *decoloratus*, thence continuous through blunt angles to the slightly concave antero-lateral margins. (Plate III, 5.) Shape of gnathothecum ventrally as in fig. 5, C4. Surface and setae as in *decoloratus*. Post hypostomal and setae on the socket ventrally resembles that of *decoloratus* (Plate III, 5).

MALES

Rhipicephalus pravus (Plates I, 11 & III, 6. Figg. 5, D1 & 6, E1.)

Dimensions:= Dorsal aspect:- length: 0,231-0,261 mm; breadth 0,556-0,605. Socket:- breadth: 0,202-0,223 mm. Ventral aspect:- length: 0,274-0,339 mm; breadth: 0,643-0,713 mm.

Ratio between the length and breadth dorsally about 0,423 . Posterior margin between the cornua straight to slightly concave. (Plate I, 11 & fig. 5, D1.) Lateral angles (alae) prominent and

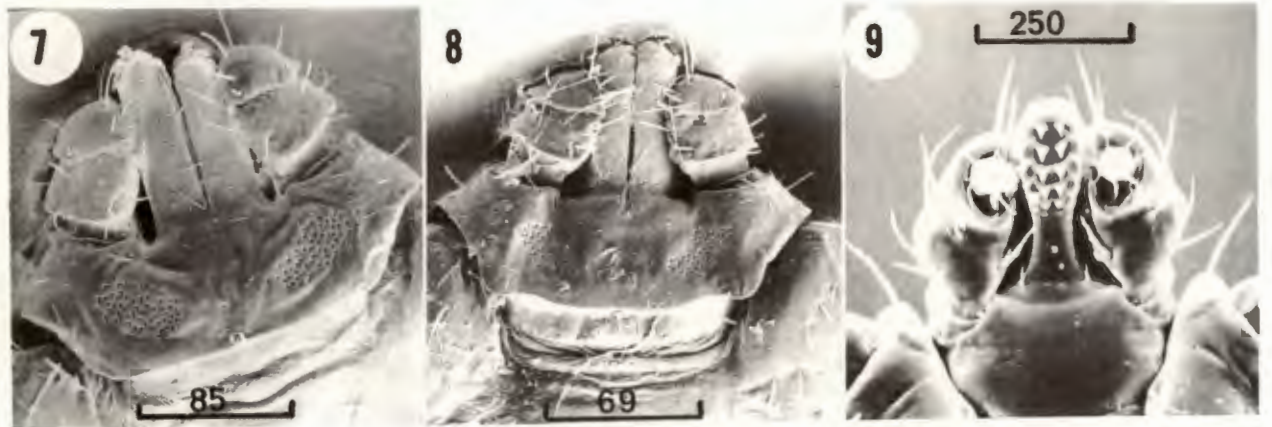


PLATE II

PLATE II⁺

Dorsal aspect of gnathosoma of males:-

1. *Rhipicephalus appendiculatus*;
2. *Boophilus decoloratus*;
3. *B. microplus*;

Dorsal aspect of gnathosoma of females:-

4. *R. pravus*;
5. *R. oculatus*;
6. *R. appendiculatus*;
7. *B. decoloratus*;
8. *B. microplus*;

Ventral aspect of gnathosoma of larvae:-

9. *R. pravus*;
10. *R. oculatus*;
11. *R. appendiculatus*;
12. *B. decoloratus*.

+ Scale lines in μm .

curved ventrally. According to Walker (1956), in small specimens the gnathotectum tends to be relatively narrower and the recurved lateral angles are more pronounced. Surface moderately punctate with larger and small punctations; the large punctations are in a transverse row; parallel to the posterior margin, each containing a seta. The smaller punctations are scattered more densely posteriorly on the gnathotectum. (Plate I, 11.) The surface is flattened mid-dorsally with two longitudinal depressions, extending from the lateral bases of the cheliseral sheaths almost to the posterior margin, mesial to the cornua. Lateral to these depressions the surface becomes elevated towards the trochantor base and then curves downwards to the periphery (Plate I, 11). Chaetotaxy dorsally: four setae in a posterior transverse row parallel to the posterior margin (Plate I, 11). In one case a fifth seta occurs anterior to this row. Two pairs of setae in a postero-lateral row. (Plate I, 11.) The socket of the gnathosoma is almost rectangular. The surface smooth, sloping gradually towards the sides. (Plate I, 11.)

Ratio between the length and breadth ventrally about 0,451 . Posterior margin slightly curved leading to concave postero-lateral margins. (Plate III, 6.) Antero-lateral margins sinuous to straight or weakly concave. Lateral angles (alae) blunt, extending above the surface of the gnathothecum ventrally. Shape of the gnathothecum ventrally as in fig. 6, E1. Surface smooth with a few moderate punctations on the posterior part and on the lateral angles. (Plate III, 6.) The gnathothecum slopes gradually anteriorly to the hypostomal base and more steeply to the postero-lateral margins. Chaetotaxy ventrally: Three pairs of small setae at the junction of the posterior and postero-lateral margins. Anterior to this, two longer setae occur in a transverse series on the alae and one pair posterior to it; this setae are partially covered by the alae ventrally. Two setae occur in a transverse row next to the antero-lateral margins. A single pair of closely-set post hypostomal setae with two shallow depressions between them. (Plate III, 6.) Two to three setae occur ventrally on the postero-lateral sides of the socket.

Rhipicephalus oculatus (Plates I, 12 & III, 7. Figg. 5, D1 & 6, E1)

Dimensions:= Dorsal aspect:- length: 0,226-0,250 mm; breadth: 0,541-0,600 mm. Socket:- breadth: 0,205-0,221 mm. Ventral aspect:- length: 0,220-0,266 mm; breadth: 0,561-0,567 mm.

Ratio between the length and breadth dorsally about 0,413. Posterior, postero-lateral, antero-lateral and cornua as in *pravus* (Plate I, 12.) Shape of gnathotectum resembles that of *pravus* (fig. 5, D1). An uneven row of five to six punctations present in a transverse row parallel to the posterior margin. Surface as in *pravus*, except that the longitudinal depressions are not so prominent. (Plate I, 12.) Dorsal chaetotaxy: Setal distribution as in *pravus*, except that the posterior transverse row usually contains five setae instead of four. The socket resembles that of *pravus*, except that just lateral to it two prominent pits occur.

Ratio of the length and breadth ventrally about 0,414 mm. Posterior margin convex with the postero-lateral margins concave. (Plate III, 7.) Lateral angles as in *pravus* as well as the surface. Antero-lateral margins slightly sinous. Shape of gnathothecum ventrally resembles that of *pravus* (fig. 6, E1). Chaetotaxy ventrally: Four setae in a postero-lateral group, with the most anterior seta about four times as long as the others. In one case another seta occurs antero-mesially to the latter. (Plate III, 7.) Posterior to the alae and partially covered by it, another pair of setae occur as in *pravus*. Setae next to the antero-lateral margins as in *pravus*. A complex of about five lateral setae on the ventro-lateral sides of the socket. (Plate III, 7.) Post hypostomal setae as in *pravus*.

Rhipicephalus appendiculatus (Plates II, 1 & III, 8. Figg. 5, D2 & 6, E2.)

Dimensions:= Dorsal aspect:- length: 0,354-0,382 mm; breadth: 0,682-0,714 mm. Socket:- breadth: 0,266-0,286 mm. Ventral aspect:- length: 0,265-0,379 mm; breadth: 0,585-0,638 mm.

Ratio between the length and breadth dorsally about 0,518. Posterior margin between the cornua concave. (Plate II, 1.) Postero-lateral margins long (longer than in *pravus* or *oculatus*), straight to slightly concave, continuous through smooth angles with the short convex antero-lateral margins. (Plate II, 1.) Lateral angles (alae) relatively anterior in position and obtuse. Cornua more prominent than in *pravus* or *oculatus*. Shape of gnathotectum as in fig. 5, D2. Four to six large punctations in a transverse row parallel to the posterior margin. Small punctations scattered over the whole surface but denser posteriorly. (Plate II, 1.) Vague longitudinal depressions occur, extending from the lateral bases of the cheliceral sheaths to the cornua. Chaetotaxy dorsally: Four to six setae in a transverse row parallel to the posterior margin. A pair of setae in a postero-lateral row as in *pravus* and three to four pairs of setae at the antero-lateral margin. According to Hoogstraal (1956) the shape of the gnathotectum is somewhat variable in that the lateral margins may be more or less angles, depending largely on the size of the individual tick. Socket resembles that of *pravus*. (Plate II, 1.)

Ratio between the length and breadth ventrally about 0,523. Posterior margin convex; postero-lateral margins concave and the antero-lateral margins convex. (Plate III, 8.) Shape of gnathotectum as in fig. 5, D2. Surface and alae as in *pravus* except that the alae are relatively smaller. (Plate III, 8.)

Chaetotaxy ventrally: A complex of seven to eight setae next to the postero-lateral margins. Two pairs of setae on the alae in a postero-lateral row and two setae on the antero-lateral margins. A complex of about five lateral setae on the ventral side of the socket. (Plate III, 8.) Post hypostomal setae as in *pravus*.

Boophilus decoloratus (Plates II, 2 & III, 9. Figg. 5, D3 & 6, E3.)

Dimensions:= Dorsal aspect:- length: 0,148-0,167 mm; breadth: 0,361-0,490 mm. Socket:- breadth: 0,221-0,259 mm. Ventral aspect:- length: 0,162-0,192 mm; breadth: 0,380-0,433 mm.

Ratio between the length and breadth dorsally about 0,387. According to Arthur (1960) the length varies from 0,23-0,28 mm and the breadth from 0,43-0,49 mm. According to Gothe (1967) the length varies from 0,182-0,202 mm and the breadth from 0,460-0,520 mm. Posterior margin concave with variably developed cornua. (Plate II, 2.) Lateral margins arcuate with the antero-lateral margins indented at the level of the trochantor. Surface flattened mid-dorsally, slightly elevated, curving downwards peripherally. Shape of gnathotectum as in fig. 5, D3. Chaetotaxy dorsally: An arch of six or seven setae slightly behind mid-length. Antero-lateral to the latter, on each side a transverse series of four setae occur, which lead to a group of about four setae at the antero-lateral boarder. Setae conspicuous.

The posterior margin of the socket bowl-shaped. No membranous structure occur as in *pravus*.

Ratio between the length and breadth ventrally about 0,442. Posterior margin concave, continuous through rounded postero-lateral angles with the postero-lateral margins which become convex at first and then concave just posterior to the smoothly rounded alae. (Plate III, D3.) Shape of the gnathothecum ventrally as in fig. 6, E3. Alae lacking. Chaetotaxy: A complex of six to ten setae next to the lateral margins with another complex of three to four setae at the antero-lateral boarders. A complex of about five lateral setae on the ventral side of the socket. (Plate III, 9.) Post-hypostomal setae as in *pravus*. (Plate III, 9.)

Boophilus microplus (Plates II, 3 & III, 10. Fig. 5, D4 & 6, E4.)

Dimensions:= Dorsal aspect:- length: 0,140-0,197 mm; breadth: 0,406-0,511 mm. Socket: breadth: 0,219-0,238 mm. Ventral aspect:- length: 0,156-0,204 mm; breadth: 0,414-0,476 mm.

Ratio between the length and breadth dorsally about 0,388. According to Cooley (1946), the breadth varies from 0,40-0,49 mm, while Roberts (1965) stated that the breadth varies from 0,42-0,48 mm. Arthur (1960) stated that the length and the breadth vary respec=

tively from 0,30-0,37 mm and 0,40-0,49 mm, while Gothe (1967) stated that the same dimensions vary respectively from 0,178-0,198 mm. and 0,515-0,535 mm. Posterior margin slightly convex to almost straight. (Plate II, 3.) Postero-lateral and antero-lateral margins asymmetrically concave, with the postero-lateral margins twice as long than the antero-lateral margins. Shape of gnathotectum as in fig. 5, D4. Cornua moderate in size, triangular and usually rather blunt. According to Arthur (1960) the cornua in some specimens are sharp tipped. Surface mid-dorsally flattened, but not curving downwards peripherally in the same extent as in *decoloratus*. Lateral angles not as in *decoloratus*, but pointed. Chaetotaxy: Two groups of two pairs of sub-mesial setae with anterior to these a series of three pairs of setae. Three to four setae occur on the antero-lateral borders (Plate II, 3.)

Socket as in *decoloratus*, except that a membranous structure occurs posteriorly. (Plate II, 3.)

Ratio between the length and breadth ventrally about 0,514 mm. Posterior margin broadly convex with the long postero-lateral margins straight to asymmetrically convex. (Plate III, 10.) Alae prominent. Shape of gnathothecum ventrally as in fig. 6, E4. Surface as in *pravus*. Chaetotaxy ventrally: A complex of nine to thirteen setae on the postero-lateral border, varying in length. Three to four setae at the antero-lateral border. Post hypostomal setae as in *pravus*. A complex of about three to four lateral setae on the ventral side of the socket. (Plate III, 10.)

FEMALES

Rhipicephalus pravus (Plates II, 4 & III, 11. Figg. 6, F1 & 7, G1.)

Dimensions: Dorsal aspect: length: 0,285-0,335 mm; breadth: 0,773-0,835 mm. Socket:- breadth: 0,350-0,377 mm. Ventral aspect:- length: 0,284-0,339 mm; breadth: 0,800-0,883 mm.

Ratio between the length and breadth about 0,381. Posterior margin between the cornua ranging from slightly convex to slightly concave. (Plate II, 4.) Postero-lateral margins concave and about twice as long as the almost straight antero-lateral margins. Lateral angles curved towards the ventral surface as in the males. Shape of the gnathotectum as in fig. 6, F1. Cornua well-developed. (Plate II, 4.) Surface smooth with fewer punctations than in the males. Chaetotaxy dorsally: Two pairs of setae in or with one just next to the porose areas. Two setae in a postero-lateral row as in the males; two setae next to the antero-lateral margins. (Plate II, 4.) The socket almost rectangular with the surface smooth sloping gradually to the lateral margins.

Ratio between the length and breadth ventrally about 0,361. Shape, surface, punctations and chaetotaxy resembles that of the males in nearly all cases. (Plate III, 11.) Shape of gnathotectum ventrally as in fig. 7, G1. Chaetotaxy ventrally: At the junction of the posterior margin with the postero-lateral margins 3-4 short setae with a longer anterior seta present. Two setae on the alae as in the males. A pair of setae at the posterior steep face of the alae as in the males. Two setae next to the antero-lateral margins as in the males. Post hypostomal setae as in the males. Three to seven very small setae are present postero-laterally on the ventral surface of the socket. (Plate III, 11.)

Rhipicephalus oculatus (Plates II, 5 & III, 12. Figg. 6, F1 & 7, G1.)

Dimensions:= Dorsal aspect:- length: 0,282-0,339 mm; breadth: 0,296-0,346 mm. Socket:- breadth: 0,313-0,345 mm. Ventral aspect:- length: 0,296-0,346 mm; breadth: 0,755-0,798 mm.

Ratio between the length and the breadth dorsally about 0,466. Posterior margin straight. Postero-lateral and antero-lateral margins as in *pravus*. (Plate II, 5.) Shape of gnathotectum resembles that of *pravus*, (fig. 6F1). Alae prominent and curved ventrally. Punctations more prominent than those of *pravus*. (Plate II, 5.) About ten punctations between the porose areas

with more densely scattered punctations laterally and one on each of the cornua, which are narrower than those of *pravus*. Chaetotaxy dorsally: two setae in the porose areas and one just outside it in a mesial position. Two pairs in an antero-lateral row and two pairs in a postero-lateral row as in *pravus*. (Plate II, 5.) Socket as in *pravus*. Lateral edges extending beyond the posterior margin of socket and curving inwards. Between this extension a membranous structure covers about one half the length of the socket. (Plate II, 5.)

Ratio between the length and breadth ventrally about 0,423. Shape surface and post hypostomal setae resemble that of the males in nearly all cases, except that the alae are more prominent. (Plate III, 12, fig. 7, G1.) Chaetotaxy ventrally: Four setae in a postero-lateral row or complex with one seta longer than the rest. Posterior to the alae, but not partially covered by the alae another pair of setae. Series of three setae on the alae as in the males and two pairs of which are in an antero-lateral row. Three to five very small setae are present postero-laterally on the ventral surface of the socket. (Plate III, 12.)

Rhipicephalus appendiculatus (Plates II, 6 & III, 1. Figs. 6 F2 & 7, G2.)

Dimensions:= Dorsal aspect:- length: 0,319-0,360 mm; breadth 0,802-0,863 mm. Socket:- breadth: 0,413-0,442 mm. Ventral aspect:- length: 0,309-0,373 mm; breadth: 0,800-0,886 mm.

Ratio between the length and breadth dorsally about 0,396. Much broader than in the males. (Plate II, 6.) Posterior margin between the cornua straight. Postero-lateral margins concave, long and continuous through blunt angles with the short, almost straight antero-lateral margins. Cornua prominent and more broadly rounded than in *pravus* or *oculatus* or in the males. Surface with scattered punctations, most of them antero- and postero-laterally and relatively few medianly between the porose areas. Longitudinal depressions more pronounced than those of *pravus*. (Plate II, 6.) Shape of the gnathotectum as in fig. 6, F2.

Chaetotaxy dorsally: Three setae in a postero-lateral row, one pair in the porose areas and another pair between these areas. Antero-lateral setae as in *pravus*. (Plate II, 6.) Socket as in *pravus*. (Plate II, 6.)

Ratio between the length and breadth ventrally about 0,404. Shape, surface, punctations and chaetotaxy resemble those of the males in nearly all respects. (Plate IV, 1, fig. 7, G2.) Much broader ventrally than the males. A few punctations scattered over the whole surface. Chaetotaxy ventrally: A complex of five setae next to the postero-lateral margins. Three pairs on the alae and in one specimen another seta just mesial to the alae. A pair of setae just next to the antero-lateral margins. (Plate IV, 1.) Three to seven very small setae occur postero-laterally on the ventral surface of the socket. (Plate IV, 1.)

Boophilus decoloratus (Plates II, 7 & IV, 2. Figg. 6, F3 & 7, G2.)

Dimensions:= Dorsal aspect:- length: 0,186-0,242 mm; breadth: 0,500-0,699 mm. Socket:- breadth: 0,411-0,446 mm. Ventral aspect:- length: 0,221-0,269 mm; breadth: 0,554-0,681 mm.

Ratio between the length and breadth dorsally about 0,317. According to Gothe (1967), the length varies to slightly convex. (Plate II, 7.) Shape of gnathotectum as in fig. 6, F3. In most specimens the cornua are absent and, if present, are poorly defined. Postero-lateral angles broadly rounded. Postero-lateral margins mildly concave and strongly divergent, continuous with short, convex or sinuous convergent antero-lateral margins. (Plate II, 7.) Sub-triangular depressed areas posterior to the chelicerae. The socket resembles that of the males, except that it is posteriorly covered by a membranous structure. (Plate II, 7.) Chaetotaxy dorsally: Two pairs of setae next to the antero-lateral margins. Porose areas lack any setae. (Plate II, 7.)

Ratio between the length and breadth ventrally about 0,399. Posterior margin broadly rounded. (Plate IV, 2.) Shape of gnathothecum ventrally as in fig. 7, G3. Posterior margin continuous through widely rounded angles with short divergent sinuous postero-lateral margins, thence slightly concave antero-lateral margins follow. Two semi-lunar elevated alae, with steep, posterior faces at the greatest breadth. Surface flattened gradually sloping anteriorly with an arcuate transverse shallow depression connecting the two alae. Ventral chaetotaxy: One to three setae postero-medially to the alae. One pair at the mesial origin of the alae, and one pair next to the antero-lateral margins. Post hypostomal setae as in *pravus*. Three to five setae posterolaterally on the ventral surface of the socket. (Plate IV, 2.)

Boophilus microplus. (Plates II, 8 & IV, 3. Figg. 6, F4 & 7, G4).

Dimensions:= Dorsal aspect: length: 0,183-0,203 mm; breadth: 0,638-0,791 mm; Socket:- breadth: 0,423-0,446 mm. Ventral aspect: length: 0,201-0,286 mm; breadth: 0,668-0,722 mm.

Ratio between the length and the breadth dorsally about 0,319. According to Arthur (1960) the length and the breadth is respectively about 0,3 and 0,79 mm, while Gothe (1967) stated that the same dimensions vary respectively from 0,180-0,200 and 0,600-0,800 mm. Dorsal aspect hexagonal, with the surface between the porose areas and the base of the outer cheliceral sheaths slightly undulated and elevated. (Plate II, 8.) Shape of the gnathotectum as in fig. 6, F4. Posterior margin between the cornua slightly convex. Cornua small to moderately well-defined and broadly rounded. The long postero-lateral margins concave and divergent to maximum breadth, where they are continuous through sharp angles with the straight to sinuous antero-lateral margins. (Plate II, 8.) Dorsal chaetotaxy: Setae restricted to one or two in the region of the antero-lateral margins.

Ratio between the length and the breadth ventrally about 0,400. Surface and shape correspond with that of *decoloratus*, but with the alae more prominent. (Plate IV, 3.) Chaetotaxy ventrally:

A complex of four to six setae posterior to the alae and three setae in the region of the antero-lateral margin. Post hypostomal and setae on socket ventrally as in *decoloratus*. (Plate IV, 3.)

7.2.1 Porose areas

For a long time no attempt was apparently made to determine the function of the areae porosae on the dorsal surface of the gnathotectum of the female ixodid tick. Most acarologists merely used their size and shape as auxiliary characters for specific diagnosis. Then in 1963, Feldman-Mühsam stated that these porose areas are the outlets of glands which become evident soon after the onset of feeding and are essential for the proper functioning of Gene's organ. Their main function is probably lubrication of the evagination-invagination mechanism of this organ. According to Wooley (1972), there are variations in the presence and numbers of sensillae in the areae porosae.

FEMALES

Rhipicephalus pravus (Plates II, 4 & IV, 4.)

According to Walker (1956) they vary in form from kidney-shaped to oval and in size from relatively large to small. Those examined in this study were oval in shape, widely separated by about twice their length and slightly sunken into the median part of the gnathotectum. (Plate II, 4.) Each area contains about 40-80 pit-like structures. (Plate IV, 4.) One small seta occurs in each area and in some cases two. Another longer seta mesial from the areas and medianly directed.

Rhipicephalus oculatus (Plates II, 5 & IV, 5.)

Sub-circular, a little smaller than in *pravus* twice their own diameter apart from each other and slightly sunken into the median part of the gnathotectum. (Plate II, 5.) Two setae occur in the porose areas and one seta is adjacent mesially to the areas. (Plate VI, 5.) Each area contain about 50-80 pit-like structures.

Rhipicephalus appendiculatus (Plates II, 6 & IV, 6.)

Almost circular and corresponding with those of *oculatus*. (Plate II, 6.) According to Hoogstraal (1956) the areas vary with the size of the individual tick. A very small setae in each porose area and another adjacent to it medianly. Each area contains from about 60-80 pit-like structures. (Plate IV, 6.)

Boophilus decoloratus (Plates II, 7 & IV, 7.)

Elongate oval with a definite ridge antero-laterally and postero-laterally. (Plate II, 7.) Areas divergent antero-laterally from each other and situated about their own length apart. No setae occur within the area or adjacent to it. (Plate IV, 7.) About 55-65 pit-like structures occur in each area.

Boophilus microplus (Plates II, 8 & IV, 8.)

Usually oval in shape, sometimes piriform. (Plate II, 8.) Moderate in size and on a level with the general surface of the gnathothecum. Strongly divergent anteriorly and situated about one to one and a half times their own length apart. No setae in or adjacent to them. (Plate IV, 8.) About 65-80 pit-like structures occur in each area.

7.1.3 Chelicerae

Between the palps the gnathothecum wall is continuous with the dorsal walls of tubular sheaths enclosing the chelicerae. The chelicerae are long shafts deeply buried in the gnathothecum and extending into the body. Distally each chelicera bears a free, strongly toothed digit, (Plate V, 1.) moveable by means of a pair of muscles arising in the shaft. The digit consists of two main parts (fig. 3 D & E): (a) rigid prolongation from the base of the segment, with a pair of outwardly directed teeth at its apex and (b) a broad lateral lobe with two large teeth flexibly attached to the side of the fixed process. The moveable digit of the chelicera is homologized with the apotele which form the ambulacrum of the walking appendage of ticks. The fixed digit is regarded as having been arrived from up to four birefringent setae on the penultimate segments (Evans et al., 1961). The

digits move in a transverse plane on the ends of the shafts so that the cutting action of the teeth is in a lateral direction. The shafts can be moved in and out of the surrounding sheaths. On their bases are inserted the usual cheliceral muscles. The cheliceral sheaths are double-walled tubular folds of the gnathosoma integument intended individually around the shaft of each chelicera. The outer wall of each fold (outer sheath) is produced forward from the dorsal wall of the gnathothecum (gnathotectum) and from the base of the cheliceral shaft; it is then invaginated into itself to form an inner sheath closely investing the chelicera. The outer cheliceral sheath bears many rows of transverse plicating teeth. The teeth in each row alternate with those in the preceding and succeeding rows. Those in the anterior rows are more sharply pointed while those further back are more rounded.

LARVAE

Rhipicephalus pravus (Plate I, 1.)

Dorsally the outer cheliceral sheaths bear about ten transverse rows of teeth. Except for the first two and last three each row contains from six to eleven teeth. The last three rows contain respectively five, four and three very poorly defined teeth. The teeth in the first four rows are sharp and narrow but further back they become broader and more rounded. Teeth stretched about two-thirds the length of the outer cheliceral sheaths dorsally.

Rhipicephalus oculatus (Plate I, 2.)

Dorsally the outer cheliceral sheaths correspond with that of *pravus*.

Rhipicephalus appendiculatus (Plate I, 3.)

Dorsally the outer cheliceral sheaths correspond with that of *pravus*.

Boophilus decoloratus (Plate I, 4.)

Dorsally the outer cheliceral sheaths bear about 15 transverse rows of teeth covering almost its whole length. The remaining

part of the sheaths vaguely defined into teeth. The teeth increase in size posteriorly. The teeth in the first six rows are narrow and more broadly rounded posteriorly.

Boophilus microplus (Plate I, 5.)

Dorsally the outer cheliceral sheaths correspond with that of *decoloratus*.

NYMPHAE

Rhipicephalus pravus (Plate I, 6.)

About 17 transverse rows of the cheliceral teeth occupy about two thirds of the dorsal surface of the outer cheliceral sheaths. The teeth in the first seven transverse rows are sharp and narrow, but they become broader and more rounded posteriorly. The last five to seven rows vaguely defined.

Rhipicephalus oculatus (Plate I, 7.)

Resemble those of *pravus*.

Rhipicephalus appendiculatus (Plate I, 8.)

Correspond with those of *pravus*, except that the posterior transverse rows are better defined.

Boophilus decoloratus (Plate I, 9.)

Chelicerae and outer cheliceral sheaths a little longer than the palps and almost the entire dorsal surface of the outer cheliceral sheaths covered with teeth.

Boophilus microplus (Plate I, 10.)

Corresponds with that of *decoloratus*.

MALES

Rhipicephalus pravus (Plate I, 11.)

The palps cover the chelicerae almost entirely. Chelicerae and cheliceral outer sheaths about equal in length to the palps. About two-thirds of the surface of the outer cheliceral sheaths are covered with teeth.

Rhipicephalus oculatus (Plate I, 12.)

Resemble that of *pravus*.

Rhipicephalus appendiculatus (Plate II, 1.)

Resemble that of *pravus*.

Boophilus decoloratus (Plate II, 2.)

Almost the entire surface of the outer cheliceral sheaths are covered with teeth. The palps partially cover the cheliceral sheaths. Cheliceral sheaths are about equal in length to the palps and partially covered the chelicerae, with the cheliceral digits protruding anteriorly.

Boophilus microplus

Resemble that of *decoloratus*.

FEMALES

The different studied species chelicerae and outer cheliceral sheaths resemble that of the males.

7.1.4 Hypostome

The ventral wall of the gnathosoma extends forwards between the palps and forms a large hypostome which is armed ventrally with strong retrograde denticles. These serve to anchor the tick to its host. The dentition is recorded as the numbers of denticles on either side of a median longitudinal line; i.e. 3/3 indicates three longitudinal files of denticles each side of this median line. The formula 3,5/3,5 indicates that there are three complete and one shorter file of few denticles anteriorly on each side of the hypostome. When the hypostome is described as having a corona it means that the tip bears a number of very minute denticles. The upper surface of the hypostome has a median gutter-like groove leading back to the mouth opening.



PLATE III

PLATE III⁺

Ventral aspect of gnathosoma of larvae:-

1. *Boophilus microplus*;

Ventral aspect of gnathosoma of nymphae:-

2. *Rhipicephalus pravus*;
3. *R. appendiculatus*;
4. *B. decoloratus*^{*}
5. *B. microplus*;

Ventral aspect of gnathosoma of males:-

6. *R. pravus*;
7. *R. oculatus*;
8. *R. appendiculatus*;
9. *B. decoloratus*;
10. *B. microplus*;

Ventral aspect of gnathosoma of females:-

11. *R. pravus*;
12. *R. oculatus*.

+ Scale lines in μm .

* After Arthur & Londt (1973).

LARVAE

Rhipicephalus pravus (Plate II, 9.)

Dimensions:= length: 0,076-0,096 mm; minimum breadth: 0,016-0,021 mm; maximum breadth: 0,029-0,040 mm.

Hypostome sputulate in shape with the apex broadly rounded. Narrowest just posterior to the denticles and widest at about the level of the third transverse row of denticles. Dentition 2/2. Median longitudinal rows each with five large denticles plus one reduced denticle posteriorly. The lateral longitudinal files bear six large, and two reduced denticles posteriorly. Denticles in the four anterior transverse rows sharply pointed, while those in the posterior rows are more rounded.

Rhipicephalus oculatus (Plate II, 10.)

Dimensions:= length: 0,073-0,084 mm; minimum breadth: 0,017-0,020 mm; maximum breadth: 0,029-0,032 mm.

Shape and dentition as in *pravus*.

Rhipicephalus appendiculatus (Plate II, 11.)

Dimensions:= length: 0,073-0,084 mm; minimum breadth: 0,018-0,024 mm; maximum breadth: 0,032-0,036 mm.

Shape as in *pravus*. The lateral longitudinal rows sometimes bear only one reduced tooth. The denticles in the transverse rows are blunter except for those in the first two transverse rows.

Boophilus decoloratus (Plate II, 12.)

Dimensions:= length: 0,076-0,084 mm; minimum breadth: 0,024-0,029 mm; maximum breadth: 0,039-0,040 mm.

According to Gothe (1967) the length varied from 0,084-0,092 mm, while Arthur & Londt (1973) stated that the length varied from 0,082-0,090 mm. Hypostome spatulate in shape, with the apex broadly rounded, widest at about two-thirds the length anteriorly.

Narrowest just in front of post hypostomal setae. Dentition 2/2, usually with six denticles per longitudinal file, though in some cases only five denticles per file were seen. Teeth in the three transverse rows sharply pointed, those in the posterior rows rounded.

Boophilus microplus (Plate III, 1.)

Dimensions:= length: 0,075-0,095 mm; minimum breadth: 0,023-0,033 mm; maximum breadth: 0,039-0,046 mm.

According to Cooley (1946) the length is 0,065 mm, while Arthur (1960) stated that it is 0,060 and Roberts (1965) 0,07 mm. According to Gothe (1967) the length ranged from 0,080-0,088 mm. Hypostome spatulate in shape with the apex broadly rounded, narrowest just posterior to the denticles and widest at about the third row of denticles. Dentition 2/2 with the median longitudinal rows usually containing six denticles; in a few cases only five occur. The lateral longitudinal rows usually have six large denticles plus one very small denticle, but the latter is absent in some specimens. In a very few cases only five denticles occur in the lateral longitudinal rows. Teeth in the anterior three rows sharply pointed while those in the posterior rows are rounded.

NYPHAE

Rhipicephalus pravus (Plate III, 2.)

Dimensions:= length: 0,122-0,129 mm; minimum breadth: 0,027-0,030 mm; maximum breadth: 0,046-0,051 mm.

Minimum breadth just posterior to the denticles. Maximum breadth at about the third transverse row of denticles. The shape resembles that of the larvae. Dentition 2/2. Median longitudinal rows with seven denticles plus two to three much reduced denticles posteriorly. Lateral longitudinal rows with seven large denticles each plus three reduced denticles posteriorly. Anterior four transverse rows of denticles sharply pointed and the posterior rows

more rounded.

Rhipicephalus oculatus (Plate XIV, 4.)

Dimensions:= length: 0,147-0,160 mm; minimum breadth: 0,030-0,034 mm; maximum breadth: 0,052-0,055 mm.

Shape, dentition and shape of denticles resemble that of *pravus*.

Rhipicephalus appendiculatus (Plate III, 3.)

Dimensions:= length: 0,143-0,151 mm; minimum breadth: 0,036-0,042 mm; maximum breadth: 0,052-0,063 mm.

Shape, dentition and shape of denticles resemble that of *pravus*.

Boophilus decoloratus (Plate III, 4.)

Dimensions:= length: 0,131-0,168 mm; minimum breadth: 0,042-0,064 mm; maximum breadth: 0,068-0,095 mm.

Spatulate in shape, tapering only gradually for about two-thirds its length from the apex, broadly basally. Denticulated for more than two-thirds of its length. According to Gothe (1967) the hypostome is about 0,144-0,152 mm in length. Dentition 3/3. Median longitudinal rows with seven denticles each plus in some cases one to two reduced denticles. The adjacent longitudinal rows contain eight denticles, plus in some cases one reduced denticle. The lateral longitudinal rows contain nine denticles. Anterior three transverse rows sharply pointed and the posterior rows more rounded.

Boophilus microplus (Plate III, 5.)

Dimensions:= length: 0,146-0,160 mm; minimum breadth: 0,045-0,068 mm; maximum breadth: 0,072-0,077 mm.

According to Cooley (1946) the length is about 0,14 mm; Arthur (1960) gives 0,13-0,16 mm; Roberts (1964) 0,11 mm and Gothe (1967) 0,150-0,154 mm.

Shape as in *decoloratus*. Dentition 3/3. Median longitudinal rows with seven to eight denticles. The adjacent rows contain

the same number while the lateral rows contain seven to nine denticles.

MALES

Rhipicephalus pravus (Plates III, 6 & V, 2.)

Dimensions:= length: 0,337-0,386 mm; maximum breadth: 0,125-0,132 mm.

Hypostome is spatulate in shape. (Plate III, 6.) Dentition 3/3. Seven to nine denticles in each longitudinal file with those in the first two and last three transverse rows more broadly rounded. Corona of small denticles occupying up to one tenth of the length of the hypostome. (Plate V, 2.) Denticles on the corona arranged more or less in six transverse rows. The apical row contains 18 (9/9) denticles and is succeeded by rows containing 18 (9/9); 11-12 (5-6/6); 14 (7/7); 12 (6/6) and the sixth row with 7-8 (3-4/4) denticles. (Plate V, 2.)

Rhipicephalus oculatus (Plates III, 7 & V, 3.)

Dimensions:= length: 0,320-0,341 mm; maximum breadth: 0,105-0,109 mm.

Dentition and shape as in *pravus*. (Plate III, 7.) Corona contains six rows of small denticles arranged transversely as follows: 24 (12/12) denticles in the apical row, succeeded by rows containing 16 (8/8); 2-3 (1-2/1); 8 (4/4); 8-9 (4-5/4) and the sixth row contain 8-9 (4-5/4) denticles. (Plate V, 3.)

Rhipicephalus appendiculatus (Plate III, 8.)

Dimensions:= length: 0,350-0,437 mm; maximum breadth: 0,128-0,157 mm.

Dentition and shape as in *pravus*. (Plate III, 8.) The corona contains six rows of small denticles arranged transversely as follows: 28-30 (14-15/14-15) denticles in the apical row, succeeded by rows containing 16 (8/8); 18-20 (9-10/9); 14-15 (7-8/7); 18-19 (9-10/9) and the sixth row contain 8-9 (4-5/5) denticles.

Boophilus decoloratus (Plate III, 9 & V, 4.)

Dimensions:= length: 0,199-0,213 mm; maximum breadth: 0,916-0,964 mm.

According to Arthur (1960) the length is about 0,08 mm, while Gothe (1967) stated it varies from 0,175-0,185 mm; and Arthur & Londt (1973) stated that it varies from 0,17-0,20 mm. Dentition and shape as in *pravus*. (Plate III, 9.) According to Hoogstraal (1956), Arthur (1960) and Arthur & Londt (1973) the dentition is 3/3 and in some cases 3,5/3,5. In the present investigation the dentition was found to be 3/3 throughout, with each file containing seven to eight denticles per file. (Plate III, 9.) The smaller denticles on corona more or less arranged in five rows. (Plate V, 4.) The distal row contains 18 (9/9) denticles and is succeeded by rows containing 16 (8/8); 10 (5/5); 8 (4/4) and the fifth row containing 4 (2/2) denticles. (Plate V, 4.)

Boophilus microplus (Plates III, 10 & V, 5.)

Dimensions:= length: 0,214-0,265 mm; maximum breadth: 0,080-0,104 mm.

According to Roberts (1965) the length varies from 0,18-0,20 mm, while Gothe (1967) stated that it varies from 0,210-0,220 mm. Shape of hypostome resembles that of *pravus*. (Plate III, 10.) Dentition 4/4 with seven to nine denticles per file. The smaller denticles on corona arranged more or less in five rows. (Plate V, 5.) The distal row contains 18 (9/9) denticles and is succeeded by rows containing 12 (6/6); 12 (6/6); 10 (5/5) and 6 (3/3) denticles in the fifth row. (Plate V, 5.)

FEMALES

Rhipicephalus pravus (Plates III, 11 & V, 6.)

Dimensions:= length: 0,425-0,467 mm; maximum breadth: 0,153-0,171 mm.

Hypostome rectangular in shape. (Plate III, 11.) Dentition 3/3 with eleven to twelve denticles in each longitudinal file.

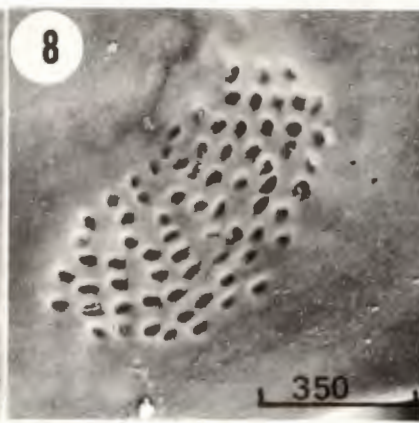
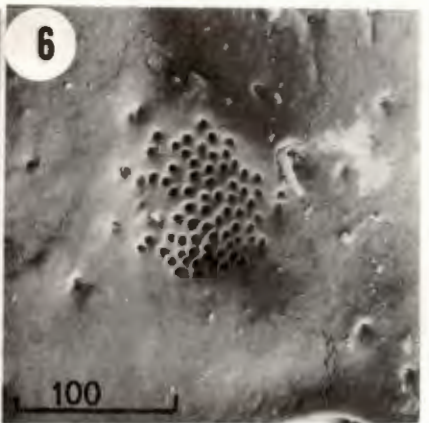
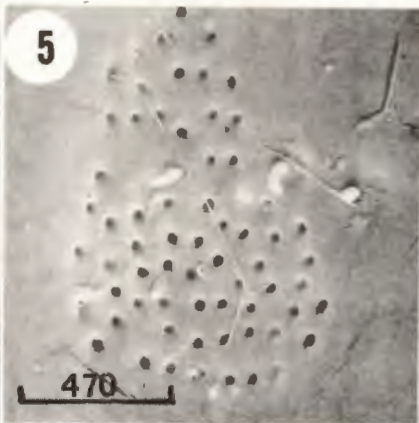
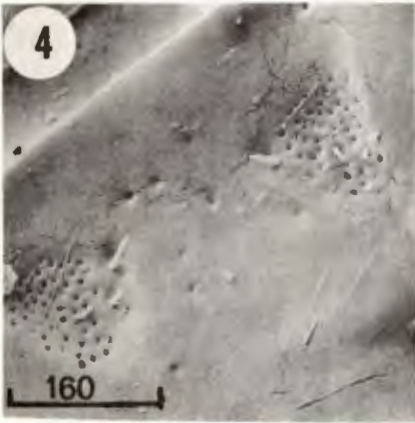


PLATE IV

PLATE IV⁺

Ventral aspect of gnathosoma of females:-

1. *Rhipicephalus appendiculatus*;
2. *Boophilus decoloratus*;
3. *B. microplus*;

Porose areas:-

4. *R. pravus*;
5. *R. oculatus*;
6. *R. appendiculatus*;
7. *B. decoloratus*;
8. *B. microplus*;

Setal types of gnathosoma:-

9. *R. pravus* larva
10. *R. appendiculatus* female
11. *R. pravus* larva
12. *R. oculatus* larva

+ Scale lines in μm .

One or two of the proximal denticles reduced. First five transverse rows sharply pointed and the remainder more broadly rounded. Smaller denticles on the corona, (Plate V, 6.) varying in size, occupying about one tenth the length of the hypostome and arranged more or less in five rows. The distal row contains about 24 (12/12) denticles and successive rows contain 20 (10/10); 18 (9/9); 12 (6/6) and 10 (5/5) denticles respectively. (Plate V, 6.)

Rhipicephalus oculatus (Plates III, 12 & V, 7.)

Dimensions:= length: 0,357-0,467 mm; maximum breadth: 0,153-0,169.

Dentitions as in *pravus*. (Plate III, 12.) Corona provided with four rows of smaller denticles in four transverse rows as follows, starting distally 24 (12/12); 18 (9/9); 14 (7/7) and 8 (4/4). (Plate V, 7.)

Rhipicephalus appendiculatus (Plates IV, 1 & V, 8.)

Dimensions:= length: 0,485-0,508 mm; maximum breadth: 0,169-0,211 mm.

Shape and dentition as in *pravus*. (Plate IV, 1.) Corona with very small denticles, (Plate V, 8.) which are arranged in rows as follows, starting distally: 24 (12/12); 28 (14/14); 31-32 (15-16/16); 25-26 (12-13/13) and 26 (13/13). A number of poorly defined denticles are also present posteriorly. (Plate V, 8.)

Boophilus decoloratus (Plates IV, 2 & V, 9.)

Dimensions:= length: 0,263-0,296 mm; maximum breadth: 0,128-0,166 mm; minimum breadth: 0,076-0,103 mm.

According to Gothe (1967) the length varies from 0,220-0,240 mm, while Arthur & Londt (1973) stated that it varies from 0,27-0,29 mm. According to Hoogstraal (1956) the dentition is as in the males (e.g. 3/3 and rarely 3,5/3,5). The dentition obtained during the present study was throughout 3/3. (Plate IV, 2.) A longitudinal furrow in the median, basal part of the hypostome. Hypostome spatulate in shape. (Plate IV, 2.) Nine to ten den=

ticles, which may become reduced proximally, in each longitudinal file. Corona denticles varying in size, arranged in four rows as follows: 18 (9/9); 18 (9/9); 18 (9/9) and 14 (7/7). Plate V, 9.)

Boophilus microplus (Plates IV, 3 & V, 10.)

Dimensions:= length: 0,167-0,357 mm; maximum breadth: 0,143-0,161 mm; minimum breadth: 0,110-0,136 mm.

According to Roberts (1965) the length of the hypostome varies from 0,210-0,230 mm, while Gothe (1967) stated that it varies from 0,22-0,28 mm. Dentition 4/4 with the longitudinal files containing from nine to eleven denticles. (Plate IV, 3.) The posterior teeth in some specimens reduced. According to Arthur (1960) 7-8, rarely 9 denticles present, while Roberts (1965) referred to 8 and in some cases only 6. Gothe (1967) stated that 7-9 denticles occur. In some specimens a mid-longitudinal depression are present which resembles that of *decoloratus*. (Plate IV, 3.) Corona denticles varying in size, (Plate V, 10.) arranged in five rows as follows: 19-20 (9-10/10); 20 (10/10); 16 (8/8); 12-13 (7/6-7) and 5-6 (2-3/3).

7.1.5 Palps

The palps are moveable and each consists typically of four segments. The first of these is a small basal ring, which was regarded by Schulze (1938) as the trochantor. The second and third segments are long and broad and represent the femur and genu respectively. The fourth segment represent the tibia-tarsus complex, which is a sensory structure embedded in the meso-ventral surface of the genu. No setae occur on the trochantor. Setae on the rest of the palps are of the following morphological types:

- (a) Those which are fine, tapered from the base and without any barbs:- fine setae. (Plate IV, 12.)
- (b) Those which are curved, slender setae of greater diameter than (a), repetitively barbed on their outer surfaces:- slender-barbed setae. (Plate IV, 11.)
- (c) Those which are curved, but stouter than (b) and repetitively

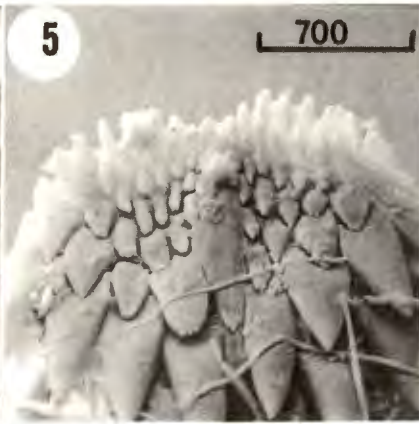


PLATE V

PLATE V⁺

Lateral view of gnathosoma of female:-

1. *Rhipicephalus pravus*;

Corona of males:-

2. *R. pravus*;

3. *R. oculatus*;

4. *Boophilus decoloratus*;

5. *B. microplus*;

Corona of females:-

6. *R. pravus*;

7. *R. oculatus*;

8. *R. appendiculatus*;

9. *B. decoloratus*;

10. *B. microplus*;

Tibia-tarsus complex of larvae

11. *R. pravus*;

12. *R. oculatus*.

+ Scale lines in μm .

barbed on one margin-single-barbed setae. (Plate IV, 9: the left one.)

- (d) Those which are straight or apically curved setae, stouter than the others and only barbed apically:- apically barbed setae. (Plate IV, 9.)
- (e) Those which are curved, stouter than the others and barbed very strongly:- multi-barbed setae. (Plate IV, 10 & 12.)

The interspecific differences in the palps, according to Theiler (1947) are slight in the rhipicephalids, but they do appear to be the most constant of the classificatory features. However, only a few workers have paid attention to them.

LARVAE

Rhipicephalus pravus (Plate I, 1 & II, 9.)

Dimensions:= Length:- combined segments: 0,077-0,094 mm; femur: 0,031-0,040 mm; genu: 0,036-0,042 mm. Breadth:- femur: 0,041-0,045 mm; genu: 0,036-0,042 mm.

The palps seemed dorsally short broad at the base and tapering towards the tips. The femur and genu in most cases not visibly separated into two units. (Plate I, 1.) Only a small insertion at the mesial sides indicate the demarcation between the two segments. The trochantor distinguishable from the femur. The ratio between the length and breadth of the femur about 0,805. The ratio between the length and breadth of the genu about 1,022. Lateral profile of combined segments slightly sinuous. Mesial margin approximately straight. Lateral and mesial margins of the femur concave and those of the genu almost straight with the lateral margins gently curved anteriorly. (Plate I, 1.) Surface of the femur with tumescent protruberance meso-posteriorly continued obliquely antero-laterally, mesial of the basal lateral seta on the femur terminating baso-lateral of the antero-lateral seta on the same segment. A narrow depression occur on the femur. A sensory pit occur on the femur antero-laterally, more or less mid-dorsally and just behind the demarcation of the femur and

the genu. Surface of the genu smooth and curved mesially and laterally. Setae arranged in four longitudinal series: (Plate I, 1.). (a) Mesial series (M) consisting of two setae, with M1 on the femur, parallel and about equal in length to a similar one (M2) on the genu. (b) A sub-mesial series (D) consisting of one seta, mid-dorsally near the edge of the meso-posterior protuberance on the femur: (c) Three sub-median, setae (SM) on the genu. SM1 slightly postero-lateral from M2 and SM2 antero-laterally from the latter SM3 on the apex of the genu. (d) Three lateral (L) setae with L1 and L2 on the femur and L3 on the genu. Chaetotaxy dorsally: 2M; 1D; 3SM; 3L.

Ventrally the demarcation between the trochantor and the femur well defined, but not to the same extent as between the femur and the genu. (Plate II, 9.) A depression indicates the demarcation region. The demarcation between the genu and the tibia-tarsus complex well defined. Lateral profile of the femur and the genu arcuate. On the genu an elevation occurs around the excavation between this segment and the tibia-tarsus complex. Posteriorly the elevation is narrow but it broadens laterally and mesially. Posteriorly it is broadly rounded and slopes rapidly further posteriorly and postero-medially but more gradually postero-laterally and laterally. Three setae occur ventrally of which two occur on the femur and one on the genu. (Plate II, 9.) These setae arranged in two series: (a) The ventral mesial seta (VM); (b) A mid-ventral seta (MV1) located more to the side of the mid-ventral region, adjacent to the elevation around the tibia-tarsus complex. A very small seta, MV2, also present. Chaetotaxy ventrally: 1VM; 2MV.

Rhipicephalus oculatus (Plates I, 2 & II, 10.)

Dimensions: Length:- combined segments: 0,089-0,106 mm; femur: 0,038-0,049 mm; genu: 0,038-0,051 mm. Breadth:- femur: 0,045-0,049 mm; genu: 0,038-0,044 mm.

The palps are short, broad at the base and tapering

The palps are short, broad at the base and tapering distally. (Plate I, 2.) Dorsally the femur and genu not visibly separated as in *pravus*. A small insertion indicates the demarcation as in *pravus*. Ratio between the length and breadth of the femur about 0,903, and that of the genu about 1,035. Lateral profile of combined segments arcuate. Mesial margins almost straight. Lateral profile of the femur strongly convex and the mesial margin gently curved both posteriorly and anteriorly. Surface and sensory pits as in *pravus*. Mesial and lateral margins of genu as in *pravus*. Chaetotaxy dorsally as in *pravus*. (Plate I, 2.)

Ventrally the palps correspond in shape, topography and chaetotaxy with those of *pravus*. (Plate II, 10.)

Rhipicephalus appendiculatus (Plates I, 3 & II, 11.)

Dimensions:= Length:- combined segments: 0,086-0,101 mm; femur: 0,034-0,045 mm; genu: 0,035-0,046 mm. Breadth: 0,037-0,045 mm; genu: 0,035-0,045 mm.

Palps about as broad at the base as at the tips. (Plate I, 3.) Dorsally the femur and genu usually not clearly separated into two segments. Only a small incision mesially and laterally indicates the demarcation. The trochantor clearly separated from the gnathotectum and the femur. The ratio between the length and breadth of the femur about 0,926 and that of the genu about 1,068. Shape of palps almost quadrangular. According to Howard (1908) the trochantor is very short and almost invisible while the femur and genu longer than wide. Mesial and lateral margins of combined segments sinuous. Lateral margin of the femur concave posteriorly and convex anteriorly. The mesial margin of the same segment is straight. The lateral margin of the genu is almost straight while the mesial margin is almost straight, except for a convex projection posteriorly. The surface of the femur as in *pravus*, except for a depression posteriorly to seta SM1, stretching antero-medianly. In this depression occurs a sensory pit. The genu is quadrangular and not conical as stated by Howard (1908). The genu is broadly rounded anteriorly and not

tapering as in *pravus*. Chaetotaxy dorsally as in *pravus*. (Plate I, 3.)

Ventrally the demarcations between the trochantor, femur and genu are well defined. The surfaces of the segments as in *pravus*. Ventral chaetotaxy as in *pravus*. (Plate II, 11.)

Boophilus decoloratus (Plates I, 4 & II, 12.)

Dimensions:= Length:- combined segments: 0,083-0,102 mm; femur: 0,036-0,042 mm; genu: 0,041-0,043 mm. Breadth:- 0,038-0,045; genu: 0,039-0,041 mm.

According to Gothe (1967) the length of the palps varied from 0,084-0,091 mm and according to Arthur & Londt (1973) 0,084-0,091 mm. The palps show a tendency to be bulbous. (Plate I, 4.)

A faint line of demarcation between the femur and genu can be observed. The ratio between the length and breadth of the femur about 0,982 and that of the genu about 1,020. The lateral and mesial profile of the femur concave and that of the genu almost straight converging to a broad rounded apex. The surface of the femur with a relatively tumescent oblique protuberance meso-posteriorly that continuous obliquely antero-laterally and mesial of the basal lateral seta on the femur, terminating baso-laterally of the antero-lateral seta of the same segment. The femur lacks any sensory pits as in the rhipicephalids. The surface of the genu smooth, evenly and gently curved to the mid-line and laterally. The setae are arranged in three longitudinal series as in *R. pravus*. (Plate I, 4.) Seta M1 sub-parallelled to M2 and shorter than the latter.

Chaetotaxy dorsally 2M; 1D; 3SM; 3L.

Ventrally the palps show a clear demarcation between the trochantor and the femur, but not between the femur and the genu. (Plate II, 12). Lateral profile of the combined segments broadly arcuate; mesial profile slightly arcuate at the position of the femur.

Chaetotaxy ventrally as in *R. pravus*. (Plate II, 12.) According to Gothe (1967) the segments, other than the tibia-tarsus complex, contain eight setae dorsally and four setae ventrally. The total

amount of setae is correct but I doubt the arrangement as described by Gothe. Nine setae occur dorsally and only three ventrally.

Boophilus microplus (Plates I, 5 & III, 1.)

Dimensions:= Length:- combined segments: 0,088-0,104 mm; femur: 0,036-0,046 mm; genu: 0,035-0,046 mm. Breadth:- femur: 0,040-0,051 mm; genu: 0,041-0,051 mm.

Palps short. (Plate I, 5.) According to Gothe (1967) the length is about 0,080 mm. The shape of the palps corresponds with that of *decoloratus*. The demarcation between the femur and genu very faint, not discernable in all specimens. The trochantor distinguishable from the femur and not absent as quoted by Arthur (1960) and Cooley (1946) or apparently fused with the femur (Gothe, 1967). The ratio between the length and breadth of the femur about 0,883 and that of the genu about 0,906. According to Gothe (1967) the length and breadth range of the femur and genu is respectively 0,038-0,042 mm and 0,042-0,046 mm. The lateral and mesial profile of the femur concave and that of the genu more bulging at the posterior edge of the mesial margins and concave laterally. The lateral and mesial margins of the genu converge in a broadly rounded apex, but not to the same extent as in *decoloratus*. The surface of the femur strongly tumescent, protuberant meso-posteriorly, but to a lesser extent than in *decoloratus*. Surface of the genu smooth and curved mesially and lateral. Setae arranged as in *R. pravus*, (Plate I, 5.) with M1 and M2 parallel and about equal in length.

Chaetotaxy dorsally 2M; 1D; 3SM; 3L.

Ventrally the demarcation between the trochantor and the femur well defined, but this is not the case between the femur and the genu. (Plate III, 1.) This demarcation is indicated by a depression. Lateral profile of the femur and genu arcuate. On the genu a elevation occurs between the genu and the tibia-tarsus complex. This differs from that of *decoloratus*. Posteriorly this elevation is broadly rounded and quite well defined as it extends to the lateral and median walls. At this described positions it is broader than it is in *decoloratus*. It differ fur-

ther from the latter in that it extends laterally and not antero-laterally. From the palpal insertion between the genu and the tibia-tarsus complex it slopes sharply posteriorly and postero-laterally and laterally. According to Gothe (1967) eight setae occur dorsally and four ventrally on the palps. In this study nine setae were observed dorsally and only three ventrally. Chaetotaxy ventrally as in *R. pravus*, with seta VM1 considerably longer than that of *decoloratus*. (Plate III, 1.)

NYMPHAE

Rhipicephalus pravus (Plates I, 6 & III, 2.)

Dimensions:= Length:- combined segments: 0,137-0,144 mm; femur: 0,069-0,073 mm; genu: 0,059-0,063 mm. Breadth:- femur: 0,069-0,075 mm; genu:- 0,057-0,064 mm.

Length to breadth ratio of the femur about 0,973 and that of the genu about 1,019. Palps tapering to the tips with a blunt ended triangular genu. (Plate I, 6.) The palps are provided with clearly differentiated segments. The trochantor is narrowly elongated while the femur is almost rectangular. Lateral profile of the femur is straight to sinuous and that of the mesial margin concave. Lateral and mesial margins of the genu convex. Surface of the femur smooth, sloping abruptly posteriorly to the junction with the trochantor and with a tumescent protruberance antero-laterally just anterior to seta L1. A narrow depression occurs at about the halfway point on the mesial walls, which extends about one third of the femur's breadth medianly. Two sensory pits occur on each palp, one on the mid-dorsal region of the femur in level with the sub-median seta and the other on the genu between the sub-median and lateral setae. Setae arranged as in the larvae except that one dorsal series is lacking. (Plate I, 6.) (a) A mesial series (M) consisting of two setae M1 on the femur and M2 on the genu. (b) Three setae in a sub-median series: SM1 on the femur (this is probably the seta which occurs in the dorsal series in the larvae) and SM1 and SM2 on the genu. Three lateral setae: L1 and L2 on the femur and L3 on the

genu.

Chaetotaxy dorsally: 2M; 3SM; 3L.

Seven setae occur ventrally on the palps (Plate III, 2.) (a) Two ventral mesial setae VM1 and VM2 both on the femur. VM1 is much larger and more barbed than VM2. (b) Two ventral sub-mesial setae on the genu: VSM1 just next to, or just on the elevation round the tibia-tarsus complex and VSM2 at the apex of the genu. (c) Three mid-ventral setae: MV1 and MV2 on the femur and MV3 on the genu.

Chaetotaxy ventrally: 2VVM; 2VSM; 3MV.

A tumescent protruberance is present antero-laterally, mesial from MV1 on the femur, and an elevation round the tibia-tarsus complex. Posteriorly this elevation is narrow but it broadens laterally and anteriorly. A spur-like structure occurs postero-laterally (Plate III, 3.)

Rhipicephalus oculatus (Plates I, 7 & XIV, 4.)

Dimensions:= Length:- combined segments: 0,158-0,164 mm; femur: 0,076-0,089 mm; genu: 0,064-0,072 mm. Breadth:- femur: 0,069-0,071 mm; genu: 0,057-0,062 mm.

Length to breadth ratio of the femur about 1,175 and that of the genu about 1,132. According to Theiler & Robinson (1953) the palps are longer than the scutum; this statement, however, appears to be a misprint. According to the same authors the genu is as long as the femur, and the femur only slightly broader than the genu. However, in this study the average lengths of the femur and genu respectively are 0,081 and 0,067 mm, and the breadths are respectively 0,070 and 0,059 mm. Shape, surface, profiles, sensory pits and chaetotaxy as in *pravus*. (Plate I, 7.)

Ventrally the palps resemble that of *pravus*.

Rhipicephalus appendiculatus (Plates I, 7 & III, 3.)

Dimensions:= Length:- combined segments: 0,182-0,199 mm; femur: 0,092-0,098 mm; genu: 0,065-0,073 mm. Breadth:- femur 0,065-

0,092 mm; genu: 0,079-0,091 mm.

Length to breadth ratio of the femur about 1,271 and that of the genu about 0,841. Palps become broader towards the tips. (Plate I, 7.) Femur broadest at its junction with the genu. Femur more or less rectangular and the genu, hemispherical. Mesial and lateral margins of the femur sinuous to concave. Mesial and lateral margins of the genu almost straight. Surface of the femur as in *pravus* except that the narrow depression at about mid-length extends to about the mid-dorsal level. In some cases a vague depression extends right to the lateral margin. Sensory pits and chaetotaxy as in *pravus*. (Plate I, 7.)

Ventrally the palps correspond with those of *pravus* except that the tumescent protuberance is not so large as it is in *pravus*. (Plate III, 3.) This protuberance extend posteriorly to seta MV1. The elevation round the tibia-tarsus complex protrudes more posteriorly. It bears seta VSM1. Chaetotaxy ventrally as in *pravus*. (Plate III, 3.)

Boophilus decoloratus (Plates I, 8 & III, 4.)

Dimensions:- Length:- combined segments: 0,138-0,145 mm; femur: 0,072-0,086 mm; genu: 0,065-0,070 mm. Breadth:- femur: 0,056-0,059 mm; genu: 0,056-0,061 mm.

Length to breadth ratio of the femur about 1,132 and that of the genu about 1,034. According to Gothe (1967) the total length of the palps is about 0,128-0,146 mm, the length of the femur being 0,094-0,098 and that of the genu 0,034-0,038 mm. According to Arthur & Londt (1973) the length of the femur varies from 0,040-0,045 and that of the genu 0,034-0,038 mm. According to Gothe (1967) the breadth of the femur varies from 0,048-0,052 mm, and that of the genu from 0,032-0,036, while Arthur & Londt (1973) stated that these dimensions are 0,061-0,065 mm and 0,056-0,059. The palps are rectangular in shape. (Plate I, 8.) The trochantor not separated from the femur. Lateral profile concave in the vicinity of the presumptive trochantor thence beyond a slight dilation, straight to the junction between the femur and genu. Me=

sial profile of the femur arcuate and that of the genu convex becoming sharply rounded sub-apically, thence to a somewhat flattened apex which passes into the lateral margin through a broad curve. Surface of the femur tumescent gently curved except basolaterally, where it curves steeply downwards. At about two-thirds of its length from the gnathotectum an irregular transverse groove occurs. Genu gently curved from the mid-dorsal line. A pair of sensory pits between setae M1 and SM1. Chaetotaxy dorsally as in *R. pravus*. (Plate I, 8.)

Ventrally no separation between the trochantor and the femur. Lateral profile of both these segments concave. Chaetotaxy ventrally as in *R. pravus*.

Boophilus microplus (Plate I, 9 & III, 5.)

Dimensions:= Length:- combined segments: 0,092-0,096; femur: 0,054-0,055 mm; genu: 0,038-0,039 mm. Breadth:- femur: 0,062-0,064 mm; genu: 0,056-0,058 mm.

Length to breadth ratio of the femur about 0,873 and that of the genu about 0,655. The length of the palps, according to Roberts (1964) about 0,10-0,11 mm, and according to Gothe (1967) 0,120-0,128 mm. Gothe (1967) stated that the length of the femur and the genu is respectively 0,072-0,076 mm and 0,048-0,052 mm, while the breadth is respectively 0,056-0,064 mm and 0,040-0,044 mm. The trochantor is apparently fused with the gnathotectum (Plate I, 9.) Lateral profile bulging in the vicinity of the trochantor, thence straight to the junction between the femur and the genu. Mesial profile arcuate with a sharp angle at the junction with the genu. Femur rectangular in shape. Surface smooth except for a depression behind the M1 seta and a sensory pit between SM1 and L1 setae. Mesial profile of the genu arcuate becoming widely rounded apically. Lateral profile sinuous, postero-laterally it overlaps the femur at the base through a sharp angle. Genu sub-triangular. Chaetotaxy dorsally as in *pravus*. (Plate I, 9.)

Ventrally no separation between the trochantor and the femur. (Plate III, 5.) A well-defined transverse ridge across the whole

breadth of the palp indicate the junction between the trochantor and femur. A triangular elevation round the tibia-tarsus complex occupies almost the whole surface of the genu ventrally. (Plate III, 5.)

Chaetotaxy ventrally as in *pravus* except that only one ventral mesial seta (VM1) occurs on the femur. (Plate III, 5.)

MALES

Rhipicephalus pravus (Plates I, 11 & III, 2.)

Dimensions:= Length:- combined segments: 0,273-0,338 mm; femur: 0,118-0,152 mm; genu: 0,112-0,141 mm. Breadth:- femur: 0,145-0,191 mm; genu: 0,135-0,188 mm.

Length to breadth ratio of the femur about 0,812 and of the genu about 0,743. According to Theiler & Robinson (1953), the femur is broader than the genu, while the femur and genu are about equal in length. Mesial margin of the combined segments arcuate. (Plate I, 11.) Surface of trochantor irregular while that of the femur is smooth except for a deep, narrow transverse depression commencing at about one-third of the length of the mesial wall anteriorly. This depression continues for about one quarter the breadth antero-laterally; from about the mid-dorsal point it continues as a vague depression to the lateral margin's extreme. A sharp ridge, extending from the lateral to the mesial wall, just posterior to seta SM1. Posterior surface of the femur sloping strongly from this ridge. (Plate I, 11.)

Chaetotaxy dorsally: Setae in four linear series: (Plate I, 11.)

- (a) Three setae in a mesial series, with two on the femur and one on the genu. These setae do not resemble those of the larvae and nymphae, because they are reduced to small and fine setae.
- (b) A series of five sub-mesial (SM) setae with SM1 & 2 on the femur and the remainder on the genu.
- (c) A series of six sub-median setae with two on the flattened

surface of the femur and one on the steep posterior face.

The other three setae on the genu.

- (d) Two lateral setae with one on the femur and one on the genu.

Chaetotaxy formula: 2M; 5SM; 6DSM; 2L.

Posterior part of the mesial margin of the femur ventrally partially covered by a triangular bristle-bearing structure. (Plate III, 2.) A broad tooth-like projection on the postero-lateral margin of the genu, just anterior to its junction with the femur which becomes broadly rounded to the apex. Surface of the femur smooth except for a sharp ridge anterior to the steep posterior face. Surface of the genu smooth except for a sub-triangular elevated structure, which overlap the junction between the femur and genu and surrounding the tibia-tarsus complex partially. (Plate III, 2.)

Chaetotaxy ventrally: Four linear series of setae occur on the palps. (Plate III, 2.)

- (a) The bristle-bearing structure bears seven broad setae which are multi-barbed ventrally. Another six setae of the same type, but a little smaller, and in some cases not so barbed, on the remaining mesial margin of the femur. Three fine mesial setae on the mesial margin of the genu.
- (b) A series of five sub-mesial setae with SM1 on the steep posterior face of the femur, lateral to the bristle-bearing structure. SM2 mid-ventrally on the flattened surface of the femur. Seta SM3 postero-lateral to the spur-like structure on the genu and setae SM4 & 5 on the apex.
- (c) A ventral sub-median series consisting of five setae with one on the steeper face and another on the flattened surface of the genu. (VSM1). Another two closely situated setae (VSM2 & 3) lateral to the spur-like structure on the genu and VSM4 on the apex.
- (d) A series of three lateral setae with one on the steep face of the femur, just anterior to the junction with the trochanter and another on the flattened surface. Just lateral to setae VSM3 & 4 another lateral seta (L3) on the genu.

Chaetotaxy formula: (7 + 6 + 3)VM; 3SM; 5VSM; 3L.

In the case of the ventral mesial setae the first number indicates the setae on the bristle-bearing structure, the following number the seta on the remainder of the mesial margin of the femur and the last number the setae on the mesial margin of the genu.

Rhipicephalus occulatus (Plates I, 12 & III, 3.)

Dimensions:= Length:- combined segments: 0,178-0,319 mm; femur: 0,086-0,152 mm; genu: 0,070-0,138 mm. Breadth:- femur: 0,110-0,195 mm; genu: 0,096-0,196 mm.

Length to breadth ratio of the femur about 0,796 and of the genu about 0,763. According to Theiler & Robinson (1953) the femur and genu equal in length and the femur broader than the genu. The trochantor as in *pravus*. (Plate I, 12.) Chaetotaxy of the palps dorsally as in *pravus*, (Plate I, 12.) except that in one case another lateral seta occurs on the femur just anterior to the junction with the trochantor.

Chaetotaxy formula: 2M; 5SM; 6DSM; 3L.

Ventrally the palps resemble those of *pravus* except that the number of setae on the mesial series differ and the spur-like structure posterior to the tibia-tarsus complex is more sharply pointed. (Plate III, 3.) Five to six setae occur on the bristle-bearing structure, while three to four setae occur on the remainder of the mesial margin. These setae are multi-barbed ventrally, but much more finely than in *pravus*. Only two setae occur on the mesial margin of the genu. (Plate III, 3.)

Chaetotaxy formula: (5-6) + (3 - 4) + 2 VM; 3SM; 5VSM; 3L.

Rhipicephalus appendiculatus (Plates II, 1 & III, 4.)

Dimensions:= Length:- combined segments: 0,433-0,463 mm; femur: 0,193-0,226 mm; genu: 0,171-0,196 mm. Breadth:- femur: 0,245-0,267 mm; genu: 0,243-0,263 mm.

Length to breadth ratio of the femur about 0,822 and that of the genu about 0,726. Palps resemble those of *pravus*.

Chaetotaxy formula as in *pravus*. (Plate II, 1.)

Ventrally the palps resemble those of *pravus* except that the bristle-bearing structure is more elongate rectangular, while the steep posterior face is much longer and more prominent than in *pravus*. The spur-like structure posterior to the tibia-tarsus complex is also broader and more elongated than in *pravus*. (Plate III, 4.) The mesial series of setae differs from that of *pravus*. The bristle-bearing structure of the femur bears five setae, while the remaining of the mesial margin bears five setae. In one specimen only four setae were present. Two mesial setae occur on the genu as in *oculatus*. (Plate III, 4.)

Ventral chaetotaxy formula:- 5 + (4 - 5) + 2 VM; 3SM; 5VSM; 3L.

Boophilus decoloratus (Plate II, 2 & III, 5.)

Dimensions:= Length:- combined segments: 0,171-0,205 mm; femur: 0,093-0,114 mm; genu: 0,058-0,082 mm. Breadth:- femur: 0,111-0,146 mm; genu: 0,092-0,122 mm.

Length to breadth ratio of the femur about 0,781 and that of the genu about 0,631. According to Gothe (1967) the femur varies from 0,091-0,101 mm in length and 0,110-0,120 mm in breadth, the genu varies from 0,059-0,069 mm in length and 0,105-0,115 mm in breadth and the length of the combined segments is from 0,175-0,185 mm. According to Arthur & Londt (1973) the suture between the trochantor and the femur is absent. The present author found that this suture was constantly present. (Plate II, 2.) Lateral margin of the steep face of the femur concave and sharply angled at its junction with the anterior part of the margin. Surface smooth except for a few irregular depressions and a ridge that occurs posteriorly between the flattened anterior surface and the steep posterior face. This ridge becomes broadly curved to the mesial margin. (Plate II, 2.) Chaetotaxy dorsally: Setae in four linear series. (Plate II, 2.)

- (a) Four setae in the mesial series with two on the femur and two on the genu.
- (b) A series of six dorsal sub-mesial (SM) setae with SM1 on the posterior steep face and SM2 on the flattened surface of the

femur. SM3-6 on the genu with SM3 & 4 more postero-mesially and SM5 & 6 more antero-mesially.

- (c) A series of five dorsal sub-median setae with DSM1 on the posterior steep face and DSM2 & 3 on the flattened anterior face of the femur. DSM4 & 5 on the genu.
- (d) A lateral serie of one seta on the femur.

Chaetotaxy formula: 4M; 6SM; 5DSM; 1L.

Ventrally a triangular bristle-bearing structure occurs on the femur, but it differs greatly from that of the rhipicephalids. (Plate III, 5.) The posterior steep face continue mesially through a small retrograde spurlike structure with the irregular mesial margin. Ventro-median surface thickened to form a salient curved flange posteriorly. This ridge continues laterally and form a rectangular projection with the lateral margin. Mesial profile of the genu sinuous with a sub-triangular spur overlapping the posterior margin, beyond this it curve laterally in a steep face extending into the dorsal ridge of the genu and projecting beyond the lateral margin of the femur. Femur sub-rectangular. Surface smooth to irregularly depressed or elevated. Genu triangular with the tibia-tarsus complex slightly elevated anteriorly and antero-laterally. (Plate III, 5.)

Chaetotaxy ventrally: Four linear series of setae occur. (Plate III, 5.)

- (a) The bristle-bearing structure bears one seta while two other mesial setae occur on the rest of the mesial margin of the femur. These setae are stout and slightly barbed distally. Another two mesial setae occur on the genu.
- (b) A series of four sub-mesial setae with SM1 on the steep posterior face of the femur and SM2 on the flattened surface. Seta SM3 on the steep posterior face of the genu and SM4 on the apex.
- (c) A ventral sub-median series consisting of three setae with VSM1 on the steep posterior face of the femur and VMS2 on the flattened face. VMS3 on the steep posterior face of the genu.
- (d) Two setae in a lateral series with L1 on the femur and L2 on

the genu.

According to Hoogstraal (1956), the bristle-bearing structure (protruberance) on the internal ventral surface is most important; this feature may be difficult to discern in small specimens and the bristles are often broken, though their attachment knobs may usually be seen.

Chaetotaxy formula: (1 + 2 + 2)VM; 4SM; 3SVM; 2L.

Boophilus microplus (Plates II, 3 & III, 6.)

Dimensions:= Length:- combined segments: 0,134-0,156 mm; femur: 0,068-0,079 mm; genu: 0,056-0,061 mm. Breadth: femur: 0,114-0,163 mm; genu: 0,097-0,134 mm.

Length to breadth ratio of the femur about 0,570 and that of the genu about 0,536. According to Roberts (1965) the length of the combined segments varies from 0,19-0,21 mm. According to Gothe (1967) the length of the palps varies from 0,175-0,185 mm. According to the same author the length and the breadth of the femur are 0,080-0,090 mm and 0,110-0,120 mm respectively while the same dimensions of the genu is 0,060-0,070 mm and 0,105-0,115 mm. Dorsally the palps resemble that of *decoloratus* except that the shape of the segments differ slightly. (Plate II, 3.) The femur is almost rectangular and much broader and shorter as in *decoloratus*. The mesial and lateral margins about equal in length; postero-mesial angle more narrowly rounded and projecting more posteriorly and the genu more depressed triangular than in *decoloratus*. Chaetotaxy dorsal as in *decoloratus* (Plate II, 3.)

Ventrally the palps resemble those of *decoloratus* except for a few variations. (Plate III, 6.) The posterior ridge of the femur more or less straight and the bristle-bearing structure more triangular as in *decoloratus*. Chaetotaxy ventrally as in *decoloratus*, (Plate III, 6.) except that the bristle-bearing structure lacks any setae. Only two mesial setae occur on the femur and two on the genu. Mesial setae much smaller in diameter than in *decoloratus*.

Chaetotaxy formula: (0 + 2 + 2)VM; 4SM; 3SVM; 2L.

FEMALES

Rhipicephalus pravus (Plates II, 4 & III, 11)

Dimensions:= Length:- combined segments: 0,396-0,473 mm; femur: 0,193-0,245; genu: 0,167-0,193 mm. Breadth:- femur: 0,222-0,244 mm; genu: 0,213-0,230 mm.

Length to breadth ratio of the femur about 0,889 and that of the genu about 0,804. According to Theiler & Robinson (1953), the femur and the genu are equal in length, with the femur slightly broader than the genu. The dorsal aspect of the palps resembles that of the males. (Plate II, 4.)

Ventrally the palps resemble those of the males in detail, except that the spur-like structure just posterior to the tibia-tarsus complex is lacking. Ventral chaetotaxy: Four linear series of setae ventrally on the palps. (Plate III, 11.) A mesial series on the bristle-bearing structure containing 8-9 broad setae which resemble that of the males; another 5-8 structurally similar, though slightly smaller, occur on the femur, resembling those of the males; three fine mesial setae on the genu as in the males; mesial setae on the apex of the genu as in the males. The sub-mesial, sub-median and lateral series resemble those of the males.

Rhipicephalus oculatus (Plates II, 4 & III, 12.)

Dimensions:= Length:- combined segments: 0,415-0,431 mm; femur: 0,200-0,269 mm; genu: 0,163-0,177mm. Breadth: femur: 0,163-0,231 mm; genu: 0,210-0,215 mm.

Length to breadth ratio of the femur about 1,106 and that of the genu about 0,811. According to Theiler & Robinson (1953) the femur is broader than the genu and the genu nearly as long as the femur. Shape, surface and chaetotaxy as in the males (Plate II, 4.)

Ventrally the shape, surface and chaetotaxy resemble that of the males except that a prominent spur-like structure posterior to the tibia-tarsus complex is lacking. (Plate III, 12.) Mesial series consists of 5-8 setae on a bristle-bearing structure, plus 4-6 on the remainder of the mesial margin and three setae on the genu as in the males of *pravus*.

Rhipicephalus appendiculatus (Plates II, 5 & IV, 1.)

Dimensions:= Length:- combined segments: 0,459-0,500 mm; femur: 0,237-0,265 mm; genu: 0,160-0,205 mm. Breadth:- femur: 0,227-0,280 mm; genu: 0,227-0,263 mm.

Ratio between the length and the breadth of the femur about 1,012 and that of the genu about 0,779. Dorsal aspect of the palps resembles that of the males. (Plate II, 5.)

Ventrally the shape, surface and chaetotaxy resemble that of the males except that the spur-like structure is less prominent. (Plate IV, 1.) The mesial series consists of 6-8 setae on the bristle-bearing structure, plus 5-7 setae on the remainder of the mesial wall of the femur and three setae on the genu. The rest of the mesial wall, as well as the sub-mesial, sub-median and lateral series as in the males.

Boophilus decoloratus (Plates II, 6 & IV, 2.)

Dimensions:= Length:- combined segments: 0,229-0,279 mm; femur: 0,125-0,133 mm; genu: 0,090-0,116 mm. Breadth:- femur: 0,140-0,148 mm; genu: 0,125-0,140 mm.

Length to breadth ratio of the femur about 0,871 and that of the genu about 0,804. According to Gothe (1967), the length of the combined segments is from 0,240-0,260 mm, while Arthur & Londt (1973) stated that the length of these segments varies from 0,23-0,25 mm. According to Gothe (1967), the lengths of the femur and genu vary respectively from 0,110-0,120 mm and 0,090-0,100 mm, while the breadths of the femur and genu vary respectively from 0,120-0,140 mm and 0,112-0,120 mm. Surface, shape and chaetotaxy as in the males. (Plate II, 6.)

Ventrally the shape, surface and chaetotaxy as in the males except that the bristle-bearing structure bears one or two setae (Plate IV, 2.) Two to three setae occur on the rest of the mesial wall of the femur.

Boophilus microplus (Plates II, 6 & IV, 3.)

Dimensions:= Length:- combined segments: 0,221-0,278 mm; femur: 0,102-0,168 mm; genu: 0,085-0,110 mm. Breadth:- femur: 0,131-0,165 mm; genu: 0,126-0,162 mm.

Length to breadth ratio of the femur about 0,868 and that of the genu about 0,662. According to Roberts (1965), the length of the combined segments varies from 0,18-0,22 mm, while Gothe (1967) stated that the length of these segments varies from 0,240-0,260 mm. Gothe (1967) stated that the lengths of the femur and the genu vary respectively from 0,110-0,120 mm and 0,080-0,100 mm, while the breadths of these segments vary respectively from 0,120-0,140 mm and 0,105-0,115 mm. Dorsally the shape and chaetotaxy as in the males. (Plate II, 6.)

Ventrally the shape, surface and chaetotaxy as in the males except that the posterior part of the mesial wall of the femur is short and deeply concave and, as in the males, no bristle-bearing protruberance is found. (Plate IV, 3.) In one specimen a seta arises from the postero-concavity of the femur. The anterior part of the mesial wall bears three setae while the rest of the series resembles that of the males.

7.1.6 Tibia-tarsus complex

According to Wilkonson (1953) the tibia-tarsus complex bears chemoreceptors which are thought to be concerned with the final stimuli causing attachment after the animal host has been reached. The importance in copulation of the tibia-tarsus complex of the male was mentioned by Feldman-Muhsam & Borot (1971). They stated that when the male seeks the female's genital aperture, the tibia-tarsus complex protrudes from its pit and is seen in continuous motion. It remains in this state as long as the ticks are in

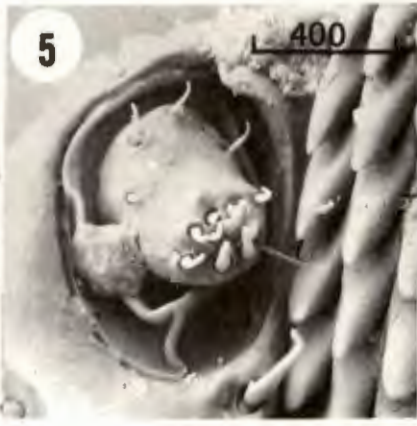


PLATE VI

PLATE VI⁺

Tibia-tarsus complex of larvae:-

1. *Rhipicephalus appendiculatus*;
2. *Boophilus decoloratus*;
3. *B. microplus*;

Tibia-tarsus complex of males:-

4. *R. pravus*;
5. *R. oculatus*;
6. *R. appendiculatus*;
7. *B. decoloratus*;
8. *B. microplus*;

Tibia-tarsus complex of females:-

9. *R. pravus*;
10. *R. oculatus*;
11. *R. appendiculatus*;
12. *B. decoloratus*.

+ Scale lines in μm .

copula. To ascertain the importance of this structure during copulation the authors cauterized it in seven males after five days of feeding. The cauterized males were then put together with females for observation. The males had not copulated, not even approach the females. Woolley (1972) stated that a comparison of the types, numbers and positions of the distal palpal sensillae might provide taxonomically important information that would be particularly useful for the separation of closely related species.

LARVAE

Rhipicephalus pravus (Plate V, 11.)

Dimensions: Length of sensillae: VS2, 26-28 μ m; VS1, 16-17 μ m; SVs1, 14 μ m; Vs2, 14 μ m; SDs1, 11 μ m; SDs2 & 3, 8-10 μ m and Ds1, 8-9 μ m.

The tibia-tarsus complex is columnar with a flattened seta-bearing apex. Four setae arise from the sides of the column, one proximally (nearest to the hypostome) C1, C2; sub-dorsally to sub-proximally; C3 sub-dorsal to sub-distally and C4 distally (farthest to hypostome). Eight sensillae present on the flattened apex of tibia-tarsus apex. From the dorsal to the ventral axis of the segment the setae are arranged in four linear transverse rows as follows:- on the dorsal side seta Ds1; three setae in a sub-dorsal row, SDs1-3; two in a supra-ventral row, SVs1-2 and two in a ventral row Vs1-2. (Plate V, 11.) Vs2>Vs1>SVs1>SVs2>SDs1>DS1>SDs2 & 3.

Rhipicephalus oculatus (Plate V, 12.)

Dimensions: Length of sensillae: Vs2, 25-35,6 μ m; Vs1, 13,9-19,6 μ m; SVs1, 13,3-16,6 μ m; SVs2, 12,2-14,3 μ m; SDs1, 10,1-11,4 μ m; SDs2, 9,1-10,5 μ m; SDs3, 9,0-9,7 μ m and DS1, 8,1-9,2 μ m.

Tibia-tarsus complex columnar as in *pravus*. Position of setae on the apex and on the column as in *pravus*. (Plate V, 12.)

Vs2>VS1>SVs1>SVs2>SDs1>SDs2>SDs3>Ds1.

Rhipicephalus appendiculatus (Plate VI, 1.)

Dimensions: Length of sensillae Vs2, 25-35 μ m; Vs1, 13,9-19,6 μ m; SVs1, 13,3-16,6 μ m; SVs2, 12,2-14,3 μ m; SDs1, 10,1-11,4 μ m; SDs2, 9,1-10,5 μ m; SDs3, 9,0-9,7 μ m and Ds1, 9,1-9,2 μ m.

Tibia-tarsus complex columnar and chaetotaxy as in *pravus* (Plate VI, 1.)

Vs2>Vs1>SVs1>SVs2>SDs1>SDs2>SDs3>Ds1.

Boophilus decoloratus (Plate VI, 2.)

Dimensions: Length of sensillae Vs2, 23-24 μ m; Vs1, 18-19,3 μ m; SVs1, 14,4-16 μ m; SVs2, 13,4-15 μ m; SDs1, 13,7-14,0 μ m; SDs2, 13-13,3 μ m; SDs3, 12,1-13,0 μ m and Ds1, 11-12 μ m.

Tibia-tarsus complex columnar as in the previous described species with a somewhat fattened setal bearing apex. (Plate VI, 2.) Three setae arise from the sides of the column; one dorsal; one latero-dorsal (proximally to the hypostome) and the other latero-ventral (distally to the hypostome). Eight setae present on the apex and arranged as in *R. pravus*. According to Arthur & Londt (1973) there are three setae in the supra-ventral row, but this do not correspond with the findings during this investigation, where only two setae occur in this row.

Vs2>Vs1>SVs1>SVs2>SDs1>SDs2>SDs3>Ds1.

Boophilus microplus (Plate VI, 3.)

Dimensions: Length of sensillae: Vs1, 29,7-32,8 μ m; Vs2, 20,4-24,0 μ m; SVs1, 16,5-18,7 μ m; SVs2, 14,3-19,3 μ m; SDs1-3, 13,6-14,2 μ m and Ds1, 12,2-13,0 μ m.

Tibia-tarsus complex also columnar with a flattened setal bearing apex. Three to four setae arise from the sides of the column, one being proximally (C1), C2 more dorsally than dorso-distally and C3 dorso-laterally. It seemed that the setal arrangement for the Australian strains and in some cases in the South African strains correspond to this arrangement. However in some cases of the South African strains another seta C4 occurs distally.

Eight setae present on the apex and arranged as in *R. pravus* (Plate VI, 3.)

Vs1>Vs2>SVs1>SVs3>SDs1-3>DS1.

Wilkinson (1953) stated that the eversible flap of the larvae bears four short setae about 0,01 mm long, two setae of intermediate length, and two long setae. That however, is not the case as can be seen from the dimensions of the setae.

NYMPHAE

Setal position on the column and on the apex of the studied species as in the larvae.

MALES

Rhipicephalus pravus (Plate VI, 4.)

Tibia-tarsus complex columnar with a flat seta-bearing apex. Five setae arise from the sides of the column with two on the sides, two dorso-laterally and one dorsally. From the dorsal to the ventral axis of the column the setae on the apex are arranged in four linear transverse rows as follows: on the dorsal side seta DS1; three setae in a sub-dorsal row (SDs1-3); three in a supra-ventral row (SVs1-3) and two in a ventral row (Vs1-2).

Rhipicephalus oculatus (Plate VI, 5.)

Columnar with five setae arising from the latter as in *pravus*. From the dorsal to the ventral axis of the column, the setae on the apex are arranged in four transverse rows as follows: on the dorsal side setae Ds1 & 2; three setae in a sub-dorsal row (SDs1-3); three in a supra-ventral row (SVs1-3) and two in a ventral row (Vs1 & 2).

Rhipicephalus appendiculatus (Plate VI, 6.)

Setae on the column and on the apex arranged as in *oculatus*.

Boophilus decoloratus (Plate VI, 7.)

The column bears five setae with one seta dorso-laterally near the apex; two dorso-laterally at the base of the column; one seta

dorsally and another situated halfway the length on the column. From the dorsal to the ventral axis of the column the setae on the apex arranged in four linear transverse rows as follows: on the dorsal side seta Ds1; three setae in a sub-dorsal row (SDs1-3); three in a supra-ventral row (SVs1-3) and one in a ventral row (Vs1).

Boophilus microplus (Plate VI, 8.)

Setae on the column and on the apex arranged as in *decoloratus*.

FEMALES

Rhipicephalus pravus (Plate VI, 9.)

Tibia-tarsus complex columnar with a flat seta-bearing apex as in the males. One of the columnar setae almost next to the seta in the dorsal series. In one specimen two setae occur in the ventral series.

Rhipicephalus oculatus (Plate VI, 10.)

Tibia-tarsus complex columnar with a flat seta-bearing apex as in the males, except that seven setae arise from the column; one pair laterally, two pairs dorso-laterally and one seta almost next to the seta in the dorsal series. Two setae occur in the ventral series.

Rhipicephalus appendiculatus (Plate VI, 11.)

Tibia-tarsus complex columnar with a flat, setae-bearing apex as in *pravus*. Two setae are present in the ventral series.

Boophilus decoloratus (Plate VI, 12.)

Tibia-tarsus complex columnar with a flat seta-bearing apex as in the males, but differs from the latter in that the column bear one pair laterally, three pairs dorso-laterally, with one seta situated higher up on the column, but still dorso-laterally. Another seta almost reaching the dorsal series. Setae on the apex as in the males.

Boophilus microplus (Plate XVI, 8.)

Tibia-tarsus complex columnar with a flat seta-bearing apex, with

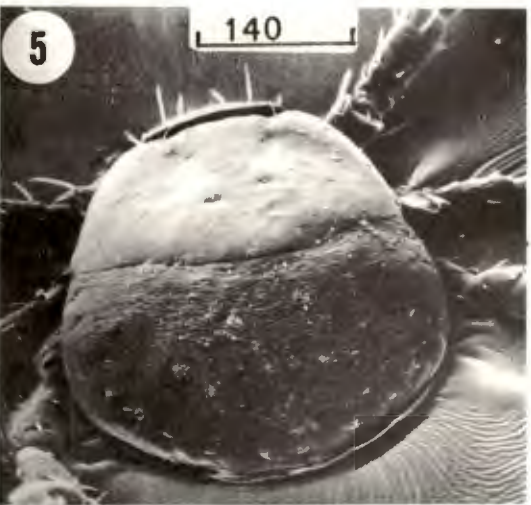
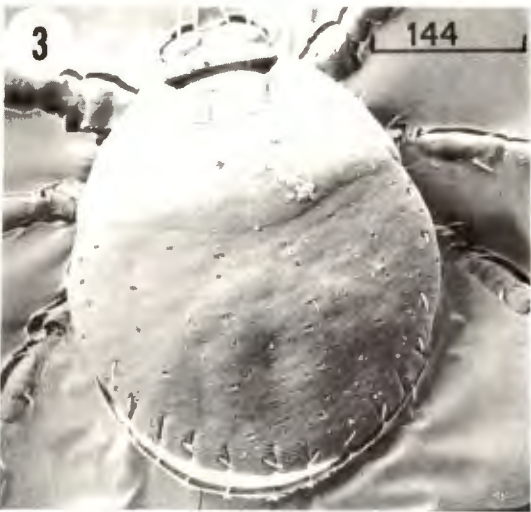
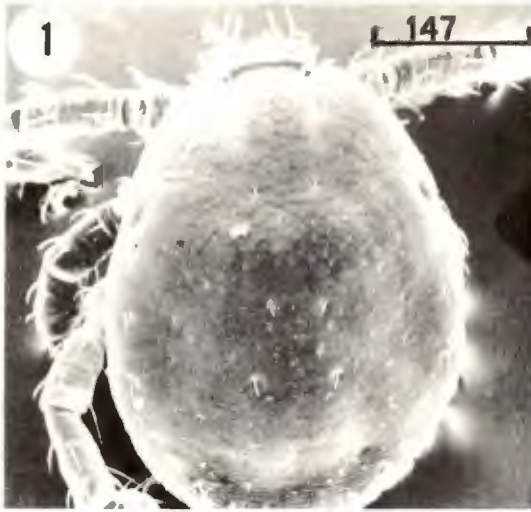


PLATE VII

PLATE VII⁺

Dorsal aspect of larvae:-

1. *Rhipicephalus pravus*;
2. *R. oculatus*;
3. *R. appendiculatus*;
4. *Boophilus decoloratus*;
5. *B. microplus*;

Ventral aspect of larva:-

6. *R. pravus*.

+ Scale lines in μm .

one seta in the dorsal series; three setae in sub-dorsal series; three setae in a supra-ventral series and one seta in a ventral series. The column bear two lateral setae, two dorso-laterally and one near the dorsal series on the apex.

7.1.7 Gene's organ

Gene's organ, so named by Nuttall (1908) in honour of its discoverer, Gene, in 1844. It is solely concerned with the act of oviposition and is therefore peculiar to the female tick. According to Robinson & Davidson (1913a) it is present in all the Ixodoidea and has been the subject of more or less detailed consideration in most works dealing with tick anatomy. The organ is first evident during the final nymphal moult, but only becomes fully developed when the sexual organs reach their peak of activity. It consists of a pair of eversible membranous sacs, derived from the chitinous cuticle of the body, which in the inactive state are contained within a pair of similar sacs of hypodermal origin into which the ducts of large glands open (Robinson & Davidson, 1913a). The external opening of Gene's organ is a broad crescentic slit with everted lips, which extends across the camerostomal depression immediately anterior to the fold formed by the union of the camerostomal integument with the proximal margin of the dorsal part of the gnathotectum.

FEMALES

It is evident from this investigation that the external aperture of Gene's organ is lacking in the unengorged females in both genera, although the organ becomes evident during the final nymphal moult and fully developed when the sexual organs reach their peak of activity.

7.2 Idiosoma

7.2.1 Dorsum

The dimensions of a specimen may be of some assistance but marked variations occur, diminishing the value of this characteristic



PLATE IX

PLATE VIX⁺

Ventral aspect of larvae:-

1. *Rhipicephalus oculatus*;
2. *R. appendiculatus*;
3. *Boophilus decoloratus*;
4. *B. microplus*;

Dorsal aspect of nymphae:-

5. *R. pravus*;
6. *R. oculatus*.

+ Scale lines in μm .

considerably. Mere size seems to be of less account in the rhipicephalids than in any other genus of the Ixodidae (Warburton, 1912).

LARVAE

Rhipicephalus pravus (Plate VII, 1.)

Dimensions:= Length: 0,418-0,453 mm; maximum breadth: 0,323-0,359 mm.

Maximum width is found about halfway along the length. Ratio between the length and the breadth about 1,287. Narrowly oval in shape, longer than broad.

Rhipicephalus occulatus (Plate VII, 2.)

Dimensions:= Length: 0,505-0,579 mm; maximum breadth: 0,414-0,471 mm.

Maximum breadth about halfway along the length. Ratio between the length and breadth about 1,185. Broad oval in shape.

Rhipicephalus appendiculatus (Plate VII, 3.)

Dimensions:= Length: 0,416-0,471 mm; maximum breadth: 0,345-0,437 mm.

Maximum breadth also about halfway along the length. Ratio between the length and breadth about 1,131. Oval in shape. According to Howard (1908) the length is 0,75 and the breadth 0,50 mm.

Boophilus decoloratus (Plate VII, 4.)

Dimensions:= Length: 0,472-0,505 mm; maximum breadth: 0,371-0,403 mm.

Ratio between the length and breadth is about 1,252. According to Arthur & Londt (1973) the unfed specimens are about one and a third times as long as breadth. According to Gothe (1967) the maximum breadth is found between the level of the eyes and the posterior end of the scutum, ranging from 0,418-0,437 mm and a

range of 0,456-0,465 mm in length. In this investigation the maximum breadth was found at about the level of the third pair of coxae. Almost round, a little longer than wide.

Boophilus microplus (Plate VII, 5.)

Dimensions:= Length: 0,374-0,457 mm. Maximum breadth: 0,408-0,427 mm.

Maximum breadth at a level just posterior to the scutum. Ratio between the length and the breadth about 1,040. According to Roberts (1965) the length varies from 0,40 and according to Gothe (1967) the length varies from 0,40-0,52 mm. According to Roberts (1965) the breadth ranges from 0,37-0,45 mm. According to Gothe (1967) the breadth ranges from 0,408-0,427 mm. Cooley (1946) and Arthur (1960) stated that maximum breadth is about 0,42 mm. Pear-shaped and approximately as wide as long.

NYMPHAE

Rhipicephalus pravus (Plate VIX, 5.)

Dimensions:= Length: 0,714-0,735 mm; maximum breadth: 0,489-0,540 mm.

Length to breadth ratio about 1,360. Body elongate oval in shape. Maximum breadth at about mid-length.

Rhipicephalus oculatus (Plate VIX, 6.)

Dimensions:= Length: 0,799-0,880 mm; maximum breadth: 0,427-0,603 mm.

Length to breadth ratio about 1,616. Body broadly ovate in shape. Maximum breadth at about mid-length. According to Theiler & Robinson (1953) the dimensions of the body, plus the gnathosoma, of the unfed nymphae are 0,9 mm x 0,5 mm.

Rhipicephalus appendiculatus (Plate X, 1.)

Dimensions:= Length: 0,922-1,028 mm; maximum breadth: 0,636-0,696 mm.

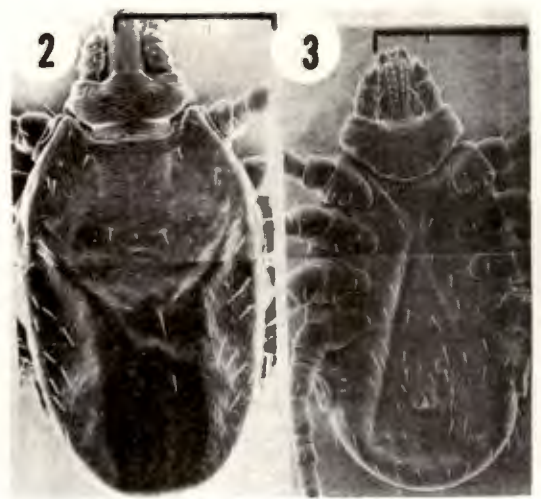


PLATE X

PLATE X⁺

Dorsal aspect of nymphae:-

1. *Rhipicephalus appendiculatus*;
2. *Boophilus decoloratus**;
4. *B. microplus*;

Ventral aspect of nymphae:-

3. *B. decoloratus**;
5. *R. pravus*;
6. *R. oculatus*;
7. *R. appendiculatus*.

+ Scale lines in μm .

* After Arthur & Londt (1973)

Length to breadth ratio about 1,457. Maximum breadth at about mid-length. According to Howard (1908) unengorged numphae are about 1,25 mm in length and 0,75 mm in breadth. Broadly ovate in shape.

Boophilus decoloratus (Plate X, 3.)

Dimensions:= Length: 0,955-0,961 mm; maximum breadth: 0,663-0,668 mm.

Length to breadth ratio about 1,442. Maximum breadth at about one-third the length posteriorly. According to Arthur & Londt (1973) the whole length of unfed specimens are about twice as long as maximum breadth. Oval in shape.

Boophilus microplus (Plate X, 4.)

Dimensions:= Length: 0,875-0,892 mm; maximum breadth: 0,580-0,600 mm.

Length to breadth ratio about 1,519. Narrowly ovate in shape. Widest at the level of the second coxae.

MALES

Rhipicephalus pravus (Plate XI, 2.)

Dimensions:= Length: 2,014-3,128 mm; maximum breadth: 0,1342-1,934.

Maximum breadth is at about the level of coxae IV. Ratio between the length and breadth 1,563. According to Hoogstraal (1956) all Sudanese specimens are small — about 3,5 mm long and 2,1 mm wide. According to Walker (1956) the dimensions are 3x 1,8-1,9 x 1,2 mm. A large, triangular dorsal projection of coxa I visible from the dorsal surface.

Rhipicephalus oculatus (Plate XI, 3.)

Dimensions:= Length: 2,700-3,408 mm; maximum breadth: 1,552-2,300 mm.



PLATE XI

PLATE XI⁺

Ventral aspect of nymphae:-

1. *Boophilus microplus*;

Dorsal aspect of males:-

2. *Rhipicephalus pravus*;
3. *R. oculatus*;
4. *R. appendiculatus*;
5. *B. decoloratus*;
6. *B. microplus*.

+ Scale lines in μm .

Maximum breadth is found just posterior to coxae IV. Ratio between the length and the breadth about 1,713. According to Theiler & Robinson (1953) the average size is 3,1 x 1,5 mm to 3,6 x 2,2 mm. Coxa I projection visible dorsally.

Rhipicephalus appendiculatus (Plate Xi, 4.)

Dimensions:= Length: 2,843-4,176 mm; maximum breadth: 2,033-2,612 mm.

Maximum breadth is just posterior to coxa IV. Ratio between the length and breadth about 1,415. Oval in outline. According to Howard (1908) the length varies from 3-4 mm and according to Hoogstraal (1956) from 1,8-4,4 mm, but the "normal" length be above 3,0 mm.

Boophilus decoloratus (Plate XI, 5.)

Dimensions:= Length: 1,645-2,563 mm; maximum breadth: 1,069-1,734 mm.

Maximum breadth is at about the level of coxa IV. Ratio between the length and breadth about 1,527. According to Arthur (1960) the length varies from 2,5-2,9 mm and the breadth from 1,4-1,8 mm. According to Hoogstraal (1956) the length is about 2,7 mm and the breadth 1,5 mm. Gothe (1967) stated that the dimensions average 2,7 mm by 1,6 mm. According to Arthur & Londt (1973) an examination of samples of males of *B. decoloratus* during biological investigations makes it clear that there is a particularly wide range of sizes and that within a single population there may be two discrete peaks in size. Concomitant with this, certain morphological characters may be reduced or enhanced.

Boophilus microplus (Plate VIX C.)

Dimensions:= Length: 1,251-2,343 mm ; maximum breadth: 0,909-1,412 mm.

Maximum breadth is found at about the middle. Ratio between the length and the breadth about 1,312. According to Cooley (1946) the length from the tips of the palp to the posterior margin va=

ries from 1,75-2,00 mm, while the greatest width from 1,05-1,20 mm. Arthur (1960) stated that it varies from 1,5-2,5 mm in overall length and from 1,0-1,4 mm breadth. According to Hoogstraal (1956) it varies from about 1,6-2,5 mm in overall length and from 1,0-1,4 mm in width. According to Roberts (1965) the dimensions are 1,6 x 1,2 mm - 2,0 x 1,35 mm (tip of scapula to tip of caudal process). Gothe stated that it averages 2,6 mm by 1,3 mm.

FEMALES

Rhipicephalus pravus (Plate XII, 6.)

Dimensions:= Length: 2,257-3,485 mm; maximum breadth, 1,266-1,765 mm.

Maximum breadth is found just posterior to coxa IV. According to Theiler & Robinson (1953) the dimensions are 3,5-4 mm x 1,5-2 mm and according to Walker (1956) 3 x 1,8 to 1,9 x 1,2 mm. Anterior process of coxa I visible dorsally.

Rhipicephalus oculatus (Plate XIII, 1.)

Dimensions:= Length: 2,457-3,527 mm; maximum breadth: 1,620-1,956 mm.

Maximum breadth just posterior to coxa IV. According to Theiler & Robinson (1953) the dimensions vary from 3,0 x 1,5 to 3,6 x 2,2 mm.

Rhipicephalus appendiculatus (Plate XIII, 2.)

Dimensions:= Length: 2,774-3,323 mm; maximum breadth: 1,455-1,859 mm.

Maximum breadth at the level of coxa IV.

Boophilus decoloratus (Plate XIII, 3.)

Dimensions:= Length: 2,068-3,560 mm; maximum breadth: 1,180-1,540 mm.



PLATE XII

PLATE XII⁺

Ventral aspect of males:-

1. *Rhipicephalus pravus*;
2. *R. oculatus*;
3. *R. appendiculatus*;
4. *Boophilus decoloratus*;
5. *B. microplus*;

Dorsal aspect of female:-

6. *R. pravus*.

+ Scale lines in μm .

Maximum breadth just anterior to the level of the spiracles.
Unfed specimens small elongate oval in outline.

Boophilus microplus (Plate XIII, 4.)

Dimensions:= Length: 1,758-2,200 mm; maximum breadth: 1,191-1,438 mm.

Maximum breadth at about level with the third coxae. Unfed specimens oval, narrow behind coxa IV. According to Arthur (1960) the dimensions vary in length from 1,9-2,1-2,15 mm and the breadth 1,1-1,3-1,6 mm and according to Roberts (1965) 1,6 x 1,1-2,1 x 1,4 mm.

7.2.2 Scutum

In males it includes the entire or nearly entire dorsal surface of the body except the gnathosoma; in females, nymphae and larvae the shield is located posterior to the gnathosoma and covers only a part of the idiosoma dorsally. According to Arthur (1956), stretching of the body during feeding may reduce the curvature and alters the orientation of the scutum. Hence, measurements of the scutum of unfed, partially fed and fully fed ticks may give results that are not comparable. Arthur stated further that, with one exception, the percentage increase in mean length of the scutum from larva to the nymph is greater than the breadth and that this increase is not constant in all species. The scutum can also alter in shape and changes are apparent in the form of the scutum after the nymphs moult. This investigation is solely based on unengorged specimens so the size and form of the scutum may be used as a taxonomic character.

LARVAE

Rhipicephalus pravus (Plate VII, 1.)

Dimensions:= Breadth: 0,289-0,316 mm; length: 0,205-0,236 mm.

Emargination:- breadth: 0,102-0,122 mm; depth: 0,031-0,040 mm.

Emargination relatively wide and deep. Scutum widest at eye-



PLATE XIII

PLATE XIII⁺

Dorsal aspect of females:-

1. *Rhipicephalus oculatus*;
2. *R. appendiculatus*;
3. *Boophilus decoloratus*;
4. *B. microplus*;

Ventral aspect of females:-

5. *R. pravus*;
6. *R. oculatus*.

+ Scale lines in μm .

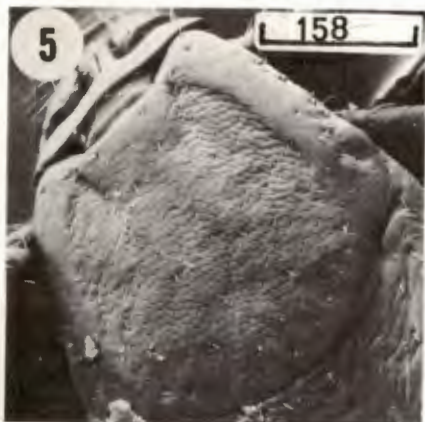
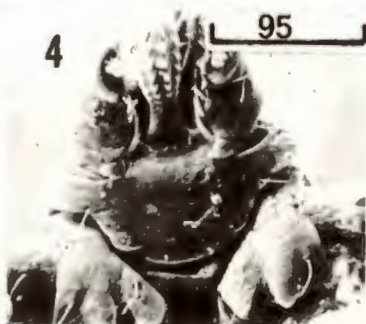


PLATE XIV

PLATE XIV⁺

Ventral aspect of females:-

1. *Rhipicephalus appendiculatus*;
2. *Boophilus decoloratus*;
3. *B. microplus*;

Ventral aspect of gnathosoma of nymph:-

4. *R. oculatus*;

Tibia-tarsus complex of female:-

8. *B. microplus*

Scutae of nymphae

5. *R. pravus*;
6. *R. oculatus*;
7. *B. microplus*;
9. *R. appendiculatus*

+ Scale lines in μm .

level. Ratio between the length and the breadth about 0,758. Posterior margin evenly curved, postero-lateral margins slightly concave, antero-lateral margins slightly convex. Scapulae smoothly rounded. (Plate VII, 1.) Cervical grooves relatively deep and broad, parallel-sided with two pits into or just mesial of the cervical grooves posteriorly. Mesial wales between grooves strongly elevated. (Plate VII, 1.) Scutal setae in three pairs (Sc1-3) as depicted on Plate VIII, 1. Pits present on the scapulae, one halfway between the scapulae and the eyes, another at eye-level in the median field, and a pair adjacent to the cervical grooves. Surface with a strongly reticulate pattern.

Rhipicephalus oculatus (Plate VII, 2.)

Dimensions:= Breadth: 0,337-0,398 mm; length: 0,201-0,270 mm.

Emargination:- breadth: 0,201-0,270 mm; depth: 0,040-0,046 mm.

Emargination wide and deep. Scutum widest at eye-level. Ratio between the length and breadth about 0,657. Posterior margin broad and blunt, postero-lateral walls weakly concave, antero-lateral walls slightly convex. (Plate VII, 2.) Scapulae smoothly rounded. (Plate VII, 2.) Cervical grooves long, deeper than in *pravus*, (Plate VII, 2.) narrow-parallel, continue anteriorly on the inner sides of the emargination as in Plate VII, 2. Mesial walls of grooves strongly elevated. Scutal setae located as in *pravus*, except that Sc3 are in line with the anterior margin of the eyes. Depressions and surface as in *pravus*.

Rhipicephalus appendiculatus (Plate VII, 3.)

Dimensions:= Breadth: 0,310-0,372 mm; length: 0,190-0,254 mm.

Emargination:- breadth: 0,134-0,147 mm; depth: 0,038-0,045 mm.

Emargination narrow and deep. Scutum widest at eye-level. Ratio between the length and the breadth about 0,656. According to Howard (1908) the scutum is as wide as long. Posterior margin of scutum broadly rounded. Postero-lateral and lateral margins as in *pravus*. Scapulae relative narrowly rounded. Cervical grooves parallel, short and shallow, continue anteriorly into the

emargination. (Plate VII, 3.) Scutal setae and depressions as in *pravus*.

Boophilus decoloratus (Plate VII, 4.)

Dimensions:= Breadth: 0,325-0,345 mm; length: 0,194-0,245 mm.

Emargination:- length: 0,125-0,139 mm; depth: 0,044-0,052 mm.

Emargination wide and deep. According to Gothe (1967) the breadth of the scutum ranges from 0,3705-0,3895 mm, while the length varies from 0,275-0,294 mm. The ratio between the length and the breadth is about 0,643. The mid-dorsal posterior margin with the posterolateral margins slightly concave, antero-lateral margins slightly convex. (Plate VII, 4.) Scapulae broadly rounded. Surface with a reticulate pattern. Cervical grooves short, shallow, parallel with two pits. (Plate VII, 4.) Surface between grooves slightly elevated and beyond them sloping gradually to the periphery. According to Gothe (1967) the cervical grooves run at first parallel and then somewhat divergent reaching halfway down the scutum. That is not the case according to Plate VII, 4. Scutal setae in three pairs and distributed as in *pravus*. Four pairs of pits (depressions) are present, one pair mesial to the cervical grooves; one pair posteriorly to setae Sc2; one pair on the scapulae and a median pair in line with the eyes. (Plate VII, 4.)

Boophilus microplus ((Plate VII, 5.)

Dimensions:= Breadth: 0,317-0,367 mm; length: 0,165-0,243 mm.

Emargination:- length: 0,126-0,158 mm; depth: 0,042-0,058 mm.

Emargination wide and deep. Ratio between the length and the breadth about 0,646. According to Roberts (1965) the length of the scutum ranges from 0,27-0,35 mm, according to Arthur (1960) 0,29-0,33 and according to Gothe (1967) 0,256-0,275. According to the same authors the breadth ranges respectively 0,32-0,38 mm; 0,40-0,43 mm and 0,370-0,389 mm.

The posterior and postero-lateral margin of the Australian strains broadly rounded, whereas in the South African strains the posterior margin is more narrowly rounded while the postero-lateral margins

are weakly concave. (Plates VII, 5.) Antero-lateral margins gently convex. Apparently the scapulae in the Australian strain is more broadly rounded than in the South African strain. Surface reticulate as in *decoloratus*, short and not extending as far posteriorly as Roberts (1965) stated. Cervical grooves parallel with a pair of pits on their mesial walls. Surface between grooves elevated. According to Cooley (1946) and Arthur (1960) no setae occur on the scutum. Scutal setae arranged as in *pravus*. Sensory pits as in *decoloratus*.

NYMPHAE

Rhipicephalus pravus (Plates VIX, 5 & XIV, 5.)

Dimensions:= Length: 0,343-0,368 mm; breadth: 0,429-0,470 mm.

Emargination covered dorsally by the gnathotectum. According to Theiler & Robinson (1953) the emargination is wide and deep. Scutum broadest at eye-level. Ratio between the length and breadth about 0,792. Posterior margin sinuous and relative broadly rounded; continuous through a widely rounded angle with the convexally lateral margins. Cervical pits deep. (Plate XIV, 5.) Cervical grooves relatively deep at first, rapidly becoming shallower and fading out at about eye-level. Lateral grooves closely located to the lateral margins, much more sharply defined than the cervical grooves and almost reach the posterior margin of the scutum and then curving inwards. According to Theiler & Robinson (1953) the lateral grooves reached the posterior margin. The inner section between the lateral grooves, markedly reticulated, except for a narrow strip anteriorly and medianly to the eyes.

Four pairs of setae occur on the positions of Sc1-3 of the larvae. Three pairs of setae occur on the scapulae and two pairs halfway between the eyes and the scapulae. Four pairs occur in a medio-lateral row just anterior and medianly to the eyes. One pair of setae anterior to the cervical pits and one pair between Sc4 and the eyes. Large to medium size punctations, more abundant

outside the lateral grooves.

Rhipicephalus oculatus (Plates VIX, 6 & XIV, 6.)

Dimensions:= Length: 0,397-0,407 mm; breadth: 0,449-0,507 mm.

Ratio between the length and breadth about 0,810. Theiler & Robinson (1953) stated wrongly that the scutum is about as broad as long, an impression probably given by the pronounced lateral grooves and raised lateral borders which make the scutum look longer than broad. Emargination covered by the gnathotectum as in *pravus*. Posterior margin more broadly convex than in *pravus*. Cervical grooves as in *pravus*, except that they are deeper anteriorly. Lateral grooves well-developed edging a raised lateral fold, more markedly defined than in *pravus*, extending posteriorly, curving inwards near the posterior margin of scutum as in *pravus*. Reticulation as in *pravus*. (Plate XIV, 6.)

Five pairs of setae occur in the position of the Sc1-3 of the larvae. Three pairs of setae occur on the scapulae and two pairs halfway between the eyes and the scapulae. Two pairs in a medio-lateral row just anterior and median to the eyes. A pair of setae between the eyes and Sc5 setae and one pair antero-lateral to the cervical pits. Punctations as in *pravus*.

Rhipicephalus appendiculatus (Plates X, 1 & XIV, 9.)

Dimensions:= Length: 0,040-0,049 mm; breadth: 0,583-0,605 mm.

Emargination covered dorsally by the gnathotectum. According to Howard (1908) unengorged specimens, including the gnathosoma, are about 1,25 mm long and 0,75 mm wide. Posterior margin relative more narrowly rounded than in *pravus* or *oculatus*, continuous through blunt angles with the convex lateral margins. Cervical grooves relatively shallow, well more edging than in *pravus* or *oculatus*. (Plates XIV, 9.) Cervical grooves arcuate and nearly reach the posterior margin. Lateral margin faintly defined and not to the same extent as in *pravus* and also not so

closely located to the lateral margins than in *pravus* or *oculatus*. Lateral grooves arcuate, running posteriorly and nearly reach the posterior margin where it curve inwards. The inner section between the lateral grooves not so markedly distinguishable as in *pravus*, because the outer section is quite well reticulated.

Setae Sc1-4 as in *pravus*. Three pairs of setae present on the scapulae; two pairs between the eyes and the scapulae; two pairs of setae in a medio-lateral row as in *oculatus*; one pair anterior to the cervical pits and one pair between the eyes and Sc4. Punctations as in *pravus*.

Boophilus decoloratus (Plate X, 2.)

Dimensions:= Length: 0,475-0,500; breadth: 0,425-0,436 mm.

Emargination partially covered by the gnathotectum. Ratio between the length and breadth about 1,176. According to Arthur (1960) the length varies from 0,44-0,47 mm, while Gothe (1967) stated that it varies from 0,456-0,475 mm. According to Arthur & Londt (1973) this dimension varies from 0,44-0,45 mm. Posterior margin narrowly rounded, postero-lateral margins rectilinear, or weakly concave, thence mildly undulate. Cervical pits very shallow or absent. Cervical grooves shallow and convergent at first, then divergent, reaching the postero-lateral margins. No lateral grooves present. Surface smooth with few, small and shallow punctations.

Setae present in comparable situations to Sc1-3 of the larvae supplemented by a pair on the scapulae; one to two pairs between the eyes and the scapulae and in some cases a pair laterally between Sc1 and Sc2.

Boophilus microplus (Plates X, 3 & XIV, 7.)

Dimensions:= Length: 0,370-0,411 mm; breadth: 0,452-0,460 mm.

Length to breadth ratio about 0,910. According to Cooley (1946) the length is 0,31 mm; to Arthur (1960): 0,43-0,48mm; Roberts (1964) 0,27-0,35 mm and to Gothe (1967): 0,370-0,380 mm. Accor=

ding to Cooley (1946) the breadth is about 0,42 mm; Arthur (1960): 0,43-0,48 mm; Roberts (1964): 0,32-0,38 mm. and to Gothe (1967): 0,418-0,4375 mm. Posterior margin narrowly rounded. Postero-lateral margins straight and the antero-lateral margins convergent and slightly concave. Cervical grooves faint, divergent posteriorly, reaching halfway down the scutum. Surface smooth with a few shallow punctations.

Setae present in comparable situations to Sc1-3. of the larvae, supplemented by a further two pairs on the scapulae, and one pair between the eyes and the scapulae.

Conscutum: MALES

Rhipicephalus pravus (Plate XI, 2.)

Emargination wide and deep, partially covered by the gnathotectum. Cervical pits deep and convergent. Cervical grooves shallow, convergent at first, becoming divergent and fading out beyond the level of the eyes and bears numerous fine superficial pittings. Lateral grooves very short. According to Walker (1956) these grooves are represented by somewhat irregular rows of medium-sized punctations. Marginal grooves well developed, originating posterior to the eyes and reaching the festoons; according to Walker (1956) sometimes almost including the first festoon. The outer edges sharply defined. Very small depressions indicate the mid-dorsal fovea. Two roughly parallel lines mesial to the marginal grooves. Postero-median and postero-lateral grooves all well developed and indicated by very small depressions. These grooves are according to Walker (1956), usually continuous with adjacent intervals of festoons. The postero-median groove about twice as long as the postero-lateral grooves. The latter a little broader than the postero-lateral groove. According to Walker (1956) a caudal appendage with terminal disc present which arise from the central festoon. Eleven festoons present. Walker (1956) stated that the punctation pattern is very variable made up of discrete medium-sized and small punctations.

Rhipicephalus oculatus (Plate XI, 3.)

Emargination relatively narrow, but as deep as in *pravus*. Cervical grooves at first deeper than in *pravus*. Cervical grooves at first convergent becoming divergent and fading out beyond the level of the eyes. Cervical grooves indicated posteriorly by small superficial depressions. Lateral grooves absent, (represented by rows of punctations.) Marginal grooves well developed with a pronounced outer edge as in *pravus* carrying irregular punctations and including last or sometimes also penultimate festoon. (Theiler & Robinson, 1953.) Eleven well developed festoons. The fovea not so quite well defined as in *pravus*, only vague elongate depressions indicate its position. Along these depressions two roughly parallel lines (as in *pravus*), the marginal grooves occur. These elongate depressions indicated by fine pitting. Postero-median and postero-lateral grooves as in *pravus*.

Rhipicephalus appendiculatus (Plate VIX A.)

Emargination wide and deep as in *pravus*. Cervical pits deep and cervical area scalpel-shaped and short. Cervical grooves shallow, convergent and fading out as they become divergent. Lateral grooves very shallow, if present and almost reach the marginal grooves. Marginal grooves much more defined than in *pravus* or *oculatus* with sharp lateral edges, originating posterior to the eyes and reaching the festoons.

The mid-dorsally fovea as in *pravus*. The roughly parallel lines occurring inside the marginal grooves as in *pravus* and *oculatus*, absent. The postero-median and postero-lateral grooves more prominent than in *pravus* or *oculatus*. The postero-median groove narrows anteriorly and is about twice the length of the postero-lateral grooves. The posterior grooves indicated by very small depressions. Eleven well developed festoons.

Boophilus decoloratus (Plate VIX B.)

Emargination wide and deep ending in strong sub-triangular scapulae. The cervical grooves are shallow, broad, diverging posteriorly and reaching beyond eye-level. In line with the cervi-

cal grooves and at midlength there is a pair of short oval shallow depressions. The postero-lateral grooves wide, deep and converging posteriorly. The postero-median groove narrow, deep and straight reaching about the midlength of the conscutum. The postero-lateral grooves about two-thirds the length of the postero-median groove. The conscutum lacks mid-dorsal fovea, marginal grooves and festoons as in the rhipicephalids. Setae absent from grooves and depressions.

Boophilus microplus (Plate VIX, C.)

Emargination wide and deep, well defined; strong subtriangular scapulae. Cervical grooves shallow, broadly rounded behind, then narrowing anteriorly. In line with the cervical grooves and at mid-length there is a pair of short, oval and shallow depressions. Postero-lateral grooves wide and deep, converging posteriorly (more markedly than in *decoloratus*). Postero-median groove narrow, deep and straight reaching almost the scutal mid-length. Postero-lateral grooves about four-fifths the length of the postero-median groove.

FEMALES

Rhipicephalus pravus (Plate XII, 6.)

Dimensions: Length: 1,256-1,382 mm; breadth: 1,229-1,365 mm.

Ratio between the length and breadth about 0,997. Maximum breadth at eye-level. Antero-lateral margins slightly convex and continuous through broadly rounded angles with the sinuous postero-lateral margins, thence a widely rounded posterior margin. Cervical pits small and deep. The cervical grooves convergent at first, then becoming divergent and fading out beyond eye-level near the posterior margin of the scutum. Cervical grooves prominent and, according to Walker (1956), they are continued posteriorly by superficial pittings. Lateral grooves very short or absent and replaced by a row of medium size punctations which tend to run in a broad arc. Cervical fields characteristic in shape, being broad anteriorly, becoming convergent thence diver-

gent and finally tapering posteriorly to eye-level. Emargination relatively wide and deep. Punctuation pattern is, according to Walker (1956) very variable. Numerous, very small setae scattered over the surface of the scutum.

Rhipicephalus oculatus (Plate XIII, 1.)

Dimensions:= Length: 1,152-1,355; breadth: 1,293-1,334 mm.

Ratio between the length and breadth about 0,961. Antero-lateral margins convex. Postero-lateral margins widely rounded and continuous with the widely rounded posterior margin. Emargination relatively wide and deep. Cervical pits small and deep. Cervical grooves relatively short, convergent at first but divergent posteriorly and becoming shallower till they fade away anterior to eye-level. Lateral groove without a clear-cut outer edge as in the males, but discernable; widely arcuate and almost reaching the posterior margin. Punctuation pattern variable.

Rhipicephalus appendiculatus (Plate XIII, 2.)

Dimensions:= Length: 1,177-1,424 mm; breadth: 1,315-1,530 mm.

Ratio between the length and the breadth about 0,909. Maximum breadth is found at eye-level. Emargination relatively broad and deep. Cervical pits small but larger than in *pravus* or *oculatus*. Cervical grooves shallow and continuous almost to the posterior margin as in *pravus*, but not so prominent; arcuate inwards. Lateral grooves very short or poorly defined; often picked out by a row of median size punctations. Punctations vary to some extent. Setae as in *pravus*.

Boophilus decoloratus (Plate XIII, 2.)

Dimensions:= Length: 0,730-0,858 mm; breadth: 0,838-0,912 mm.

Ratio between the length and the breadth about 1,025. According to Arthur (1960) the length varies from 0,96-0,98-1,1 and the breadth 0,85-0,90-1,03, while Gothe (1967) stated that the same dimensions are respectively 1,1-1,2 mm and 0,90-1,15 mm. According to Arthur & Londt (1973) the dimensions are respectively 0,94-1,1 and 0,82-1,03 mm. The antero-lateral margins convergent and slightly convex; postero-lateral margins are slightly concave.

Posterior margin narrowly rounded. Cervical pits absent. Emargination well-defined. The inconspicuous cervical grooves are broad, shallow and convergent at first, then divergent and reach halfway down the scutum. Lateral grooves absent. Surface gently convex between the cervical grooves, depressed posterolateral of the latter. A few setae of moderate length, arranged along the antero-lateral margins, between the cervical grooves as a postero-median group. Lateral grooves absent.

Boophilus microplus (Plate XIII, 3.)

Dimensions: Length: 0,769-1,079 mm; breadth: 0,873-1,050 mm.

Ratio between the length and the breadth about 0,894. Widest level anterior to the eyes. According to Hoogstraal (1956) the length varies from 0,40-0,58 mm and the breadth 0,34-0,50 mm. Roberts (1964) stated that the dimensions for the Australian species are 0,18 x 0,75-1,2 x 1,0 mm and according to Gothe (1967) they are 1,18-1,24 mm and 0,90-1,06 mm. Antero-lateral margin straight or mildly curved and a little divergent posteriorly. Postero-lateral margins sinuous or concave with the posterior margin relatively narrowly rounded. Cervical grooves long, broad and shallow but more prominent than in *decoloratus*. Cervical grooves convergent for a short distance anteriorly, then curving divergently to reach the postero-lateral margins. Lateral grooves absent. Emargination deep. Scapulae elongate and blunt. Punctations few and shallow. A few setae of moderate length arranged as in *decoloratus* but sparser.

7.2.1.2 Eyes

Minning's diagnostic characters for the separation of species in the genus *Boophilus* included the position of the eyes. He stated that in some species the eyes lie near the border of the scutum, in others on the border and yet in others overlap this border. It was recognized by Theiler (1943) that the position of the eyes varies according to the tension on the alloscutum consequent on engorgement. *R. oculatus* and *R. evertsi*, according to Warburton (1912) are dearly separated from all other species of *Rhipicephalus* by their hemispherical bead-like eyes. In a few other species the

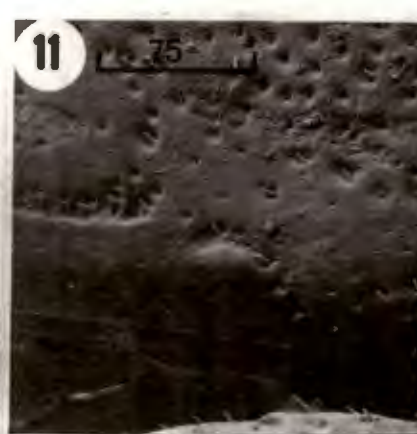
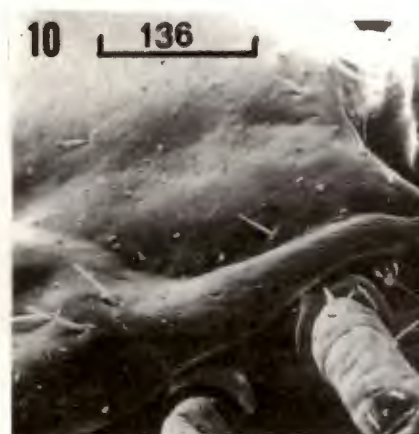
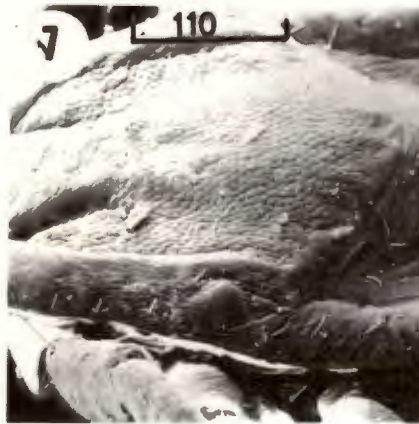
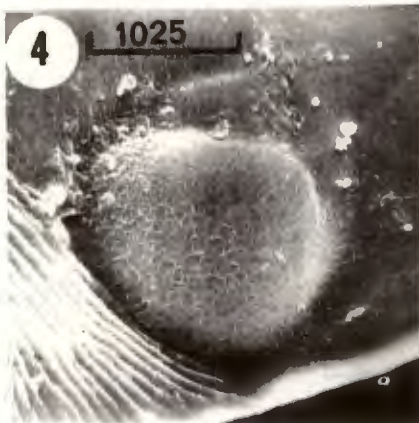
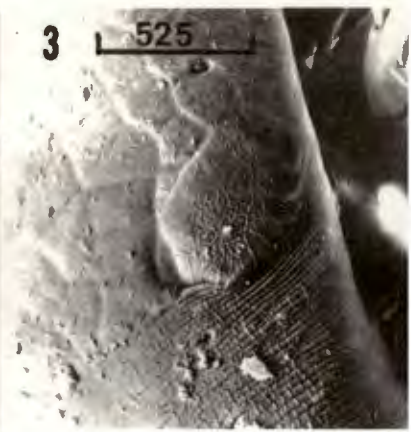
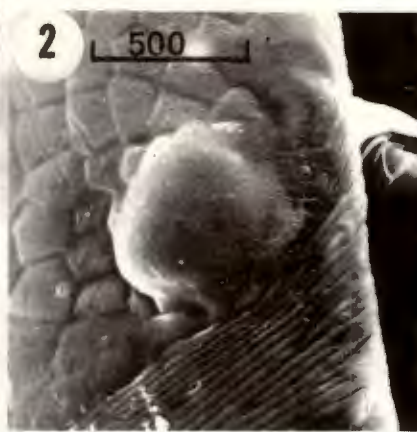
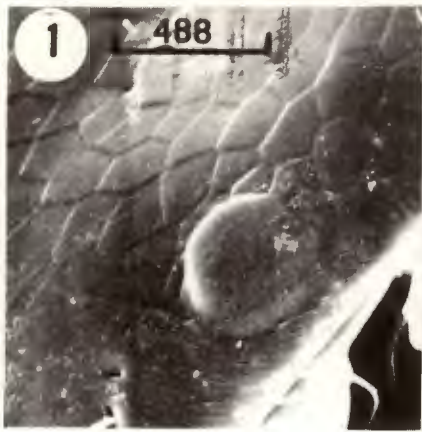


PLATE XV⁺

Eyes of larvae:-

1. *Rhipicephalus pravus*;
2. *R. oculatus*;
3. *R. appendiculatus*;
4. *Boophilus decoloratus*;
5. *B. microplus*;

Eyes of nymphae:-

6. *R. pravus*;
7. *R. oculatus*;
8. *R. appendiculatus*;
9. *B. decoloratus*;
10. *B. microplus*;

Eyes of males:-

11. *R. pravus*;
12. *R. oculatus*

+ Scale lines in μm .

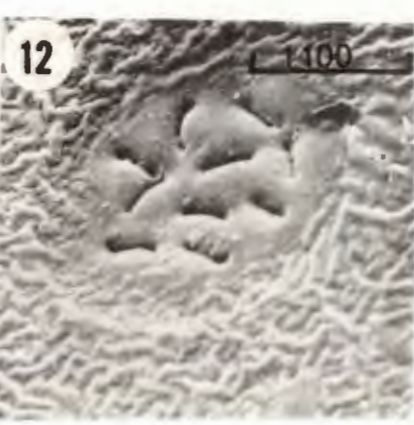
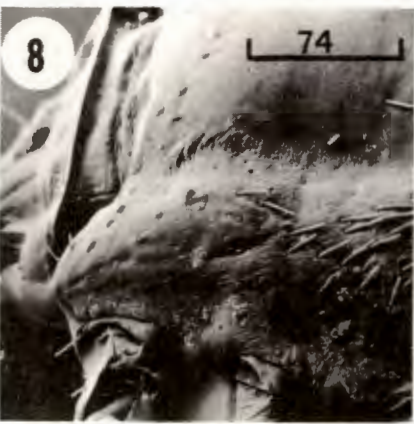
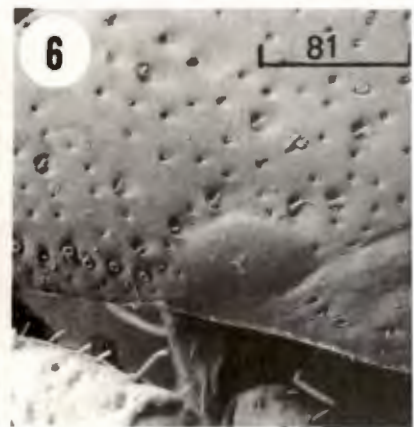
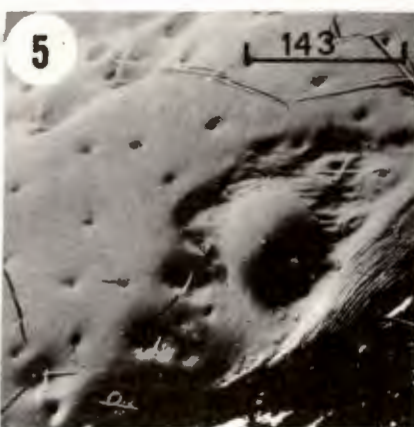
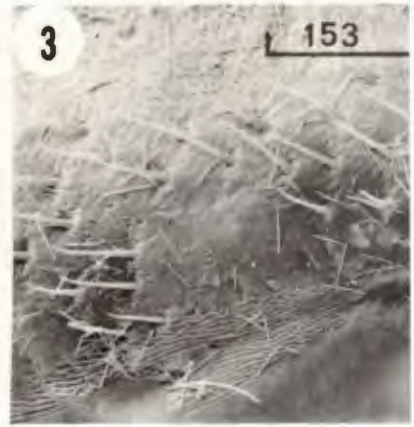
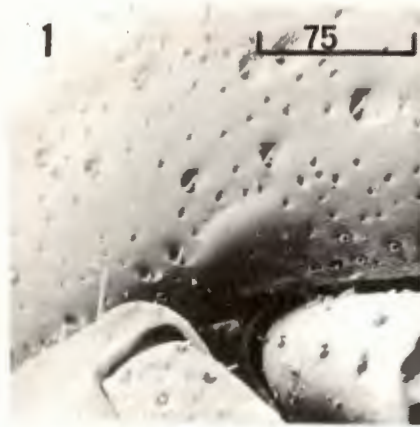


PLATE XVI

PLATE XVI⁺

1. *Rhipicephalus appendiculatus*;
2. *Boophilus decoloratus*;
3. *B. microplus*;

Eyes of females:-

4. *R. pravus*;
5. *R. oculatus*;
6. *R. appendiculatus*;
7. *B. decoloratus*
8. *B. microplis*;

Pit-like structures behind eyes of:-

9. *R. appendiculatus* female

Unknown structure:-

10. *R. oculatus* nymph;
11. *B. decoloratus* nymph;
12. *R. pravus* male.

+ Scale lines in μm .

the eyes are slightly prominent, but usually they are almost flat. Their comparative size are of some importance and, to a lesser extent, their colour. (Warburton, 1912.)

LARVAE

Rhipicephalus pravus (Plate XV, 1.)

Eyes prominent elevations oval in shape. Mesially they slope sharply and laterally more gradually.

Rhipicephalus oculatus (Plate XV, 2.)

Eyes very prominent, circular in shape and hemispherical bead-like. It is not encircled by a groove as the name suggests, but mesially and anteriorly is surrounded by a depression that does not however continue to the lateral and posterior sides of the eye. Eyes slope gradually postero-laterally and markedly antero-mesially.

Rhipicephalus appendiculatus (Plate XV, 3.)

Eyes lesser prominent as in *pravus* or *oculatus*. More or less circular in shape and flattened dorsally. It slopes gradually antero-laterally and more sharply mesially. Eyes bulging beyond the posterior edge of the scutum.

Boophilus decoloratus (Plate XV, 4.)

Eyes more or less circular and well-defined, but not bulging beyond the margin of the scutum as Arthur & Londt (1973) and Gothe (1967) suggested. The eyes are not entirely surrounded by a well-defined orbit. The anterior region is surrounded by a very shallow depression, which is in some cases not continued around the eye in a orbit.

Boophilus microplus (Plate XV, 5.)

Eyes oval, almost flattened, bulging posteriorly beyond the margin of the scutum. The eyes appear only as a slight elevation of the scutum. Surface smooth.

NYMPHAE

Rhipicephalus pravus (Plate XV, 6.)

Eyes elongate-oval in shape, edged anteriorly and mesially by a reticulate strip. Four setae occur in a latero-posterior row anterior to the eyes. Surface smooth.

Rhipicephalus oculatus (Plate XV, 7.)

Eyes circular in shape, limited mesially by a deep furrow which becomes shallower. Antero-laterally and postero-laterally. Reticulations occur in this furrow. Eyes more strongly curved mesially and meso-posteriorly than laterally and antero-laterally. Two setae occur in a latero-posterior row anterior to the eyes. Surface smooth.

Rhipicephalus appendiculatus (Plate XV, 8.)

Eyes oval in shape, limited mesially by a shallow groove. Reticulations not restricted to a special position. Eyes more strongly curved mesially. Two setae as in *oculatus*.

Boophilus decoloratus (Plate XV, 9.)

Eyes inconspicuous. Arthur & Londt (1973) stated that they are oval in shape, slightly bulging and protuberant over the scutal margin.

Boophilus microplus (Plate XV, 10.)

Eyes inconspicuous. According to Gothe (1967) the eyes are oval and bulge slightly beyond the margin of the scutum.

MALES

Rhipicephalus pravus (Plate XV, 11.)

Eyes usually rather convex oval in shape and set obliquely. Dorsally, the eyes are edged by confluent punctations which may coalesce to form grooves. Ventrally the eyes flush with the surface of the conscutum. In some specimens this "furrow" along the dorsal margin may give the eye the appearance of being orbited. Hoogstraal (1956) stated that the slightly convex eyes bordered by

at least a furrow and usually by a complete encircling groove, readily distinguishes *pravus* from other species. He stated further that in South Africa, the convexity of the eyes seems to be more variable and the encircling furrow is confined to the anterior margin of the eye. Hoogstraal (1966) mentioned that no Sudanese specimens without convex, mostly fully encircled eyes have been seen by him. Eyes situated between coxae II and III.

Rhipicephalus oculatus (Plate XV, 12.)

Eyes small and more convex than in *pravus*. Eyes circular in shape and oculated. In some cases the groove round the eyes is incomplete and ventrally they are flushed with the surface of the conscutum. In other specimens a shallow depression on the ventral side complete the encircling groove. The groove's surface punctate with moderate depressions. Eyes situated between coxae II and III.

Rhipicephalus appendiculatus (Plate XVI, 1.)

Eyes usually rather convex and not flat as stated by Walker (1970). Correspond with those of *pravus* except that they are not edged dorsally by punctations, in some cases through a depressed area does exist dorsally to the eyes, however, these depressions are not punctate. Eyes situated between coxae II and III.

Boophilus decoloratus (Plate XVI, 3.)

The eyes, small, flat to slightly elevated above the conscutum, situated on a level with the anterior margin of coxa II, not overlapping the conscutum margin. According to Arthur & Londt (1973) the eyes are large and circular. During this investigation the eyes were always found to be inconspicuous eyes.

Boophilus microplus (Plate XVI, 3.)

Eyes small, flat to very slightly elevated and inconspicuous, situated on a level with the anterior margin of coxa II. Eyes much more difficult to detect than in *decoloratus*.

FEMALES

Rhipicephalus pravus (Plate XVI, 4.)

Eyes conspicuous, convex and more oval than in the males with a groove represented by confluent punctations which partially bound the eye anteriorly and mesially. They are flushed laterally with the surface of the scutum and do not bulge beyond the scutal margin. Two setae occur mesial to the eyes.

Rhipicephalus oculatus (Plate XVI, 5.)

Eyes small, conspicuous and hemispherical. A groove, represented by confluent punctations, almost encircles each. Laterally this groove is either very shallow or incomplete; mesially it is expanded, forming a depressed triangular area which is provided with one to two setae. Anterior to the eyes three pairs of setae occur.

Rhipicephalus appendiculatus (Plate XVI, 6.)

Eyes large, not bulging beyond the scutal margin but raised above the scutal surface becoming flush together with the surface of the scutum laterally. Anteriorly to the eye a row of six to eight pit-like structures, with elevated borders occur. Two setae occur antero-laterally to the eyes and three mesially.

Boophilus decoloratus (Plate XVI, 7.)

Eyes large, oval shaped and raised above the scutal surface. Several setae present posteriorly and postero-mesially. The eyes are more conspicuous and much larger than in the males.

Boophilus microplus (Plate XVI, 8.)

Eyes smaller than in *decoloratus*, generally oval in shape and slightly raised above the scutal surface. According to Hoogstraal (1956) this character may be difficult to discern. They are bound mesially by four setae.

7.2.1.3 Alloscutum

According to Clifford & Anastos (1960), chaetotaxy is of taxonomic significance at both generic and specific levels. In this respect

they used setal distribution; positional relationships of the setae to certain body structures and to other setae; the number of setae on a particular structure; and the nature of these setae. Certain features that have no generic value could be useful at specific level. Analysis and comparison of body setae, gnathosomal setae, coxal setae and those of tarsus I were undertaken. Little is known about the specific functions of setae on the idiosoma of ticks, although these setae generally resemble the sensory setae on the palpi and certain setae on the legs. The structural similarities of these setae on the body and appendages are shown by Woolley (1972). Each of the short setae on both the scutum and alloscutum in hard ticks is known to rest in a socket over the terminal opening of a canal that penetrates the cuticle. The pattern of their distribution on the surface, particularly on the scutum, varies with the species, but the function appear to be similar and to range from tactile to chemosensory responses (Woolley, 1972.)

LARVAE

Rhipicephalus pravus (Plate VIII, 1.)

Dimensions:= Length: 0,208-0,240 mm; breadth: 0,323-0,359 mm.

Posterior margin divided into seven festoons. Eight pairs of marginal dorsal setae (Md1-8) are present. of which four pairs are anterior to the lateral dorsal sensillae sagittiformia (s), one pair just beneath sensillae and three pairs on the festoons. (Plate VIII, 1.) The middle or fourth festoon lacks setae. Two pairs of centro-dorsal setae (Cd1, 2) present. The inter-setal distance of the posterior pair greater than that of the anterior pair. (Plate VIII, 1.) Cd1 located on a level between Md1 and 2 and Cd2 located on a level between Md3 and Md4. Sensillae sagittiformia located just outside the festoons.

Rhipicephalus oculatus (Plate VIII, 2.)

Dimensions:= Length: 0,262-0,315 mm; breadth: 0,505-0,579 mm.

Posterior margin divided as in *pravus*. Eight pairs of marginal dorsal setae, whose positions resemble those of *pravus*. Chaeto=

taxy of centro-dorsal setae as in *pravus*.

Rhipicephalus appendiculatus (Plate VIII, 3.)

Dimensions:= Length: 0,242-0,273 mm; breadth: 0,345-0,392 mm.

Posterior margin divided into nine festoons. Chaetotaxy resembles that of *pravus*. Lateral dorsal sensillae sagittiformia located on the first festoons. (Plate VIII, 3.) Md5 on first festoon just beneath sensilla. Fifth festoon lacks any setae. (Plate VIII, 3.)

Boophilus decoloratus (Plate VIII, 4.)

Dimensions:= Length: 0,144-0,151 mm; breadth: 0,371-0,402 mm.

Posterior margin not divided into festoons. Eight pairs of marginal dorsal setae (Md1-8) of which Md1-2 are in one sub-marginal linear series. Md3-5 in another series and Md6-8 in a third series. Between Md5-6 there is one pair of dorso-lateral sensillae sagittiformia (s) present. (Plate VIII, 4.) Two pairs of centro-dorsal setae (Cd1,2) as in *Rhipicephalus* with the posterior pair longer and further apart anterior

Boophilus microplus (Plate VIII, 5.)

Dimensions:= Length: 0,179-0,219 mm; breadth: 0,363-0,413 mm.

Posterior margin not divided into festoons as in *decoloratus*. Eight pairs of marginal dorsal setae as in *decoloratus*. Arrangement into series as in *decoloratus* not so clear cut. Centro-dorsal setae resemble those of *decoloratus*.

NYMPHAE

Rhipicephalus pravus (Plate VIX, 5.)

Dimensions:= Length: 0,371-0,423 mm; breadth: 0,489-0,540 mm.

An abundance of moderately deep pits occur from some of which setae arise. Posterior border divided by grooves into nine festoons. The postero-median and postero-lateral grooves narrow and about equal in length with the postero-median groove a little longer, reaching about two-thirds the length of the alloscutum

anteriorly. Postero-median groove terminate posterior just in front of the central festoon, while the postero-lateral grooves terminate just in front of the separation between the second and third festoon. Marginal grooves deep, narrow, extending posteriorly from the postero-lateral margins of the scutum, to the festoons. The marginal grooves are relatively closely located to the lateral borders of the alloscutum.

Chaetotaxy: Marginal dorsal setae arrange with eleven pairs of setae anterior to the festoons, between the marginal groove and the lateral boarder of the alloscutum; one pair of setae on festoons 1-3, with only one pair on the fourth festoon, while the central festoon lacks any setae. Five pairs of centro-dorsal setae occur between the postero-lateral and postero-median grooves. Six pairs of centro-sub-dorsal setae between the postero-lateral and marginal grooves. Surface scattered with moderate punctations.

Rhipicephalus oculatus (Plate VIX, 6.)

Dimensions:= Length, 0,377-0,478 mm; breadth: 0,472-0,603 mm.

Grooves, festoons and chaetotaxy resembles that of *pravus*.

Rhipicephalus appendiculatus (Plate X, 1.)

Dimensions:= Length: 0,486-0,556 mm; breadth: 0,636-0,696 mm.

Postero-median and postero-lateral grooves resemble that of *pravus*, except that it reach about two-thirds the length of the alloscutum anteriorly. Marginal grooves as in *pravus*, except that it include the first of the eleven festoons.

Chaetotaxy: Marginal dorsal setae arrange with twelve pairs of setae which occur anterior to the festoons, between the marginal groove and the lateral boarder of the alloscutum; one pair of setae on festoons 1-4, with only one pair on the fifth festoon, while the central festoon lacks any setae. Six pairs of centro-dorsal and six pairs of centro-sub-dorsal setae, located as in *pravus*. Surface scattered with moderate punctations.

Boophilus decoloratus (Plate X, 2.)

Dimensions:= Length: 0,495-0,553 mm; breadth: 0,663-0,668 mm.

Surface with a few, small deep punctations. Two vague longitudinal depressions occur, which stretched over the whole length of the alloscutum.

Chaetotaxy: Two pairs of centro-dorsal setae as in the positions of the larval Cd1&2. The marginal dorsal setae consist out of about 30 setae on the posterior, antero-lateral and lateral margins. It was impossible to detect the centro-sub-dorsal series.

Boophilus microplus (Plate X, 4.)

Dimensions:= Length: 0,489-0,570 mm; breadth: 0,580-0,600 mm.

Surface provided with a few, small deep punctations. Two vague depressions occur, which stretched over the whole length of the alloscutum.

Chaetotaxy: Two pairs of centro-dorsal setae as in *decoloratus*. The marginal dorsal setae consist out of about 40 setae on the posterior, antero-lateral and lateral margins of the alloscutum. It was impossible to detect the centro-sub-dorsal series as in *decoloratus*.

FEMALES

Rhipicephalus pravus (Plate XII, 6.)

Dimensions:= Length: 1,266-1,765 mm; maximum breadth: 1,531-1,781 mm.

Length to breadth ratio about 0,912. Eleven well-developed festoons which are variable in shape. Marginal grooves well-developed and broadly arcuate, converging posteriorly. A marginal groove extends posteriorly from the eyes and includes two festoons. Postero-median and postero-lateral grooves straight and about equal in length, occupying about two-thirds the length of the alloscutum. The postero-lateral groove continuous with the posterior margin between the third and fourth festoons. Postero-median groove terminates in front of the central festoon and sometimes borders it. Another furrow-like depression occurs anterolaterally with its origin adjacent to the origin of the marginal groove, extending almost to the anterior ends of the postero-late=

ral grooves. Alloscutum provide with relative large punctations.

Rhipicephalus oculatus (Plate XIII, 1.)

Dimensions:= Length: 1,289-1,597 mm; breadth: 1,620-1,956 mm.

Length to breadth ratio about 0,741. Resembles that of *pravus*, except that the postero-lateral grooves broadly arcuate, and provided with fewer punctations as in *pravus*.

Rhipicephalus appendiculatus (Plate XIII, 2.)

Dimensions:= Length: 1,254-1,548 mm; maximum breadth: 1,455-1,859 mm.

Length to breadth ratio about 0,774. Resembles that of *pravus*, but fewer punctations occur.

Boophilus decoloratus (Plate XIII, 3.)

Dimensions:= Length: 1,146-1,234 mm; maximum breadth: 1,180-1,540 mm.

Ratio between the length and the breadth about 0,825. Festoons absent. Idiosoma finely striated and provided with small punctations. Numerous setae present, scattered all over the surface. Postero-lateral grooves long, originate postero-laterally from the scutum. The latter is convergent at first, but just posterior to the scutum it become straight, extending backwards and reaching the posterior margin. Postero-median groove about half the length of the postero-lateral grooves and straight. Lateral walls of alloscutum sinuous. Marginal grooves are lacking.

Boophilus microplus (Plate XIII, 4.)

Dimensions:= Length: 1,094-1,289 mm; maximum breadth: 1,191-1,438 mm.

Ratio between the length and the breadth about 0,855. Festoons absent. Idiosoma finely striated with small, shallow punctations. Surface much more covered with setae than in *decoloratus*. Postero-lateral and postero-median grooves as in *decoloratus*.

7.2.1.4 Unknown alloscutal structure

A pair of circular structures occur a short distance from the posterior margin of the scutum in the nymphae and females; about mid-length of the conscutum in the males. Traces of these structures also occur in the larvae. These structures have not been described before and their function is unknown. Possibly they are gland openings. Slit-shaped apertures occur on them.

NYMPHAE

Rhipicephalus (Plate XVI, 10.)

No structural differences occur between the representatives of *pravus*, *oculatus* and *appendiculatus*. In all the specimens studied three slit-shaped apertures occur. (Plate, XVI, 10.)

Boophilus (Plate XVI, 11.)

Three to four slit-shaped apertures occurs in both *microplus* and *decoloratus*. No structural differences possibly occur.

ADULTS

Rhipicephalus (Plate XVI, 12.)

No structural differences could be seen between the three studied species, belonging to the genus *Rhipicephalus*. The number of apertures varies from 7-14 and is not constant in any of the species studied.

Boophilus

It seems that this species studied in this genus lack in the adult stages these structures, or they are virtually impossible to detect.

7.2.2 Ventral aspect

LARVAE

Rhipicephalus pravus (Plate VIII, 6.)

Oblique depressions present posterior to coxae insertions. These

extend postero-laterally and unite with a lateral depression lying dorsal to the coxae.

The collar is elevated and sharply rounded posteriorly. (Plate VIII, 6.) Three pairs of sternal setae are situated on the inter-coxal region. The opisthogaster bears two pairs of pre-anal, four pairs of pre-marginal and five pairs of marginal setae. First pair of sternal setae (St1) situated on level with the first intercoxal space; the second pair (St2) just anterior to second inter-coxal space and the third pair (St3) on level with coxa III. The inter-setal distance between St3 about twice that of St2 and St2 a little greater than that of St1. (Plate VIII, 6) Two pairs of pre-anal setae (Pa1,2). (Plate VIII, 6.) Intersetal distance between anterior pair of pre-anal setae greater than that between posterior pair. (Plate VIII, 6.) Pre-marginal setae (Pm1-4) arranged in two groups, the first two pairs (Pm1 & 2) situated in line with the pre-anal setae, just posterior to the sensilla sagittiformia III after coxa III. The posterior two pairs (Pm3 & 4) located postero-laterally of anus and almost in line with third and fourth ventral marginal seta. Of the five pairs of ventral marginal setae (Vm1-5), Vm1 and 2 not enclosed in the festoons. Fourth festoon lacks setae. Opistogastric cuticle with fine folds in a widely extended W-shape transversely across the posterior region with the two legs of the W in longitudinal depressions running alongside the anus. Between coxae I-III these folds extend more or less longitudinally forming an angle of 90° and connect with the folds on the other half of the body. At the positions of the inter-coxal spaces these folds follow a transverse direction.

Rhipicephalus oculatus (Plate XIX, 1.)

The idiosoma ventrally corresponds with *pravus* regarding its chaetotaxy, depressions and cuticular folds. Collar (c) broadly rounded. (Plate XIX, 1.)

Rhipicephalus appendiculatus (Plate XIX, 2.)

Depressions lateral to the anus not so prominent as in *pravus*. Collar sharply rounded. (Plate XIX, 2.) Ventral chaetotaxy

similar to that of *pravus* except that the intersetal distance between first pair of sternal setae about equal to the second, whereas the third pair is about twice as far apart. Intersetal distance of second pair of pre-anal setae slightly exceeds that of the first pair. The pre-anal setae on level with the first two pairs of pre-marginal setae. The third and fourth pre-marginal setae respectively on level with the second and third marginal ventral setae. Four pairs of marginal ventral setae on the festoons yM1 just outside the first festoon. Fifth festoon lacks setae. Cuticular folds as in *pravus*.

Boophilus decoloratus (Plate VIX, 3.)

Two mid-ventral longitudinal depressions parallel to the anus as in *R. pravus*, but in this case they are more prominent. The same is the case with the transverse W-shaped depression on the opisthogaster. Cuticular folds as in *R. pravus* as well as the depressions at the coxae. (Plate VIX, 3.) Collar (c) broadly rounded posteriorly but relatively narrow. Three pairs of sternal setae, four pairs of pre-marginal setae and five pairs of marginal ventral setae. Second pair of sternal setae on a level with second inter-coxal space while the third pair is situated posterior to third pair of coxae. Chaetotaxy ventrally as in *R. pravus* except that the intersetal distances between the pre-anal setae is greater than in *R. pravus*. (Plate VIX, 3.) Five pairs of ventral marginal setae (Vm1-5) with Vm1 just posteriorly to the lateral depression and slightly behind level of Pm2, thence the successive setae Vm2-5 more marginally located. (Plate VIX, 3.)

Boophilus microplus (Plate VIX, 4.)

Depression, folds and chaetotaxy as in *decoloratus* except that the first pair of sternal setae (St1) are situated just anterior to the first intercoxal space, St2 on level with intercoxal space II and St3 on level with the spur of coxa III. The collar is slender. (Plate VIX, 4.)

NYMPHAE

Rhipicephalus pravus (Olate X, 5.)

Fewer pits and setae occur on the idiosoma ventrally than dorsally. A deep groove is present each side dorsal to the coxae and extending back to the spiracular plate; these grooves are comparable with those seen in the larvae. Posterior margin divided by grooves into nine festoons of which the most anterior festoon partially hidden beneath the posterior edge of the spiracular plate. Genital grooves deep, narrow and originating just behind the third pair of coxae, extending back to and almost reaching the posterior margin near the short transverse groove adjacent to the second and third festoons. Genital grooves widely "S"-shaped. Some variation in the number of setae present and their positions but typical a specific pattern is discernable. Sternal setae arranged as follows: one pair just posterior to coxae I; two pairs on a level with the posterior edge of coxa II; two pairs on a level with coxae III and one pair on a level with coxae IV. Distances between these pairs of sternal groups I-IV decreasing progressively. Four pairs of pre-anal setae, of which three pairs occur between the genital grooves anterior to the anus and one pair just outside the grooves on a level of the intersetal space between Pa1-2. Seven to eight pairs of pre-marginal setae of which Pm1 is about on a level with Pa1 and Pm2 on a level with Pa2. Pm3 just lateral to the anus while Pm4 & 5 are situated postero-laterally to the anus. Pm6 and Pm7 posterior to the anus. Eight pairs of ventral marginal setae with one pair on each festoon, except the middle one. Usually five pairs of circumspiracular setae.

Rhipicephalus oculatus (Plate X, 6.)

Ventrally it usually correspond with *pravus*, though in some cases there are variations in the number of setae present. Eight pairs of pre-marginal setae and three pairs of circumspiracular setae occur. Ventral marginal setae as in *pravus*.

Rhipicephalus appendiculatus (Plate X, 7.)

Ventrally it corresponds with *pravus*, except that the posterior

margin is divided into eleven festoons. Sternal, pre-anal and pre-marginal setae as in *pravus*. Ten pairs of marginal ventral setae and three pairs of circumspiracular setae present.

Boophilus decoloratus (Plate X, 3.)

Surface with widely dispersed shallow pits. Supra-coxal groove absent. Genital grooves vague and shallow, extending from the level of the first intercoxal space almost to the posterior margin. Some variation in the numbers of setae but following a broad pattern of setal distribution as indicated in Plate X, 3. Sternal setae (St) arranged as follows: one pair at the level of the first intercoxal space (St1); one pair at the level of the second intercoxal space (St2); one pair at the level of the third coxae (St3) and one pair at the level of the fourth coxae (St4). One pair of pre-anal setae present just postero-mesial to St4 followed by a more widely spaced pair (Pa2). The latter are succeeded by two groups of lateral anal setae, one present antero-laterally and one postero-laterally. A group of 3-5 pairs of pre-marginal seta (Pm) present between the spiracles and the pre-anal setae, lateral to the genital grooves. Another two pairs present postero-lateral to the anus. Five pairs of marginal ventral setae (VM) present as in the larvae. Circumspiracular setae (Cs) variable in number.

Boophilus microplus (Plate XI, 1.)

Surface and genital grooves as in *decoloratus*. Some variation in the numbers of setae but following a broad pattern of setal distribution as in Plate XI, 1. Sternal setae arranged on level with the coxae. Two pairs of pre-anal setae (Pa) present; Pa1 more widely separated than Pa2. One pair of lateral-anal setae (1 a) present antero-laterally to the anus. Four pairs of pre-marginal setae (Pm) with Pm3 & 4 in the same position as either Pm4 & 5 or Pm6 & 7 of *decoloratus*. Ten to fourteen circumspiracular setae occur.

MALES

Rhipicephalus pravus (Plate XII, 1.)

Oblique depressions present posterior to coxa- insertions. These extend postero-laterally and unite with a lateral depression dorsal to the coxae. Variable numbers of setae distributed all over the venter except on the intercoxal spaces, the spiracles and genital aperture. Eleven well developed festoons which is at intervals short, broad and with the outer festoon smaller than the rest and irregular in shape. A tail-like caudal appendage with a terminal disc present, on the central festoon.

Rhipicephalus oculatus (Plate XII, 2.)

Oblique depressions as in *pravus*. Setae distributed as in *pravus*, variable in numbers. Festoons as in *pravus*. The caudal appendage ends in a small chitinous plate and originates from the central festoon.

Rhipicephalus appendiculatus (Plate XII, 3.)

A caudal appendage sometimes present. Festoons well-developed, unequal in size. Oblique depressions as in *pravus*. Setae distributed as in *pravus*, variable in numbers.

Boophilus decoloratus (Plate XII, 4.)

Males are easily determined by the presence of a small tail-like caudal appendage, which varies considerably in size, on the posterior body margin and by a narrow spur-like elongation at the internal margin of the adanal shield. Setae of moderate length distributed over ventral surface but absent from intercoxal regions.

Boophilus microplus (Plate XII, 5.)

In some cases a short tapering caudal appendage is present and more or less conical in shape. Occasionally this is reduced to a mild, broadly rounded protuberance. The interno-posterior juncture of the adanal shields does not extend beyond the posterior body margin as in *decoloratus*.

FEMALES

Rhipicephalus pravus (Plate XIII, 5.)

Depressions at the coxae as in the males. Lateral groove present. Setae distributed all over the venter except on the intercoxal spaces, and genital aperture. Setae much smaller than in the males except those anterior to the genitalia. Festoons as in the males.

Rhipicephalus oculatus (Plate XIII, 6.)

Depressions at the coxae and setal distribution as in *pravus* with the setae much smaller than in the males except those anterior to the genitalia.

Rhipicephalus appendiculatus (Plate XIV, 1.)

Depressions at the coxae and setal distribution as in *pravus* with the setae much smaller than in the males except those anterior to the genital aperture.

Boophilus decoloratus (Plate XIV, 2.)

Setae absent from intercoxal region and the genital aperture. Setae of moderate length as in the males.

Boophilus microplus (Plate XIV, 3.)

Setal distribution and depressions at the coxae as in the males, but the setae are much smaller except those anterior to the genital aperture.

7.2.2.1 Genital aperture

The genital apron is a lightly sclerotised flap originating in front of and covering the genital opening. The genital grooves start at the genital orifice, pass backwards, mesial of the coxae and then externally to the anal grooves towards the posterior margin of the body. Adler & Feldman-Muhsam (1948) reported that the genital aperture of female ticks provides a valuable taxonomic feature for identification of ticks of the genus *Hyalomma*. Subsequently, this characteristic has been utilized by several workers for diagnosing species of other ixodid genera.

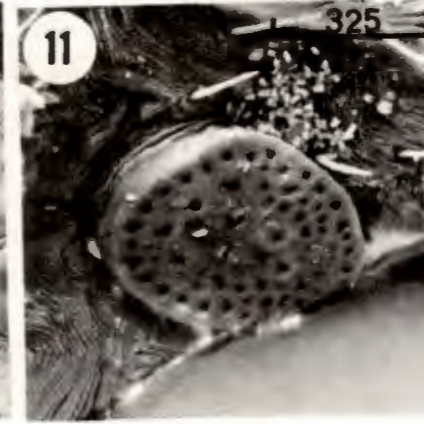
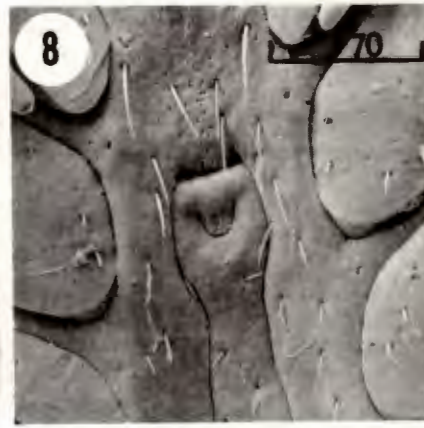
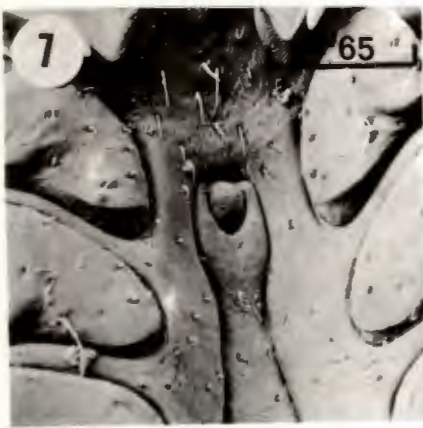


PLATE XVII

PLATE XVII⁺

Genital of males:-

1. *Rhipicephalus pravus*;
2. *R. oculatus*;
3. *R. appendiculatus*;
4. *Boophilus decoloratus*;
5. *B. microplus*;

Genital of females:-

6. *R. pravus*;
7. *R. oculatus*;
8. *R. appendiculatus*;
9. *B. decoloratus*;
10. *B. microplus*

Spiracles of nymphae:-

11. *R. oculatus*;
12. *R. pravus*.

+ Scale lines in μm .

MALES

Rhipicephalus pravus (Plates XII, 1 & XVII, 1. Fig. 8 I,1.)

Genital aperture between coxae II in a mid-ventrally depressed area. (Plate XII, 1.) Genital aperture covered by an apron which is broadly rounded anteriorly and with slightly converging straight to slightly concave lateral margin. (Plate XVII, 1.) The posterior margin more narrowly rounded than the anterior margin and finely serrated. Very fine longitudinal ridges on the posterior two-thirds of the apron, otherwise surface smooth. Shape of genitalium as in fig. 8 I,1. Genital grooves present, passing backwards, mesial of the coxae and then external to the anus towards the posterior margin cuticle. (Plate XII, 1.) Surface between the grooves smooth just posterior to the genital aperture, otherwise finely folded. Cuticle in front of the genital aperture folded longitudinally and antero-mesially folded laterally to the aperture. Anterior to the aperture a complex of 11-12 setae and two pairs lateral to the aperture.

Rhipicephalus oculatus (Plates XII, 2 & XVII, 2. Fig. 8, I,1)

Genital aperture between coxae II. (Plate XII, 2.) Resembles that of *pravus* (fig. 8. I,1) except that there are only about ten setae in the anterior complex. Two setae laterally to the aperture. (Plate XVII, 2.)

Rhipicephalus appendiculatus (Plates XII, 3 & XVII, 3. Fig. 8. I, 2.)

Position as in *pravus*. (Plate XII, 3.) Structure resembles that of *pravus* (fig. 8. I, 2) except that the posterior border is more pointed. (Plate XVII, 3.) A complex of about 14 setae anteriorly to the aperture and two laterally.

Boophilus decoloratus (Plates XII, 4 & XVII, 4. Fig. 8. I, 3.)

Between coxae II. (Plate XII, 4.) Anteriorly the aperture bordered by a narrow ridge. (Plate XVII, 4.) Posterior margin of apron pointed and more clearly serrated than in *pravus*. Shape of genitalium as in fig. 8. I, 3. Surface smooth and not ridged longitudinally. A complex of about 16 setae anteriorly and six

setae laterally.

Boophilus microplus (Plates XII, 5 & XVII, 5. Fig. 8. I, 4.)

Situated on level with second intercoxal space and anterior coxal level. (Plate XII, 5.) Bordered anteriorly by a broad ridge (Plate XVII, 5.) Lateral margins of apron angled and posterior margin pointed. Markedly serrate posteriorly. Shape of genitalium as in fig. 8. I, 4. Surface of apron smooth. An anterior complex of about 16-22 setae and five lateral setae.

FEMALES

Rhipicephalus pravus (Plates XIII, 5 & XVII, 6. Fig. 8. I,1.)

Genital aperture situated between coxae II. (Plate XIII, 5.) The genital apparatus is oval in shape with a "U"-shaped slit-like aperture. (Fig. 8.I,1.) The apron is convex and faintly ridged longitudinally. The posterior part behind the apron is "Y"-shaped and embraces the apron posteriorly and laterally. (Plate XVII, 6.) The latter is humped and becomes slightly depressed towards the slit-like aperture, more strongly depressed laterally and moderately depressed posteriorly. The genital grooves embrace the genital complex and become slightly convergent for a short distance just posterior to the genital aperture, then became slightly divergent as they extend backwards mesial from the coxae. (Plate XIII, 5.) Postero-lateral to the anus the grooves become more strongly divergent and extend almost to the inter-festoon margin of the second and third festoon. Cuticular surface in front of the genital complex longitudinally striated. Anterior to the genital plate a complex of 13-15 setae is present plus two pairs lateral to it. (Plate VIII, 6.)

Rhipicephalus oculatus (Plates XIII, 6 & XVII, 7. Fig. 8. J1.)

Resembles that of *pravus* (fig. 8, J1.) but is situated slightly more posteriorly. (Plate XIII, 6.) Anterior to the genital complex 12-14 setae occur plus one to two pairs lateral to it. (Plate XVII, 7.)

Rhipicephalus appendiculatus (Plates XIV, 1 & XVII, 8. Fig. 8. J2)

Resembles that of *pravus* (Fig. 8. J2, Plate XIV, 1.) except that the apron is somewhat smaller. (Plate XVII, 8.) Anterior to the genital complex 9-10 setae occur plus three pairs lateral to it.

Boophilus decoloratus (Plates XIV, 2 & XVII, 9. Fig. 8. J3.)

Genital aperture situated on intercoxal space in line with the posterior margins of coxae II. (Plate XIV, 2.) Genital complex differs markedly from those of the rhipicephalids. The apron is almost "V"-shaped and more narrowly rounded posteriorly. (Plate XVII, 9.) The area surrounding the apron is not elevated as it is in the rhipicephalids and is not delimited by well-defined genital grooves. Shape as in fig. 8. J3. Apron and the body wall in front of it longitudinally ridged. Genital grooves faintly marked, corresponding in shape with those of *pravus*. (Plate XVII, 9.) A complex of about 30 setae anterior and antero-lateral to the genital complex.

Boophilus microplus (Plates XIV, 3 & XVII, 10. Fig. 8. J4.)

Differs considerably from that of *decoloratus*. Genital aperture situated between coxae II. (Plate XIV, 3.) Shape as in fig. 8. J4. Its apron is "V"-shaped and embraced anteriorly by an elevated crescentic fold which extends back on either side of the genital aperture. (Plate XVII, 10.) This anterior fold embraces another slightly raised area posterior to the genital aperture. Genital grooves more faintly developed than in *decoloratus*. (Plate XIV, 3.) A complex of about 26 setae anterior and antero-laterally to the genital complex.

7.2.2.2 Spiracles

Nuttall et al. (1908) cited Batelli (1891) as the first person to describe in detail the spiracle of a tick (*Ixodes hexagonus*) in which the surface showed a hexagonal meshwork supporting a thin covering, and within each hexagonal area an external central pore. These pores, according to Batelli (1891) connected the spaces beneath the plate with the ambient air. Nuttall et al.

(1908) commented that little attention had been devoted to the spiracular structure in the Ixodoidea. No complete description or published figures of the spiracle had until that time been available.

Previous studies of ixodid and argasid spiracles have led to considerable controversy over different interpretations of their structure and function. Nuttall et al. (1908), Robinson & Davidson (1913b) and Hinton (1967) observed pores in the spiracular plate, but Arthur (1956b) failed to see them. According to Nuttall et al. (1908), Mellanby (1935) and Browning (1954) the respiratory mechanism is functionally controlled by the opening and closing of the spiracular ostia, or by muscular movement of the atrial walls. (Arthur 1956b) Hinton (1967), however, considered that the pores of the spiracular plate in *Boophilus microplus* Canestrini and *Ixodes hexagonus* Leach. are functional openings for gaseous exchange and that the ostium is a non-functional, collapsed ecdysial tube formed during the nymphal-adult moult. According to Roshdy & Hefnawy (1973), Hefnawy (1970) found from experimental studies on the spiracles of *Hyalomma dromedarii* Koch. and *Ornithodoros savignyi* Audouin, that the spiracles possibly exercise physiological control of water loss. According to Roshdy & Hefnawy (1973) the statement by Hinton (1967), that the "so-called" ostium is a non-functional, closed ecdysial tube, is incorrect. These authors consider that the ecdysial scar is most probably an artifact resulting from damage to the ostial lip during preparation of the specimen. The results of their experiments with CO₂ and cyanide gas exposure, provide evidence that there is a functional controlling of the spiracle. However, their results contradict the view that the pores on the plate (Hinton's aeropyles) are functional openings for gaseous exchange. They stated that if these pores communicated directly with the atrium, diffusion of cyanide gas through them would have caused the immediate death of the tick. They suggested that the sensilla-like structures at the goblet bases may be sensitive to CO₂ and other gases in the surrounding atmosphere. Response to such stimuli may regulate spiracular opening

and closing. Woolley (1972) determined further details of the respiratory features and suggested a different explanation of the structures to the one that was previously understood. He further stated that the peculiar architecture of the spiracular plate is important in classification. The size and shape of the spiracle, though by means invariable, will often be found useful in diagnosing species. The shape differs with the sex, that of the male of the rhipicephalids, mostly being more elongate and comma-shaped. In some specimens the spiracle of the male only narrows slightly towards its termination, while in others the tail of the comma is well-marked.

NYMPHAE

Rhipicephalus pravus (Plate XVII, 11.)

Dimensions:= Length: 0,102-0,129 mm; breadth: 0,076-0,099 mm.

Oval in shape. Length to breadth ratio about 1,290. Slightly elevated above the body surface, especially anteriorly. About 100-130 apertures present which vary in size. Large apertures occur on the periphery, succeeded by two to three rows of small to moderate apertures and finally medium sized apertures in the centre. The central apertures slightly elevated above the spiracular surface. The spiracles are provided with about 99-131 apertures of which about equal numbers in the antero-dorsal (20-28), antero-ventral (22-33) and postero-ventral parts (25-30), but about one-ninth more apertures occur in the postero-dorsal part (32-40).

Rhipicephalus oculatus (Plate XVII, 12.)

Dimensions:= Length: 0,109-0,121 mm; breadth: 0,078-0,093 mm.

Length to breadth ratio about 1,270. Corresponding with that of *pravus* except that only about 60-90 apertures occur. About 9-16 apertures occur in the antero-dorsal part; about 10-17 in antero-ventral part; 19-27 in the postero-dorsal part and 22-32 in the postero-ventral part.

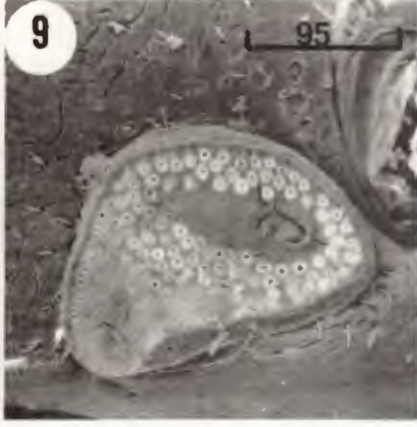
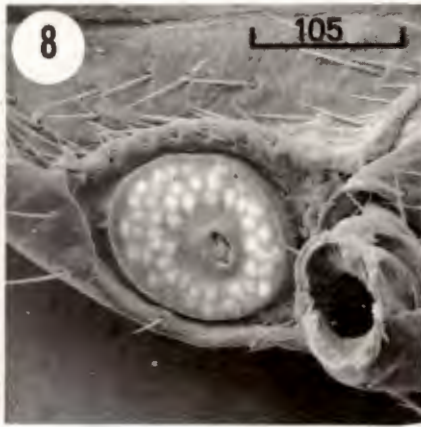
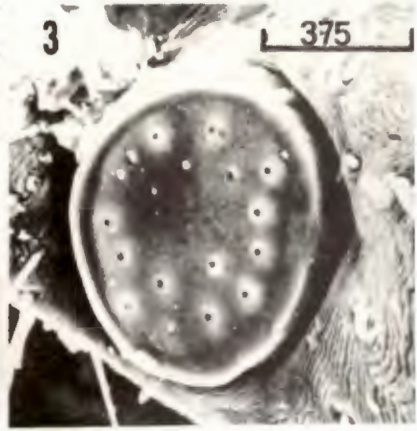
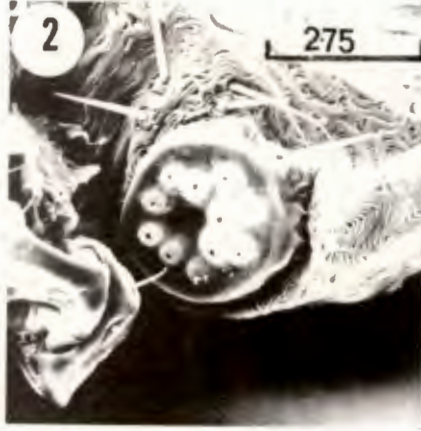


PLATE XVIII

PLATE XVIII⁺

Spiracles of nymphae:-

1. *Rhipicephalus appendiculatus*;
2. *Boophilus decoloratus*;
3. *B. microplus*;

Spiracles of males:-

4. *R. pravus*;
5. *R. oculatus*;
6. *R. appendiculatus*;
7. *B. decoloratus*;
8. *B. microplus*;

Spiracles of females:-

9. *R. pravus*;
10. *R. ovulatus*;
11. *R. appendiculatus*;
12. *B. decoloratus*.

+ Scale lines in μm .

Rhipicephalus appendiculatus (Plate XVIII, 1.)

Dimensions:= Length: 0,134-0,159 mm; breadth: 0,113-0,135 mm.

Length to breadth ratio about 1,170. Elongate oval in shape and provided with about 160-185 apertures. About 22-37 in the antero-dorsal part; about 34-41 in the antero-ventral part; 42-49 in the postero-dorsal part and 62-70 in the postero-ventral part.

Boophilus decoloratus (Plate XVIII, 2.)

Dimensions:= Length: 0,074-0,075; breadth: 0,074-0,080 mm.

Length to breadth ratio about 0,976. Circular in surface view more elevated above the body surface than in the rhipicephalids studied. Margins steep sided and not sunk into the cuticle. According to Arthur & Londt (1973) about twenty protuberances, each with apical aperture, occur. During this investigation 12-15 protuberances were found.

Boophilus microplus (Plate XVIII, 3.)

Dimensions:= Length: 0,0952-0,115 mm; breadth: 0,098-0,112 mm.

Length to breadth ratio about 0,985. Shape correspond with that of *oculatus*. Apertures 13-15.

MALES

Rhipicephalus pravus (Plate XVIII, 4. Fig. 7, H1.)

Dimensions:= Length: 0,459-0,555 mm; maximum breadth: 0,137-0,193 mm.

Ratio between the length and maximum breadth about 3,137. Spiracles are comma-shaped with the broader end bearing the elevated macula and the narrower end directed dorsally. (Plate XVIII, 4.) Peripheral walls vertical anteriorly and with a steep face postero-dorsally. Shape as in fig. 7, H1. About 350-400 small apertures on the narrow posterior part and 40-70 larger, slightly elevated apertures on the broader anterior part round the macula. Apertures also occur on the steep face of the postero-dorsal

edge.

Rhipicephalus oculatus (Plate XVIII, 5. Fig. 7. H1.)

Dimensions:= Length: 0,433-0,542 mm; maximum breadth: 0,136-0,173 mm.

Ratio between the length and maximum breadth about 3,318. Spiraculums as in *pravus*, fig. 7, H1, except that they have fewer apertures. (Plate XVIII, 5.) About 220-280 small apertures occur on the posterior part and 40-60 larger, elevated apertures on the anterior part. On the postero-dorsal steep face a few apertures occur.

Rhipicephalus appendiculatus (Plate XVIII, 6. Fig. 7, H2.)

Dimensions:= Length: 0,784-0,811 mm; maximum breadth: 0,241-0,311 mm.

Ratio between the length and maximum breadth about 2,928. Spiraculum comma-shaped but much larger than in *pravus* (fig. 7. H2.) Only 150-200 small apertures present on the narrow but more (120-200) elevated aperture present on the anterior part. (Plate XVIII, 6.)

Boophilus decoloratus (Plate XVIII, 7. Fig. 7. H3.)

Dimensions:= Length: 0,218-0,226 mm; maximum breadth: 0,163-0,188 mm.

Ratio between the length and maximum breadth about 1,235. Almost circular in surface view (fig. 7. H3.) peripheral walls vertical, not sunk into surrounding cuticle. (Plate XVIII, 7.) Macula elevated and situated more antero-dorsally in relation to the long axis of the body, surrounded by about 40-50 elevated apertures.

Boophilus microplus (Plate XVIII, 8. Fig. 7. H4.)

Dimensions:= Length: 0,173-1,889 mm; maximum breadth: 0,135-0,157 mm.

Ratio between the length and maximum breadth about 1,231. Nearly circular in shape, (fig. 7, H4) but not elevated above the cuticle to the same extent as in *decoloratus*. (Plate XVIII, 8.) Apertures vary in numbers from 8-40.

FEMALES

Rhipicephalus pravus (Plate XVIII, 9 & Fig. 8, K1.)

Dimensions: Length: 0,425-0,431 mm; maximum breadth: 0,278-0,313 mm.

Ratio between the length and maximum breadth about 1,484. Spiracles differ greatly from those of the males (fig. 8, K1). Spiracles broadly comma-shaped with the broadest part bearing the macula and the narrowest part directed dorsally. Peripheral walls vertical, bearing small openings. (Plate XVIII, 9.) The narrow pointed part bears small apertures and the broader part, large elevated apertures. No apertures occur directly around the macula. Macula staple-shaped with the inner part elevated.

Rhipicephalus oculatus (Plate XVIII, 10. Fig. 8, K1.)

Dimensions: Length: 0,356-0,376 mm; maximum breadth: 0,264-0,368 mm.

Ratio between the length and maximum breadth about 1,257. Resembles that of *pravus* (fig. 8, K1) except that it is narrower at the pointed postero-dorsal part.

Rhipicephalus appendiculatus (Plate XVIII, 11. Fig. 8, K2.)

Dimensions: Length: 0,551-0,613 mm; maximum breadth: 0,348-0,383 mm.

Ratio between the length and maximum breadth about 1,554. Resembles that of *pravus* (Fig. 8, K2) except that it is much larger and broader postero-dorsally. (Plate XVIII, 11.)

Boophilus decoloratus (Plate XVIII, 12. Fig. 8, K3.)

Dimensions: Length: 0,259-0,275 mm; maximum breadth: 0,242-0,260 mm.

Ratio between the length and maximum breadth about 1,058. Resembles that of the males (fig. 8, K3) except that the peripheral walls are steeply sloping, not vertical. (Plate XVIII, 12.) Almost circular in surface view with the macula almost centrally placed and surrounded by about 40-60 elevated apertures.

Boophilus microplus (Plate XIX, 1. Fig. 8, K4.)

Dimensions:= Length: 0,245-0,268 mm; maximum breadth: 0,203-0,279 mm.

Ratio between the length and maximum breadth about 1,033 . Sub-circular to broadly oval (fig. 8, K4) with the long axis directed dorso-ventrally. (Plate XIX, 1.) Macula almost centrally placed and surrounded by about 40-80 elevated apertures.

7.2.2.3 Integumentary sense organs

Dinnik & Zumpt (1949) stated that several authors in the past were mistaken in their interpretation of the sensillae sagittiformia as respiratory organs. According to the same authors Schulze (1942) published a detailed study of integumentary sense organs of adult ticks and found in addition to true sensory setae (sensilla trichoidea), four other types of sensilla which he called sensilla auriformia (ear-shaped organs), sensilla sagittiformia (arrow-shaped organs) and sensilla hastiformia (spear-shaped organs).

Large numbers of these organs are located within the hard and soft chitinized integument of the body. They are however, sparse on the legs and palps, and according to Dinnik & Zumpt (1949) entirely missing from the chelicerae. These authors stated that these sensillae are connected with two glandular cells which extend partially into a sensory duct and secrete a substance which emerges at the surface after passing an end organ. The authors assumed that the secretion serves as a protective coating against evaporation within the sensillum on the outer surface, and also as a chemical recognition between opposite sexes and individuals of species.

According to Dinnik & Zumpt (1949), the larvae lacked sensilla laterniformia and the other types of sensilla are more primitive in development. They stated that specific numbers of sensillae are distributed over the entire body in a definite pattern.

During this investigation attention was given to the sensillae sagittiformia on the dorso-lateral posterior margins and to those posterior or postero-lateral to the coxae. Another sensory structure on the antero-lateral edge of coxa II was studied during the present investigation.

LARVAE

Rhipicephalus pravus (Plate XIX, 5, 6.)

Three pairs of sensillae sagittiformia are present behind the coxae. The first pair is dorsal to the insertion of coxa I and mesial to its lateral insertion. (Plate XIX, 6.) The sensilla behind coxa II is just median to the lateral insertion and that behind coxa III about halfway along the length of the insertion. The sensilla posterior to coxa I is approximately circular in shape, that posterior to coxa II elongate and that posterior to coxa III consists of two sensillae, surrounded by a common wall. (Plate XIX, 8.) On the anterior distal angle of coxa II adjacent to seta C2 a coxal sense organ of unknown function is situated. It consists of a semicircular opening leading into a cavity from which a knob-like projection protrudes. (Plate XIX, 2.) Between Md4 and Md6 just above seta Md5 dorsally one pair of sensilla sagittiformia occurs. (Plate XIX, 5.) At magnifications of about 5 000x the sensillae appear to have two oblique valve-like plates as constituent parts. (Plate XIX, 5.)

Rhipicephalus oculatus (Plate XIX, 8.)

Structure and position as in *pravus*.

Rhipicephalus appendiculatus (Plate XIX, 2.)

Structure and position as in *pravus*. Sensilla behind coxa seem to be more elongate with a depression next to the sensilla.

Dorso-lateral caudal sensilla on first festoon just above setae Md5. Sensory structure on coxa II as in *pravus*. (Plate XIX, 2.)

Boophilus decoloratus (Plate XIX, 9.)

Three pairs of sensillae sagittiformia present on the venter; the first dorsal to insertion of coxa I, the second and third in line with postero-external angles of coxae II and III respectively. Coxal sense organ as in *R. pravus*. The structure of sensillae behind coxae III differs conspicuously from that of *R. pravus*. (Plate XIX, 9.) It consist of two sensillae, adjacent to each other and not surrounded by a common wall, but isolated from each other by another common wall. Between setae Md5 and Md6 are a pair of dorso-lateral sensillae sagittiformia corresponding to that of *R. pravus*.

Boophilus microplus

Structure and position as in *decoloratus*.

NYMPHAE

Rhipicephalus (Plate XIX, 3, 10, 11, 12 & XX, 1.)

The sensillae sagittiformia vary in number and distribution but the following are fairly constant: Six pairs on the opisthogaster of which two pairs occur mesially to the spiracles, one pair mesially to the posterior end of the genital grooves; one pair lateral to the post-anal median groove and two pairs on the festoons. One pair is present poster-medianly to coxae I, II and III, and a pair postero-laterally to coxa IV. (Plates XIX, 10, 11, 12 & XX, 1.) Medianly to the ventral lateral groove behind each coxa a pair of sensillae occur as in the case of the larvae behind coxa I.

The sensillae behind the coxae contain one, two or even more sensillae sagittiformia. In some cases a small knob-like structure also occurs. The sensillae mesial to the lateral groove, and posterior to the coxae contain about three sensillae sagittiformia which vary in diameter.

PLATE XIX

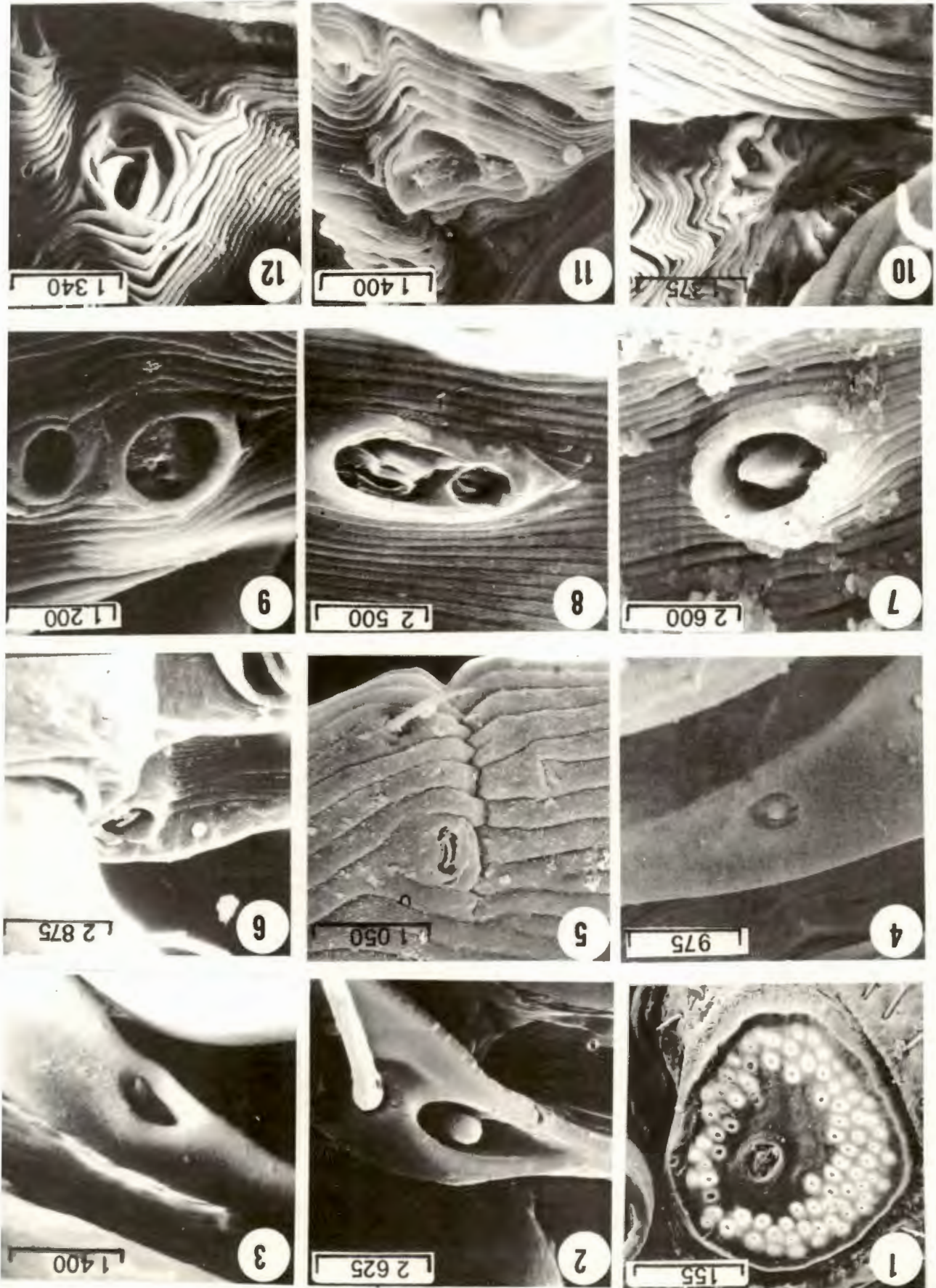


PLATE XIX⁺

Spiracle of female:-

1. *Boophilus microplus*;

Sensory structure on Coxa II.

2. *Rhipicephalus appendiculatus* larva;
3. *R. pravus* nymph;
4. *R. pravus* female;

Sensillae sagittiformia:-

5. *R. pravus* larva (dorsal on festoons);
6. *R. pravus* larva (behind coxa I);
7. *B. microplus* larva (behind coxa II);
8. *R. oculatus* larva (behind coxa III);
9. *B. decoloratus* larva (behind coxa III);
10. *R. appendiculatus* nymph (behind coxa I);
11. *R. oculatus* nymph (behind coxa II);
12. *R. pravus* nymph (behind coxa III).

+ Scale lines in μm .

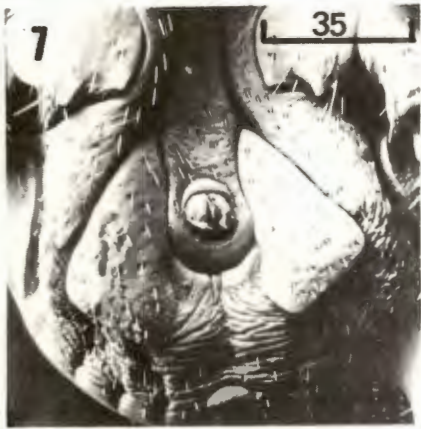
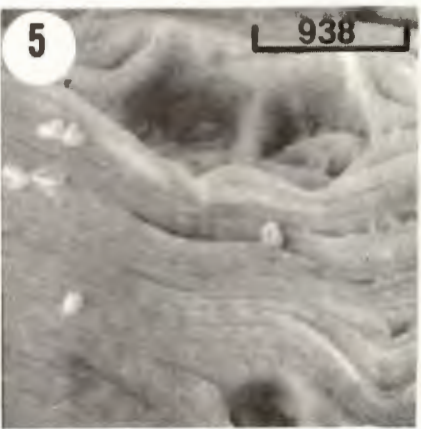


PLATE XX

PLATE XX⁺

Sensillae sagittiformia:-

1. *Rhipicephalus oculatus* nymph (behind coxa IV);
2. *R. pravus* male (behind coxa I);
3. *R. pravus* male (sensillae mesial to coxae);
4. *R. oculatus* female (behind coxa II);
5. *R. pravus* female (behind coxa III);
6. *R. pravus* female (behind coxa IV);

Anal plates of males:-

7. *R. pravus*;
8. *R. oculatus*;
9. *R. appendiculatus*;
10. *Boophilus decoloratus*;
11. *B. microplus*;

Anus of larva:-

12. *R. pravus*.

+ Scale lines in μm .

No difference in the structure of the sensillae could be found in any of the specimens studied. An unknown sensory structure present on coxa II as in the larvae. (Plate XIX, 3.)

Boophilus

Structural and positional occurrence basically as in the rhipicephalids.

MALES

Rhipicephalus (Plate XX, 2, 3.)

Four pairs of sensillae sagittiformia occur postero-laterally to coxae (1-4) just mesial to the ventral lateral groove. Three to seven sensillae occur at each of these positions. Mesial to the inner margin of coxa I three sensillae occur which are circular in shape. One pair of postero-lateral sensillae occur at coxae II-III and posterior and postero-laterally complexes of sensillae occur. A sensory structure occurs on coxa II as in the larvae and nymphae.

Boophilus

It was very difficult to do a complete study of this structure in this group, due to fixation problems. The distribution of sensillae resembles that of the nymphae to a great extent.

FEMALES

Rhipicephalus (Plate XIX, 4 & XX, 4, 5, 6.)

Sensillae in the three studied species as in the males. (Plate XIX, 4, 5, 6.) Sensory structure on coxa II as in the males. (Plate XIX, 4.)

Boophilus

Sensillae in the two studied species as in the males.

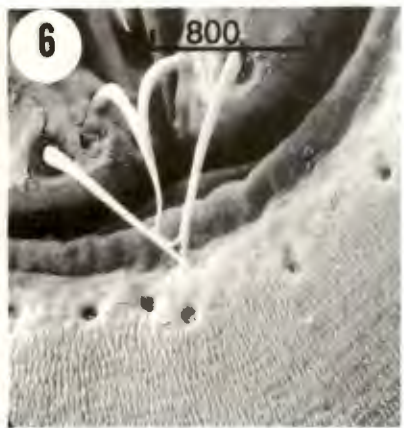
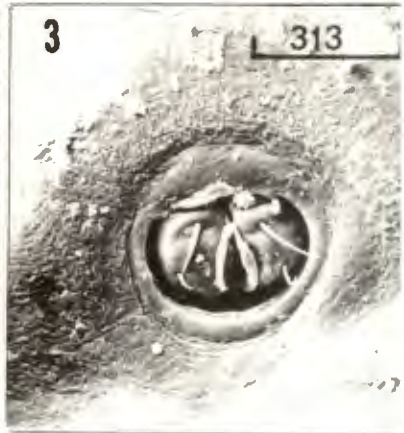
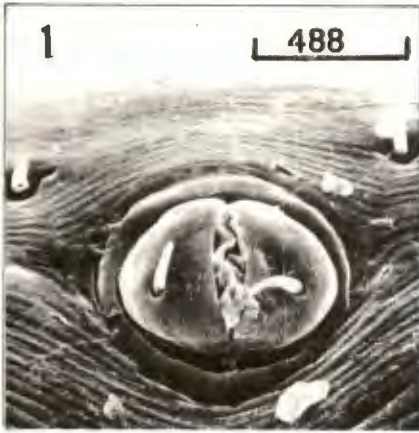


PLATE XXI

PLATE XXI⁺

Anus of:-

1. *Rhipicephalus pravus* larva;
2. *R. pravus* nymph;
3. *Boophilus microplus* nymph;
4. *R. oculatus* male;
5. *B. decoloratus* male;
6. *R. appendiculatus* female;
7. *B. decoloratus* female;
8. *B. microplus* female;

Haller's organ of larvae:-

9. *R. pravus*;
10. *R. oculatus*;
11. *R. appendiculatus*;
12. *B. decoloratus*.

+ Scale lines in μm .

7.2.2.4 Anus

The anus has a slit-like anal aperture (a a) bordered by two hard, thick, semicircular valves (a v) and surrounded by a thickened ridge of cuticle, the annulus (a an).

Between the valves and annulus there is, according to Arthur (1953), a flexible cuticle which permits the valves to open and close. He stated that the major axis of the adult anus is longitudinal but in larvae and nymphae the longitudinal and transverse axes are about equal, though in some cases it may even be longer. Anal grooves round the anus, and in the majority of cases run forward and outward to reach the genital grooves. The adanal shields are paired ventral shields near the anus in the males of *Boophilus* and *Rhipicephalus*. The accessory shields are paired shields outside the adanal shields in the males of *Boophilus* and *Rhipicephalus*. The adanal shields may show slight variations in form within species of *Rhipicephalus* (Theiler, 1947). According to Arthur (1960) the anal shield is of little significance in the classification of *Boophilus* because it is subject to variation as indicated by Bequaert (1926).

LARVAE

Rhipicephalus pravus (Plate XX, 12.)

Dimensions:= Diameter antero-posteriorly: 0,030-0,036 mm;
diameter transversely: 0,038-0,043 mm.

The anus lies on the mid-ventral surface of the opisthogaster. The anus is circular with an anal seta (An) on each valve. (Plate XXI, 1.) The encircled annulus looks rounded anteriorly.

Rhipicephalus oculatus

Dimensions:= Diameter antero-posteriorly: 0,034-0,039 mm;
diameter transversely: 0,045-0,048 mm.

Position and structure of anus as in *pravus*. (Plate XXXI, 1.)

Rhipicephalus appendiculatus

Dimensions:= Diameter antero-posteriorly: 0,039-0,046 mm;
diameter transversely: 0,037-0,039 mm.

Position and structure of anus as in *pravus*. (Plate XXI, 1.)

Boophilus decoloratus

Dimensions:= Diameter antero-posteriorly: 0,038-0,052 mm;
diameter transversely: 0,040-0,052 mm.

Position and structure as in *R. pravus* (Plate XXI, 1.)

Boophilus microplus

Dimensions:= Diameter antero-posteriorly: 0,036-0,044 mm;
diameter transversely: 0,046-0,052 mm.

Position and structure as in *R. pravus*. (Plate XXI, 1.)

NYMPHAE

Rhipicephalus pravus (Plate XXI, 2.)

Anus circular with three setae on each valve. An annulus encircles the anus and is more broader anteriorly than posteriorly. Posterior half of the anal margin separated from the rest of the body cuticle by a semi-circular anal plate, which is in turn delimited by a deep semi-circular anal groove. This groove is continued postero-medially to the anterior margin of the middle festoon. The semi-circular anal plate is densely covered with fine reticulations but not to the same extent as the outer margin of the groove.

Rhipicephalus oculatus

Structure corresponds with that of *pravus*. (Plate XXI, 2.)

Rhipicephalus appendiculatus

Structure corresponds with that of *pravus*. (Plate XXI, 2.)

Boophilus decoloratus

Only two setae present on each valve. An annulus encircles the anus. No anal or post-anal-median grooves present. (Plate XXI, 3.)

Boophilus microplus (Plate XXI, 3.)

As in *decoloratus*.

MALES

Rhipicephalus pravus (Plate XX, 7. Fig. 9, 01.)

According to Walker (1956) the shape of the anal plates varies considerably, but Hoogstraal (1956) stated that the shape of anal shields distinguish the males. The anal shield or plate triangular with the external margin straight to sinuous meeting the slightly convex posterior margin in a rounded angle. (Plate XX, 7.) The internal margin slightly sinuous and scooped out opposite and posterior to the anus, with a spur-like projection more posteriorly. Posterior internal angle about a right angle, though sometimes more acute. Anterior internal angle pointed. (Fig. 9, 01.) Surface with both large punctations, each bearing a seta, and scattered fine punctations. (Plate XX, 7.) From 18-24 setae present, not arranged in any definite pattern. Small triangular anal plates present. The anus circular in shape with the annulus broader anteriorly; surrounded posteriorly, postero-laterally and laterally by a thickened ridge. (Plate XXI, 4.) Just outside this ridge the anal groove surrounds the anus posteriorly, then runs forward on each side before diverging slightly antero-laterally towards the genital grooves, which it may reach. Posterior to the anal groove a shallow mid-ventral furrow continues backwards and almost reaches the central festoon. This groove represents the post-anal median groove. The anal valves each bears four setae of which one is antero-mesial, two postero-mesial and one mid-lateral.

Rhipicephalus oculatus (Plates XX, 8 & XXI, 4. Fig. 9, 02.)

Adanal plates, anus (Plate XXI, 4.) and anal grooves almost resemble those of *pravus*, (Plates XX, 8 & XXI, 4.) except that the adanal plates differ in shape. The internal margin is almost straight. (Plate XX, 8.) Shape of adanal plates as in fig. 9, 02.

Rhipicephalus appendiculatus (Plate XX, 9. Fig. 9, 03.)

Anus and anal grooves resemble those of *pravus*. Adanal plates elongate sub-triangular. According to Hoogstraal (1956), the characteristic elongate shape of the adanal plates with their slightly rounded angles is most distinctive (fig. 9, 03). However, some variations in the shape of these adanal plates occur. External margin sinuous, continuous through a broadly rounded angle with the sinuous to concave posterior margin. (Plate XX, 9.) The internal margin first convex, becoming concave adjacent to the anus and then convex again; postero-internal angle relatively narrowly rounded. Inner edge longer than the outer, giving the adanal plates an elongated appearance. Accessory anal plates according to Howard (1908) lacking or very small. During this investigation it was found that they vary from small to rather well-developed plates, but are not as well-developed as in the boophilids. The distal ends of these plates almost reaching the postero-external angles of the adanal plates. Adanal punctate as in *pravus*. Adanal plates with 17-22 setae while the accessory plates lack any setae.

Boophilus decoloratus (Plate XX, 10 & XXI, 5. Fig. 9, 04.)

There is considerable variation in the size and development of the adanal and accessory anal plates. Adanal plates elongate, with the internal spur strong, triangular and separated by either a shallow concavity or a cleft from the smaller external spur. (Plate XX, 10.) The latter may be absolutescent. According to Hoogstraal (1956) Arthur (1960), Gothe (1967) and Arthur & Londt (1973) the internal spur may project beyond the posterior margin but on small specimens it frequently does not reach the margin. The inner margin of the adanal plate at first slightly convex,

then slightly scooped out adjacent to the anus, (fig. 9, 04.) Between the anus and the internal spur it is markedly convex. Outer margin of adanal plate straight to slightly convex. Accessory plates (Plate XX, 10.) drawn out to single points, according to Arthur & Londt (1973) whether they protrude beyond the posterior margin or not, depending on the size of the male. Accessory plates on a fold-like elevation with the inner margin straight to slightly sinuous and the outer margin widely arcuate. The adanal plates bear about 30-35 setae and the accessory plates about 13 setae. Anus circular, surrounded by an annulus, with moderately inclined anterior and posterior faces. (Plate XXI, 5.) Anterior and posterior to the annulus the body surface is longitudinally striated. Anus bears six setae with one pair antero-mesially; one pair laterally and one pair postero-mesially on the anal valves. Anal grooves absent.

Boophilus microplus (Plate XX, 11. Fig. 9, 05.)

Adanal plates variable in shape, usually sub-rectangular posteriorly, rounded anteriorly. External margin broadly arcuate (fig. 9, 05). Inner margin bean-shaped. About four times longer as broad. Posterior margin variable but usually a postero-internal angle occur which is blunt and mostly shorter than the external spur. Between the two spurs the posterior margin is concave. Adanal plates punctate and bearing about 35-40 setae. (Plate XX, 11.)

Accessory plates shorter, bent and triangular in shape, bearing about 40 setae. Accessory plate posteriorly with an internal point which may be blunt or pointed to varying degrees. Internal margin sinuous while the outer margin is almost straight. In some specimens the plates are asymmetrical in shape. The adanal plates never reaching beyond the posterior margin of body as in *decoloratus*. Anus circular with the surrounding annulus bearing anteriorly a steep face and posteriorly a more moderate face. Cuticle anterior to the anus longitudinally striated and posteriorly reticulate. Anal valves bearing only two setae; one antero-laterally and one postero-laterally. Anal grooves absent.

FEMALES

Rhipicephalus pravus (Plate XXI, 6.)

Anus surrounded posteriorly and laterally by a thickened ridge which bears very fine teeth-like structures, (Plate XXI, 6.) and about eight pit-like structures. Anus surrounded entirely by the annulus which is relatively broader anteriorly than posteriorly. The anal grooves surround the anus posteriorly and slightly antero-laterally divergent. In some specimens the antero-lateral arms of the grooves reach the genital grooves. A deep mid-ventral post-anal groove extends almost to the central festoon. Anal valves bear four setae as in the males.

Rhipicephalus oculatus

Anus and grooves resemble those of *pravus*.

Rhipicephalus appendiculatus

Anus and grooves resemble those of *pravus* except that the setae on the valves are longer.

Boophilus decoloratus (Plate XXI, 7.)

Anus surrounded entirely by an annulus which is smooth and equal in breadth all the way round. (Plate XXI, 7.) Post-anal median groove a vague, shallow depression. Anal valves bear only three setae, one antero-mesially, one postero-mesially and one laterally.

Boophilus microplus (Plate XXI, 8.)

Anus and grooves resemble those of *decoloratus* except that the annulus is much broader anteriorly. Valves bear only two setae. (Plate XXI, 8.)

7.3 The legs

The setae on the segments of the legs, except for the coxae and tarsus I, have not been studied during this investigation because of their uniformity in several species (Clifford & Anastos, 1960 and Edwards & Evans, 1967).

7.3.1 Haller's organ

Haller (1881) published a description of the sensory organ of ticks which he believed to be an auditory organ. For a long time other zoologists appear to have given little attention to this structure, the majority of those who have had occasion to mention it, contenting themselves with a brief resume of Haller's observations and a reference to his paper. According to Nuttall et al. (1908), Lahille (1905) was the first to question the accuracy of Haller's interpretation of the function of this organ. The conclusion which Lahille drew from his observations was that the function of Haller's organ is olfactory and not auditory. Nuttall et al. (1908) investigated the anatomical structure of the organ in every genus of the Ixodoidea, but information on the morphology of Haller's organ was still limited. The phylogenetic significance of Haller's organ in different genera of ticks was first investigated by Schulze (1941), and Arthur (1953b, 1955, 1956) studied the structure of this organ in the British tick species. Studies of its fine structure by means of electron microscopy were undertaken by only a few investigators, e.g. Woolley (1972) and Foelix et al. (1972).

Haller's organ is located on the dorsal surface of the tarsi of the first pair of legs of ticks. It is found in all genera and, according to Arthur (1956), the details of the structure may vary from one species to another. Other investigators (Nuttall et al., 1908) showed that this organ consists of two parts: A cluster of sensory setae, termed the accessory pit (sometimes referred to as the anterior pit or anterior trough) and immediately posterior to it a capsule containing several sensillae. According to Foelix et al. (1972) and Lees (1948) there is good evidence that the anterior pit functions as a humidity receptor while the capsule is an olfactory organ. Foelix et al. (1972) suggest that the morphological diversity of the sensillae of the anterior pit (3-4 types) indicates that they have several functions: possibly chemo-, humidity and temperature reception. One might expect that the enclosed capsule sensillae are shielded from the environment and could there=

fore hardly function as olfactory receptors. Yet, ticks wave their first pair of legs in a similar fashion to insects waving their antennae and do not use them for walking (except for the larvae). An alternating up and down movement of the first pair of legs would certainly facilitate perception of olfactory stimuli. The capsule is considered to serve mainly as a protective device since the thin-walled and non-socketed capsular sensilla could easily be damaged mechanically.

Haller's organ is present in all three developmental stages. Detailed studies with the aid of the S.E.M. and T.E.M. done by Roshdy, et al. (1972) revealed numerous fine structural details of Haller's organ in the different stages. It is evident that Haller's organ in adults, particularly in the females, has received the greatest attention, while the immature stages have been largely neglected. As so little is known of the detailed structure of this organ in all stages, the object of this work was to ascertain whether it might provide useful taxonomic characters and whether differences exist in its structure in the mature and immature stages. There are no essential structural differences between the nymphal and adult forms, but the larvae and nymphae differ as follows: Besides a continuous increase in size between the different developmental stages, the A2 sensillum shows an increase in pore density from the larval and nymphal (Plates XXIII, 3 & 4) forms to the adult form. (Plate XXII, 10.) The combination of both factors (increased surface area and increased density) yields a much higher pore number in the adult. The capsule roof in the larvae is often perforated, or at least indented. This is not the case in the nymphae or adults. The enclosed capsule sensillae are normally not accessible for study with the S.E.M. but apparently, Foelix et al. (1972) and Bruce (1971) successfully opened it partially. Chaetotaxy in the case of the larvae is as follows: one pre-halleral (prH), two halleral (H1, 2), two post-halleral (poH1, 2), two antero-medio-dorsal (amdH1, 2) and two postero-medio-dorsal (podH1, 2) setae. Five setae are arranged in the anterior pit while the sixth seta is just within or just outside the pit.

These setae are termed A1-6 according to their length, with A1 the longest and A6 the shortest. Setae A1 and A2 are located lateral and mesad respectively, flanking the remaining setae.

LARVAE

Rhipicephalus pravus (Plates XXI, 9 & XXIII, 4 & 5. Fig. 9, L1.)

Dimensions:= Length:- A1: 112,7-176,2 μ m; A2: 57,1-94,0 μ m; A3: 37,6-66,8 μ m; A4: 20,5-50,0 μ m; A5: 25,7-42,8 μ m and A6: 20,2-34,8 μ m. Basal diameter:- A1: 27,8-35,6 μ m; A2: 19,0-21,6 μ m; A3: 12,7-17,7 μ m; A4: 12,0-16,5 μ m; A5: 8,4-12,6 μ m and A6: 15,2-18,5 μ m. Aperture:- transverse section: 85,7-113,7 μ m; longitudinal section: 84,4-127-3 μ m.

Chaetotaxy: One pre-halleral (prH); two halleral (H1, 2); two post-halleral (poH1, 2); two antero-medio-dorsal (amdH1, 2) and two widely separated postero-median-dorsal setae (PmdH1, 2) (pmdh1, 2) poH1 are closely associated with Haller's organ and about equal in length, with poH2.

Seta amdH1 a little anterior to amdH2. (Plate XXI, 9.) and larger. The pre-halleral, A1 and A2-5 setae located as on steps. The pre-halleral and A1 setae point laterally, more or less in the direction of H2 seta while A2 points mesad. (Plate XXIII, 4.) A sub-triangular pit (p) contains 5 setae (A2-6); seta A1 is situated more laterally, just inside the anterior pit (ap) but not in the sub-triangular pit. (Plate XXIII, 4.) Three setae in the sub-triangular pit (A3, 4 & 6) are arranged in a triangle, with seta A5 halfway between A3 and A6. Seta A2, 4 & 6 are in an antero-lateral row. The aperture of the capsule (fig. 9,4) is cross-shaped. The walls of the aperture are irregularly undulating. (Plate XXIII, 5.)

Rhipicephalus oculatus (Plates XXI, 10 & XXIII, 3 & 6. Fig. 9, L1.)

Dimensions:= Length:- A1: 140-186,0 μ m; A2: 78,2-86,5 μ m; A3: 41,3-57,7 μ m; A4: 32,3-46-8 μ m; A5: 13,4-17,5 μ m and A6: 27,3-36,0 μ m. Basal diameter:- A1: 27,9-32,0 μ m; A2: 21,9-31,2 μ m; A3: 13,4-17,5 μ m; A4: 8,9-11,7 μ m; A5: 15,2-17,3 μ m and A6: 7,2-10,1 μ m. Aperture:- transverse section: 76,3-94,8 μ m; longitudinal sec=

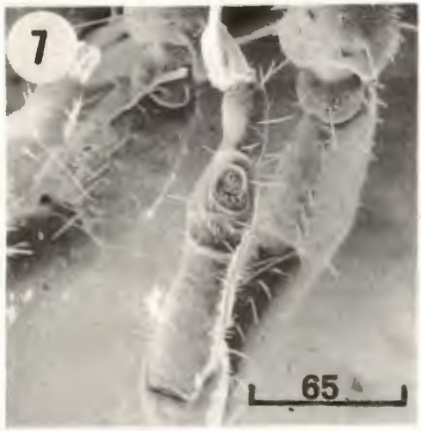


PLATE XXII

PLATE XXII⁺

Haller's organ of larva:-

1. *Boophilus microplus*;

Haller's organ of nymphae:-

2. *B. decoloratus*;
3. *Rhipicephalus appendiculatus*;
4. *R. pravus*;

Haller's organ of males:-

5. *B. microplus*;
6. *B. decoloratus*;
7. *R. appendiculatus*;
8. *R. oculatus*;

Haller's organ of females:-

9. *B. microplus*;

Haller's organ from lateral view.

10. *R. pravus* (male);
11. *R. oculatus* (nymph);
12. *B. microplus*. (larva).

+ Scale lines in μm .

tion: 101,2-136,2 μ m.

Positions of setae and chaetotaxy as in *pravus*. (Plates XXI, 10 & XXIII, 3.) Aperture of capsule basically resembles that of *pravus* (fig. 9, L1. Plate XXIII, 6.)

Rhipicephalus appendiculatus (Plates XXI, 11 & XXIII, 2 & 7. Fig. 9, L2.)

Dimensions:= Length:- A1: 152,0-182,1 μ m; A2: 88,4-97,5 μ m; A3: 55,2-60,4 μ m; A4: 40,7-46,1 μ m; A5: 40,0-48,6 μ m; A6: 27,8-38,0 μ m. Basal diameter:- A1: 30,5-34,0 μ m; A2: 19,2-21,0 μ m; A3: 13,5-15,5 μ m; A4: 14,0-19,2 μ m; A5: 7,6-10,2 μ m and A6: 8,6-12,4 μ m. Aperture:- transverse section: 103,1-136,0 μ m; longitudinal section: 94,3-128,8 μ m.

Position and chaetotaxy as in *pravus*, (Plate XXI, 11.) except for setae A3,5 & 4 in anterior pit located as in (Plate XXIII, 2). a triangle with A2, 5 and 4 in a antero-lateral row. Seta A6 between A4 and A3. Aperture of capsule cross-shaped (fig. 9, L2) with smooth walls and a large central enlargement. (Plate XXIII, 7.)

Boophilus decoloratus (Plates XXI, 12 & XXIII, 1 & 8. Fig. 9, L3.)

Dimensions:= Length:- A1: 114,3-151,0 μ m; A2: 80,4-116,8 μ m; A3: 44,6-83,4 μ m; A4: 34,3-54,9 μ m; A5: 31,2-55,2 and A6: 26,7-41,9 μ m. Basal diameter:- A1: 23,6-37,1 μ m; A2: 22,9-33,1 μ m; A3: 13,1-19,6 μ m; A4: 11,0-12,4 μ m; A5: 15,8-22,3 μ m and A6: 8,4-10,3 μ m. Aperture:- transverse section of aperture: 92,0-108,0 μ m; longitudinal section of aperture: 47,0-53,2 μ m.

Setae and chaetotaxy basically as in *R. pravus*. (Plate XXI, 12 & XXIII, 1.) Aperture of capsule is trifurcate (fig. 9 L3) with the transverse section more widely open than the short longitudinal section.

Boophilus microplus (Plates XXII, 1 & XXIII, 9-12. Fig. 9, L3.)

Dimensions:= Length:- A1: 136,0-193,0 μ m; A2: 89,8-112,9 μ m; A3: 64,5-78,7 μ m; A4: 43,6-56,4 μ m; A5: 41,1-51,9 μ m and A6: 35,8-61,5 μ m. Basal diameter:- A1: 37,9-47,8 μ m; A2: 22,5-31,6 μ m.

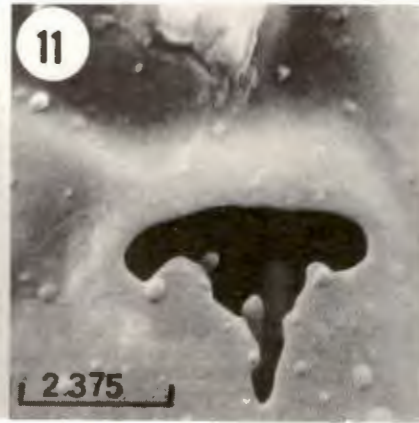
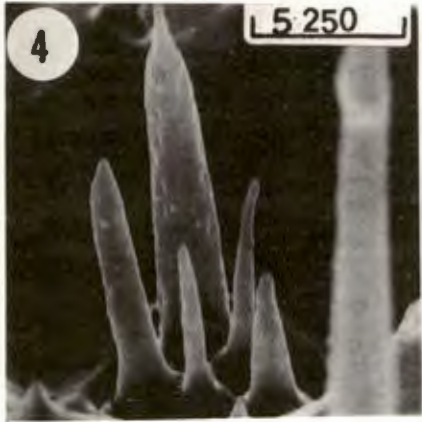
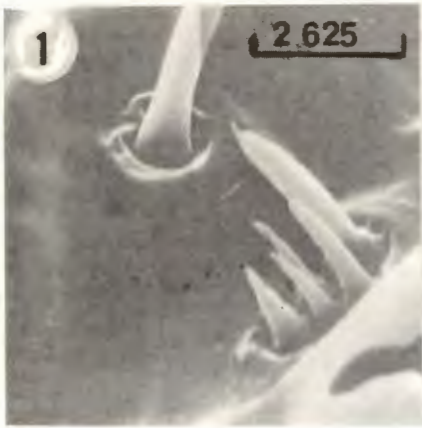


PLATE XXIII

PLATE XXIII⁺

Lateral view of Haller's organ of larvae:-

1. *Boophilus decoloratus*;
2. *Rhipicephalus appendiculatus*;
3. *R. oculatus*;
4. *R. pravus*.

Aperture of Haller's organ of larvae:-

5. *R. pravus*;
6. *R. oculatus*;
7. *R. appendiculatus*;
8. *B. decoloratus*;
- 9-12. *B. microplus*.

+ Scale lines in μm .

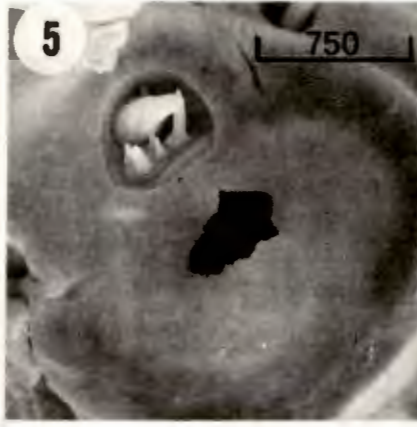
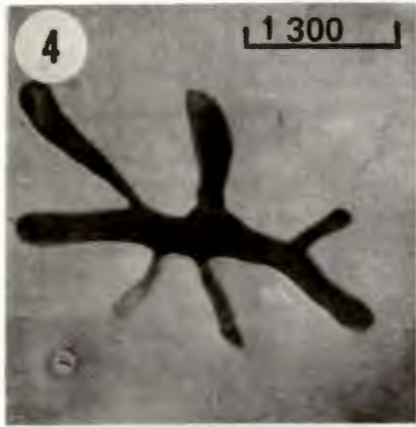
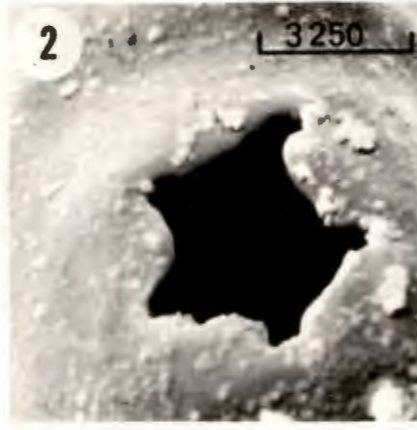


PLATE XXIV

PLATE XXIV⁺

Aperture of Haller's organ:-

1. *Rhipicephalus appendiculatus* (nymph)
- 2-3. *Boophilus microplus* (nymph)
4. *R. appendiculatus* (males)
5. *B. microplus* (males)
6. *B. decoloratus* (males)

Ambulacra of:-

7. *B. microplus* (larva) I;
8. *R. pravus*; (larva) I;
9. *R. oculatus* (male) IV;
10. *R. appendiculatus* (male) III;
11. *R. oculatus* (male) II;
12. *B. decoloratus* (male) I;
13. *B. microplus* (larva) III;
14. *B. microplus* (larva) I & II.

+ Scale lines in μm .

A3: 13,5-17,6 μ m; A4: 12,0-12,2 μ m; A5: 9,2-12,8 μ m and A6: 17,6-22,0 μ m.

Setal position and chaetotaxy basically the same as in *pravus*. (Plates XXII, 1 & 12.) Seta poH1 not very close to Haller's organ and longer than poH2. Aperture of capsule tridiate (fig. 9, L3) with the transverse section more widely open than the short longitudinal section. The basic shape of the aperture varies greatly, particularly in the Australian strain. (Plate XXIII, 9-12.)

NYMPHAE

Rhipicephalus pravus (Plate XXII, 4. Fig. 9, M1.)

One distal dorso-lateral situated seta (dH). One pair pre-halleral setae (prH1,2) with one of these immediately in front of the anterior pit. Two halleral setae (H1,2) with H1 markedly closely associated with Haller's organ. Two post-halleral setae (phH1,2) with poH1 more closely located to Haller's organ. A complex of four central median setae (CmH1-4) situated as on the corners of a parallelogram with CMH1>CMH2>CMH3>CMH4. (Plate XXII.) One pair of antero-medio-dorsal setae (amdH1,2) unequally in length and one pair of postero-medio-dorsal setae, also unequally in length. Setae A1, 2 & 3 in the anterior pit, situated as on the corners of a triangle, with A4, between A1 & 3. The aperture of the capsule is cross-shaped (fig. 9, M1) as in the larvae, but in some cases it is vaguely defined.

Rhipicephalus oculatus (Plate XXII, 11. Fig. 9, M1.)

As in *pravus*, except that in some cases seta A1 is partially isolated from the rest of the setae in the anterior pit. (Plate XXII, 11.) Aperture (fig. 9, M1) vaguely defined, to a far greater extent as in *pravus*.

Rhipicephalus appendiculatus (Plate XXII, 3 & XXIV, 1. Fig. 9. M2.)

As in *pravus*. (Plate XXII, 3. Aperture (fig. 9, M2) corres=

pond with that of the larva. (Plate XXIV, 1.)

Boophilus decoloratus (Plate XXII, 2. Fig. 9, M3.)

One distally dorsal seta, situated as in *pravus*. One pair of widely separated pre-halleral setae (prH1,2) with one of these more immediately in front of the anterior pit. The latter several times bigger than the other which is situated antero-laterally on the side of the gnathosoma. Two post-halleral (phH1,2) both closely situated to Haller's organ with PoH1 just posterior to Haller's organ and PoH2 postero-lateral. One pair of antero-medio-dorsal and one pair of postero-medio-dorsal setae as in the larvae. (Plate XXII, 2.)

Setae in the anterior pit as in *pravus*. Aperture as in the larvae (fig. 9, M3).

Boophilus microplus (Plate XXIV, 2-3. Fig. 9, M3.)

Chaetotaxy as in *decoloratus* except that the pre-halleral setae is more closely situated and of about equal dimensions. Two Halleral setae occur. The post-halleral setae both posterior to the capsule. Aperture (fig. 9, M3) as in the larvae. (Plate XXIV, 2-3.) Setae in anterior pit as in *pravus*.

MALES

Rhipicephalus pravus (Plate XXII, 10. Fig. 9, N1.)

Chaetotaxy: One antero-lateral, two pre-halleral (prH); one halleral (H); two post-halleral (poH); a complex of four median dorsal setae followed by six pairs of widely separated setae to the junction with the tibia. One of the prehalleral setae (prH) longer than the other and situated just anterior to the anterior pit. The halleral setae located lateral to the anterior pit. Seta poH1 more closely located to Haller's organ. One of the setae in the complex of four longer than the rest, the other three about equal in length.

Six setae arranged in the anterior pit with A1 antero-laterally;

A2 postero-lateral to A2 and A3 opposite and lateral to A2. Seta A6 almost, but a little anterior between A2 and A3; A5 between A1 and A2 and A4 between A1 and A3. A degressing in the length from A1-6.

The aperture (fig. 9, N1) of the capsule transversely elongate and provided with about seven lateral extensions; varying in shape. Surface of the anterior pit provided with two to three very small circular bivalved sense organs. (Plate XXII, 10.)

Rhipicephalus oculatus (Plate XXII, 8. Fig. 9, N1.)

Resembles that of *pravus*, (Plate XXII, 8.) except that the shape of the aperture (fig. 9, N1) varies to a greater extent.

Rhipicephalus appendiculatus (Plate XXII, 7 & XXIV, 4. Fig. 9, N1.)

Resembles that of *pravus*, except that only 4-5 pairs of widely separated setae occur posterior to the complex of four closely associated setae. (Plate XXII, 7.) Two to three sense organs present on the surface. (Plate XXIV, 4.)

Boophilus decoloratus (Plates XXII, 6 & XXIV, 6. Fig. 9, N2.)

Chaetotaxy: One antero-lateral; two pre-halleral (prH) two halleral (H); two post-halleral (poH); followed by 3-4 pairs of setae posterior to the junction with the tibia. Sometimes a pair of the lateral setae are more dorsally situated, occurring between the last two pairs of setae. Seta prH1 situated in an enlarged pit, next to prH2; both enclosed in the anterior pit. Seta H1 more anterior located, on a level between the anterior pit and the capsule. Setae poH1 & 2 both located close to the posterior part of Haller's organ. The latter followed by two closely situated setae with two more widely located succeeding pairs. (Plate XXII, 6.)

Setae A1-6 located as in *pravus*, except that the entire arrangement swivelled clockwise about 15 minutes. The aperture (fig. 9, N2) of the capsule provided with several incisions. (Plate XXIV, 6.) Sensory-bivalved organs absent.

Boophilus microplus (Plate XXII, 5 & XXIV, 5. Fig. 9, N3.)

Resembles that of *decoloratus*, except that five pairs of setae occur posterior to the post-halleral setae. In some cases the second pair post-halleral setae arranged between the succeeding pair. (Plate XXII, 5.) Aperture (fig. 9, N3) of the capsule differ from that of *decoloratus* in that it is more rounded and not provided with incisions to the same extent as in *decoloratus*. (Plate XXIV, 5.) Sensory-bivalved organs absent.

FEMALES

Resemble those of the males in almost fully detail.

7.3.2 Coxae

The coxae which are the proximal, immovable segments of the leg upon which the other segments are articulated, are numbered antero-posteriorly as I, II, III and IV. Coxal spurs when present can be large or small, long or short projections, usually on the posterior margin of the coxa. The shape of the coxal spurs is another character used by Minnning for the classification of Boophilids but Anastos (1950) points out that there is a considerable gradation in this character. Theiler (1947) stated that the coxae cannot be used for specific identification in the rhipicephalids because the variations within the genus are negligible. In those species examined in this study the coxal armature is very uniform in appearance. A useful character however, is the presence or the absence of an anterior projection on coxa I. When present this is visible dorsally. It readily strikes the eye, is subjected to comparatively little variation within the species and at once relegates the specimen to a particular assemblage of species.

LARVAE

Rhipicephalus pravus (Plate VII, 6.)

Coxa I sub-rectangular in shape with a very sharp spur (pspI) on the posterior margin. Coxa II thimble-shaped with a broad

rounded spur (pspII) near the edge of the posterior margin and overlapping it slightly. Coxa III also thimble-shape but not as elongated as coxa II. A smaller spur (pspIII) than that on coxa II present. Three coxal setae present on coxa I, one centro-lateral (cIal), one medio.-mesial seta (CIImm) and one antero-medial (CIam). On coxa II one antero-lateral (CIIal) and one postero-lateral (CIIp1) seta and on coxa III one antero-lateral (CIIIal) and one postero-lateral (CIIIp1) seta present.

Rhipicephalus oculatus (Plate VIX, 1.)

Shape, chaetotaxy and position of setae on coxae as in *pravus*. (Plate VIX, 1.)

Rhipicephalus appendiculatus (Plate VIX, 2.)

Coxa I triangular, coxa II and III almost rectangular with coxa II longer than coxa III. The spur on coxa I, sharply rounded posteriorly while coxae II and III resembles that of *pravus*, in chaetotaxy, position of setae and shape of spurs. (Plate VIX, 2.)

Boophilus decoloratus (Plate VIX, 3.)

Coxa I sub-triangular with a broadly rounded spur (pspI) overlapping the posterior margin very slightly, (not to the extent figures by Gothe, 1967) and following the contour of the coxal margin for a short distance. Slight indications of coxal spurs on coxae II and III (Psp II, III) are present. Coxal spur of coxa II very broad. Coxa II elongate and sub-rectangular, with mesial margin broadly rounded and pointing postero-medianly. Coxa III sub-triangular with mesial margin narrowly rounded. Chaetotaxy of coxae as in *R. pravus*.

Boophilus microplus (Plate VIX, 4.)

Coxa I sub-triangular in shape with a relative broadly rounded spur (pspI) overlapping the posterior margin more than in *decoloratus* but not as much as Gothe (1967) suggested. It is also more broadly rounded. Coxa II rectangular with a broadly rounded spur (pspII) near the inner edge of the posterior margin and somewhat overlapping it. Coxa III almost rectangular with a very small internal spur (pspIII), not a broadly rounded spur

near the outer edge of the posterior margin as described by Gothe (1967). (Both Cooley (1946) and Arthur (1960) report that coxae II and III lack spurs.) Chaetotaxy of coxae as in *R. pravus*. (Plate XIX, 4.)

NYMPHAE

Rhipicephalus pravus (Plate X, 5.)

Coxa I sub-triangular, coxa II almost rectangular and III and IV rectangular elongated with a widely rounded mesial side. A triangular internal spur on coxa I originating on the antero-mesial face and including the mesial and postero-mesial part of the coxa. A triangular external spur about equal in dimensions to the latter. A vague indication of the internal spur on coxa II. External spurs on the succeeding coxae decline progressively in size. Chaetotaxy of coxa I consisting of the following three setae:- antero-lateral (C1 al) on a partially triangular separation; a median mesial (C1 mm) on the internal spur, and a postero-lateral (C1 pl) lateral to the external spur. Chaetotaxy of the remaining coxae similar.

Rhipicephalus oculatus (Plate X, 6.)

As in *pravus* except that internal spur on Coxa I is much smaller.

Rhipicephalus appendiculatus (Plate X, 7.)

As in *pravus* except that the external spur on coxa I is narrower and more elongate than in either *pravus* or *oculatus*.

Boophilus decoloratus (Plate X, 3.)

Coxa I sub-triangular; coxa II elongately rectangular; coxa III shorter than II but as broad or even slightly broader and coxa IV sub-triangular.

A broad internal spur on coxa I, originating from the antero-mesial margin extending back to overlap the posterior edge for about a third of its length. External spur narrower and tapered apically, not overlapping the posterior edge of the coxa. External spurs on coxae II and III broadly rounded, coxa IV spur=

less. A slight indication of an internal spur on coxa II, while the succeeding coxae lack internal spurs.

Chaetotaxy of the coxae almost identical, consisting of the following three setae:- antero-lateral (Cl al), a medio-mesial (Cl mm) and a postero-lateral (Cl pl). Only one exception occurs - seta Cl mm on coxa IV lacking.

Boophilus microplus (Plate XI, 1.)

Cooley(1946) stated that coxa I has a short, broad internal spur while II and III are without spurs. Arthur (1960) stated that coxa I, II and III have broadly rounded external spurs, while Roberts (1965) stated that coxa I has a broadly rounded, distinct spur and coxae II and III each have distinct, shallow, broadly rounded, internal spurs which are least apparent on coxa III.

Coxa I triangular with internal and external spurs overlapping the posterior margin. Coxa II elongately rectangular with a broadly rounded external spur overlapping the posterior margin. Internal spur also broadly rounded, but smaller than the external spur. Coxae III and IV similar to coxa II, but coxa IV not so elongate and lacks any spurs.

Chaetotaxy of coxae as in *decoloratus*.

MALES

Rhipicephalus pravus (Plate XII, 1.)

Anterior projection of coxa I visible from the dorsal surface: coxa I sub-triangular in shape and pointed more posteriorly than mesially. Bifid posteriorly with a broad blunt internal and a narrower, sharper external spur; cleft between spurs reaching to about mid-length. Spurs about equal in length. Internal spur bears four setae at the mesial margin, while three setae occur antero-laterally on the external spur. Another small spur-like projection present antero-laterally on this coxa, anterior to which there are three setae.

Coxa II sub-triangular, bluntly pointed postero-mesially. A short, broadly rounded internal spur and a small triangular external spur. A small spur-like projection present antero-laterally as on coxa I. A complex of four setae near postero-internal margin of coxa and three setae laterally on external spur. Three setae on anterior projection.

Coxa III sub-triangular and pointed more mesially than posteriorly. Setae, projections and spurs on coxa II except that another seta occurs antero-medianly.

Coxa IV sub-triangular and pointed mesially. Setae, projections and spurs as on coxa II except that two setae occur antero-medianly.

Rhipicephalus oculatus (Plate XII, 2.)

Resembles *pravus* as regards shape, spurs, projections and distribution of setae.

Rhipicephalus appendiculatus (Plate XII, 3.)

Resembles *pravus* as regards shape, spurs, projections and distribution of setae except for a few modifications, e.g. coxa II narrower and internal spurs on coxae II-IV either lacking or very weakly developed.

Boophilus decoloratus (Plate XII, 4.)

Coxae smaller and more setose than in the rhipicephalids; from 11-14 setae on each coxa, not arranged in any definite pattern.

Coxa I triangular, drawn out postero-internally into a relative narrow rounded internal spur. A somewhat broader triangular external spur on the posterior margin. Spurs shorter than in the rhipicephalids but broader.

Coxa II sub-rectangular with the antero-internal margin broadly curved. Postero-internal margin salient. Broad internal and external spurs with the external spur projecting from the posterior margin.

Coxa III similar to coxa II but with a broader external spur.

Coxa IV sub-rectangular, broader than either II or III and with the postero-external corner drawn out. Lacks an external spur.

Boophilus microplus (Plate XII, 5.)

Minning (1934) indicated that the bluntness or acuteness of the internal spur of coxa I, is a primary, critical difference between *B. fallax* and *B. microplus*. According to Hoogstraal (1956) this character is variable among specimens from Africa and other continents. He stated that in some cases both blunt and acute internal spurs can occur on the same specimen.

Coxa I triangular, curved dorsad, extending well beyond the scapulae and therefore conspicuous dorsally. Internal spur relatively long and narrow, external spur much broader.

Coxa II sub-rectangular with two broadly rounded spurs projecting from the posterior margin.

Coxa III similar to II with spurs broader.

Coxa IV sub-rectangular, without spurs or with very weakly defined spurs.

FEMALES

Rhipicephalus (Plates XIII, 5 & 6 & XIV, 1.)

Resemble the males as regards shape, chaetotaxy and spurs.

Boophilus decoloratus (Plate XIV, 2.)

Shape and chaetotaxy mostly as in the males but a few differences occur.

Coxa I triangular to sub-triangular with two well-defined rounded spurs. Outer spur broader and shorter than the internal spur. The spurs discernibly separated by a narrow, but deep inverted "V"-shaped cleft.

Coxa II sub-rectangular with a broadly rounded external spur.

Coxa III sub-rectangular lacking a external spur, but a slight salience may be present.

Coxa IV broadly sub-triangular usually lacking a salience postero-externally.

Boophilus microplus (Plate XIV, 3.)

Coxae more elongate than in the males.

Coxa I. triangular, longer than wide with two sub-equal rounded spurs. The latter separated by a narrow relatively deep inverted "V"-shaped cleft. The external spur a little broader than the internal one.

Coxa II rectangular, with two broadly rounded spurs which are basally broader than and closer together than those on Coxa I.

Coxa III much as coxa II.

Coxa IV rectangular with the external spur as a marginal salience.

Chaetotaxy resembles that of the males.

7.3.3 Ambulacra

The ambulacrum (fig. 1, Z) consists of a pre-tarsus (pr) from which a fork-like structure arises, the condylophore (cond), on which the pulvillus (pu) is attached ventrally. On each condylophore a basilar piece (b p) articulates. The basilar piece is the remnant of the primitive apotele. On each basilar piece a claw (cl) is mounted which extends anteriorly and, beyond the pulvillus, curves downwards. Between the two basilar pieces a hinge is present which probably makes movement up and down possible. The hinge extends forwards and then divided about two-thirds along the length of the pulvillus in two sections which pass antero-laterally. Between these two extensions several spurs (ams) arise which extend forwards. Ventrally the pulvil-

lus has a striated pattern. (Plate XXIV.) The condylophores articulate with a pair of acetabula (a) on either side of the basilar piece. Greater flexibility is obtained by the condylophores as they articulate freely posteriorly with the pre-tarsus.

"The tarsal spurs are of some diagnostic value in separating Eurasian forms in the Acari". (Arthur, 1960). According to Chu-Wang & Actell (1973) the setae on the tips of the tarsus, (Plate XXIV, 8.) play a significant role in sensory perception and can therefore appropriately be referred to as sensillae.

LARVAE

Rhipicephalus pravus (Plate XXIV, 8.)

Dimensions:-

Ambulacrum I:- Length: Pulvillus 0,026-0,035 mm; pre-tarsus and condylophores 0,027-0,028 mm; claws 0,035-0,041 mm.
Breadth: Pulvillus 0,023-0,024 mm; distally fork-like structure of condylophore 0,016-0,017 mm.

Ambulacrum II:- Length: Pulvillus 0,020-0,021 mm; pre-tarsus and condylophores 0,021-0,025 mm; claws 0,023-0,031 mm.
Breadth: Pulvillus 0,015-0,020 mm; distally fork-like structure of condylophores 0,011-0,014 mm.

Ambulacrum III: Length: Pulvillus 0,020-0,023 mm; pre-tarsus and condylophores 0,027-0,032 mm; claws 0,035-0,040 mm.
Breadth: Pulvillus 0,011-0,013 mm; distally fork-like structure of condylophores 0,012-0,013 mm.

The length of the pulvillus in all three of the ambulacra is about the same, but the breadth decreases from I to III. Pulvillus oval in shape, with four to five spurs distally. The spurs are flanked by two lateral extensions of the hinge. The hinge divides at about half the length of the pulvillus into two; this part is continuous with the longitudinal folds on the pulvillus which extend distally. The basilar pieces form a wide "S" shape.

At the basal part of the claws the basilar pieces are broad. They are flank by the fork-like condylophores. The latter are an extention of the pre-tarsus. The length of the claws decreases from ambulacrum III to I. Sensilla on tips of tarsus — two dorso-laterally and two ventro-laterally.

Rhipicephalus oculatus

Dimensions:=

Ambulacrum I:- Length: pulvillus 0,022-0,030 mm; pre-tarsus and condylophores 0,020-0,029 mm; claws 0,033-0,035 mm. Breadth: Pulvillus 0,019-0,024 mm; distally fork-like structure of condylophores 0,012-0,019 mm.

Ambulacrum II:- Length: Pulvillus 0,019-0,020 mm; pre-tarsus and condylophores 0,021-0,022 mm; claws 0,034-0,036 mm. Breadth: Pulvillus 0,016-0,018 mm; distally fork-like structure of condylophores 0,012-0,013 mm.

Ambulacrum III:- Length: Pulvillus 0,020-0,025 mm; pre-tarsus and condylophores 0,025-0,026 mm; claws 0,039-0,041 mm. Breadth: Pulvillus 0,016-0,017 mm; distally fork-like structure of condylophores 0,012-0,014 mm.

Sensilla on tips of tarsus as in *pravus*. Structure of Ambulacra resembles that of *pravus*.

Rhipicephalus appendiculatus

Dimensions:=

Ambulacrum I:- Length: Pulvillus 0,036-0,050 mm; pre-tarsus and condylophores 0,044-0,048 mm; claws 0,045-0,062 mm. Breadth: Pulvillus 0,030-0,038 mm. Distally fork-like structure of condylophores 0,018-0,023 mm.

Ambulacrum II:- Length: Pulvillus 0,028-0,033 mm; pre-tarsus and condylophores 0,023-0,029 mm; claws 0,045-0,051 mm. Breadth: Pulvillus 0,020-0,025 mm; distally fork-like structure of condylophores 0,0137-0,0145 mm.

Ambulacrum III:- Length: Pulvillus 0,022-0,029 mm; pre-tarsus and condylophores 0,019-0,021 mm; claws 0,045-0,066 mm.

Breadth: Pulvillus 0,023-0,027 mm; distally fork-like structure of condylophores 0,013-0,018 mm.

Sensilla on tips as in *pravus*. Structure of ambulacra resembles that of *pravus* except that the claws are longer.

Boophilus microplus and *B. decoloratus* (Plates XXIV, 7, 13 & 14.)

Dimensions:=

Ambulacrum I:- Length: Pulvillus 0,033-0,063 mm; pre-tarsus and condylophores 0,032-0,055 mm; claws 0,042-0,067 mm.

Breadth: Pulvillus 0,022-0,043 mm; distally fork-like structure of condylophores 0,017-0,027 mm.

Ambulacrum II:- Length: Pulvillus 0,031-0,048 mm; pre-tarsus and condylophores 0,022-0,033 mm; claws 0,033-0,044 mm.

Breadth: Pulvillus 0,021-0,037 mm; distally fork-like structure of condylophores 0,018-0,020 mm.

Ambulacrum III: Length: Pulvillus 0,033-0,038 mm; pre-tarsus and condylophores 0,028-0,029 mm; claws 0,033-0,039 mm.

Breadth: Pulvillus 0,023-0,028 mm; distally fork-like structure of condylophores 0,017-0,018 mm.

Shape, measurements and position of ambulacra of *B. microplus* and *B. decoloratus* overlapping. No significant differences could be found. Shape and sensillae on tarsus as in *pravus*. Structure of ambulacra resembles that of *pravus* except that the pulvilli are about twice as long as that of *pravus*.

NYMPHAE

No structural differences, except that the ambulacra of both studied groups are much larger than that of the larvae.

MALES AND FEMALES

No structural differences could be detected between the species studied, nor between the representatives of the genera.

8. PHENETIC RELATIONSHIPS

The classical taxonomic method has been described as a process that is self-correcting in the course of time as new data from described species and newly perceived characters are introduced into the system. However, where the conservation of previous group concepts, or previous character weightings, arbitrarily over-rules the weight of new information then the taxonomic method ceases to be self-correcting, and sometimes a distorted classification results.

In the previous chapters the species are studied conventionally. Characters indicating sible phylogenetic relationships within the taxons are used. The species must also be examined by using quantitative methods, to test if sufficient objectivity was maintained.

The principles and intentions of quantitative or numerical taxonomy are described in detail by Gilmour (1937, 1940, 1951, 1961), Carn & Harrison (1958), Carn (1959), Sokal & Sneath (1963), Simpson et al. (1960), Mayr (1965, 1968) and Sheals (1964, 1969). Sokal & Sneath, 1963 stated that "numerical taxonomy is the evaluation by numerical methods of the affinity or similarity between taxonomic units and the employment of these affinities in erecting a hierarchic order of taxa.

Numerical taxonomy would have no claim to the serious attention of biologists unless it could overcome some of the faults in conventional taxonomic procedure and be of assistance in conventional taxonomy.

The basic principle of numerical taxonomy is that organisms are arrange in taxons wherein a greater degree of equality exist between any two organisms in a taxon as is between two organisms in different taxons on the same order of preference.

In conventional taxonomy certain characters carry more weight than others. In numerical taxonomy all the characters of an organism are of equal importance. Numerical taxonomy accepts all kinds of characters being of equal taxonomic status (Mayr et al. 1953).

To define the relationship between different organisms the percentage of resemblance or equality between them is considered. The percentage of equality is not only implemented to decide whether certain organisms belong to the same taxon, but also to determine taxonomic orders of preference or to create taxons on different levels. The requirements of a natural taxon are that its members have a greater percentage of equality among themselves than with members of a related taxon.

8.1 Characters

The proper selection of characters is clearly a critical point in the application of numerical taxonomy, as it is in other types of taxonomy. Misunderstandings have arisen on this score (Sokal & Sneath, 1963). Numerical taxonomy requires measurements of many characters for determining congruence. Admittedly, when a life stage shows very few measurable characters, one might be misled. Should serious incongruences between different stages of the life history occur in a given study, it would be difficult on theoretical grounds to justify any decisions between taxonomies based on one stage and those based on another. Where possible, one should choose characters from all stages of the life cycle when performing a numerical analysis. Sex differences will, according to Sokal & Sneath (1963), seldom prove troublesome in taxonomy because it seems certain that if one compares all the features of a male with those of a female belonging to the same species, the overall resemblance in most instances will be very high i.e. the great majority of features will not be appreciably affected by sex. In ticks sexual forms should be treated as if they were stages in the life cycle, thus male characters compared only with other male characters, and so on.

In addition to characters from all parts of the body and all stages of the life cycle, all the characters that vary within the group studied must be used, not merely the conventional diagnostic characters. The latter are likely to be constant within the members of any given category. The exclusive use of such characters would prejudge the very issue — the establishment of taxonomic categories free from subjective bias — which numerical taxonomy wishes to solve.

Of particular interest are the methods by which characters are weighed, i.e. to the degree to which emphasis is placed on different characters when taxonomic decisions are made. Numerical taxonomists have suggested that all characters should be given equal weight, while most classical taxonomists often disagree about which characters should be given the most emphasis. And, indeed, most serious disagreements about the classification of ticks can be traced to this problem.

Differences in character weighing have originated in the following ways:

(1) perceptual and methodological differences between taxonomists; (2) disagreements as to the phylogenetic significance of a character; (3) disagreement as to the stability of a character within a specified group of taxa, and finally (4) historical considerations, involving different interpretations of previous classifications and the character weighing implied in them (Hansell & Chant, 1971).

When considering a character such as the shape of the gnathotectum in ticks, it was found that considerable variation occurred.

A numerical taxonomist might express this variation minimally by measurements; he might then give all characters equal weight. The implication here is that, given the same specimen and using the same unit characters, different taxonomists can form entirely different classifications, depending upon the way in which these unit characters are combined to form taxons and by the level of

character complexity at which the taxonomists work. According to Sokal & Sneath (1963) a unit character can be defined as "... a taxonomic character of two or more states, which within the study at hand cannot be subdivided logically....". Differences in perception and working methods may produce considerable differences in the resultant classification. According to Sokal & Sneath (1963) a minimum of 40 characters but a number of 60 and more is preferable. For this purpose 17 characters for the larvae (only 17 was obtainable); 45 for the nymphae; 54 for the males; 47 for the females and a total number of 160 were isolated which was applied. The following characters were selected to divide the studied species into groups by means of numerical taxonomy.

8.2 Selected variable characters

Larvae

1. Gnathotecum

1.1 Shape of gnathotectum

1. (Fig. 4, A1); 2. (Fig. 4, A2); 3. (Fig. 4, A3)
4. (Fig. 4, A4).

1.2 Post-hypostomal setae

1. Short; 2. Relative short; 3. Long.

2. Chelicerae

1. Outer cheliceral sheaths covered about two-thirds the length with teeth; 2. Covered almost entirely by teeth.

3. Hypostome

3.1 Dentition

1. 2/2 with 6-8 denticles per longitudinal file;
2. 2/2 with 5-6 denticles per longitudinal file.

4. Palps

4.1 Shape

1. Tapering towards the tips; 2. Almost rectangular;

3. Bulbous.

4.2 Sensory pits

1. Pits occur on both femurs; 2. Pits absent.

5. Tibia-tarsus complex

1. Four setae on column; 2. Three setae on column;
3. Three to four setae on column.

6. Idiosoma

6.1 Shape

1. Narrowly oval; 2. Broadly oval; 3. Oval;
4. Almost round; 5. Pear shape.

7. Scutum

7.1 Cervical grooves

1. Relatively shallow and short; 2. Relatively deep,
broad and long; 3. Deep, narrow and long;
4. Shallow and short.

7.2 Emargination

1. Relatively wide and deep; 2. Wide and deep.

7.3 Scapulae

1. Broadly rounded; 2. Smoothly rounded; 3. Rela-
tively narrowly rounded.

8. Eyes

1. Oval elevations; 2. Prominent bead-like structures;
3. More or less circular and slightly elevated; 4. Circu-
lar, slightly elevated and not bulging beyond scutal
margins; 5. Oval, slightly elevated and bulging beyond
scutal margin.

9. Alloscutum

9.1 Festoons

1. Seven festoons occur; 2. Nine festoons occur;

3. Absent.

10. Sensillae sagittiformia

1. Sensillae behind coxae III consist out of two sensillae, surrounded by a common wall; 2. Two separated sensillae behind coxa III.

11. Coxae

11.1 Coxa I

1. Sharply pointed spur on coxa I; 2. Broadly rounded spur; 3. Relative broadly rounded spur.

11.2 Coxa III

1. Small spurs occur; 2. Slight indications of spurs.

12. Haller

12.1 Shape of aperture

1. (Fig. 9, L1); 2. (Fig. 9, L2); 3. (Fig. 9, L3).

Nymphae

1. Gnathothecum

1.1 Shape of gnathotectum (dorsally)

1. (Fig. 4, B1); 2. (Fig. 4, B2); 3. (Fig. 4, B3); 4. (Fig. 4, B4).

1.2 Shape of gnathotectum (ventrally)

1. (Fig. 5, C1); 2. (Fig. 5, C2); 3. (Fig. 5, C3); 4. (Fig. 5, C4).

1.3 Sensory pits

1. One pair on the gnathotectum; 2. Two pairs on the gnathotectum.

1.4 Setae on socket ventrally

1. Two pairs present; 2. One pair present.

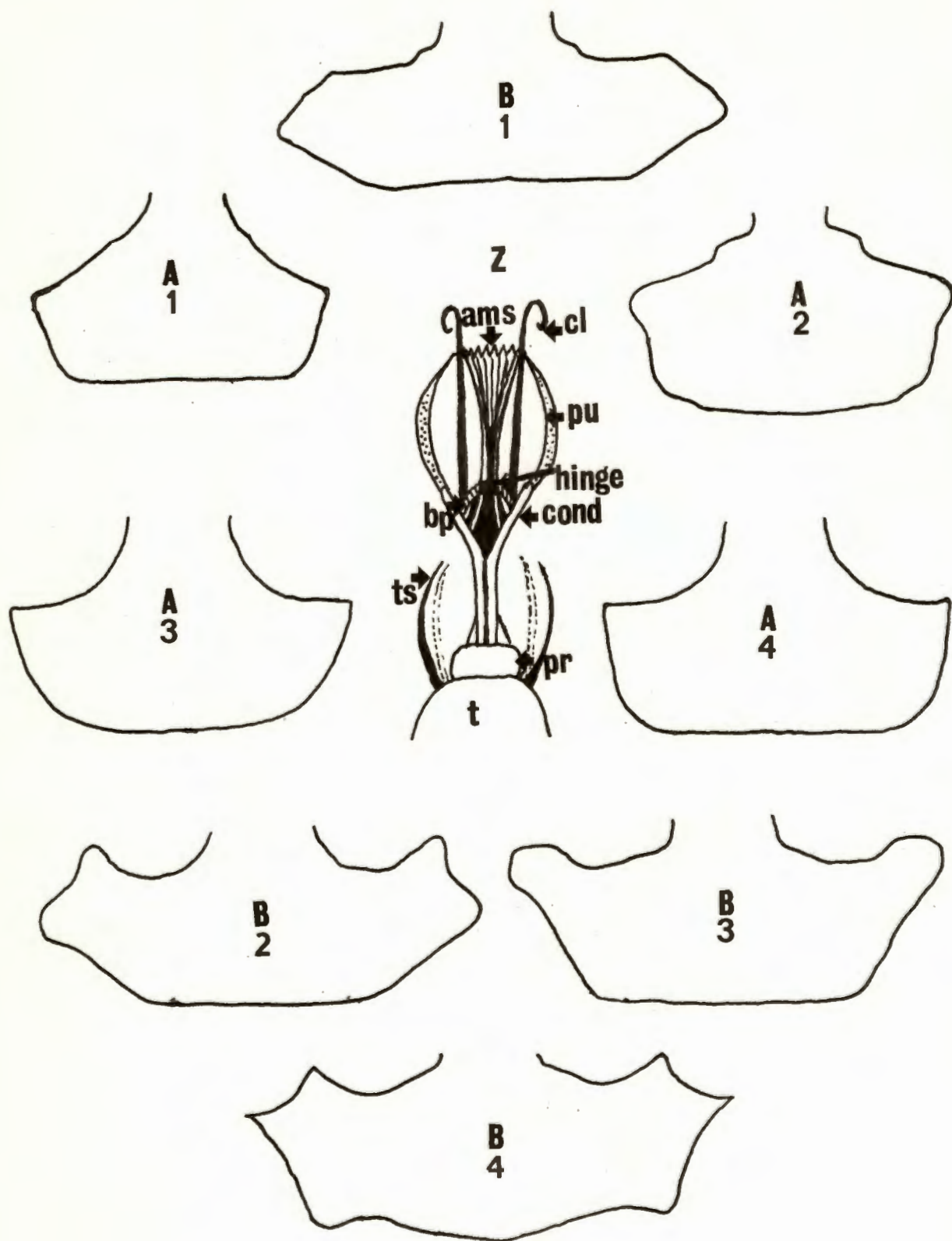


FIGURE 4

FIGURE 4

A1-4 Gnathotectum of larvae:-

A1: *Rhipicephalus pravus* & *R. oculatus*

A2: *R. appendiculatus*

A3: *Boophilus decoloratus*

A4: *B. microplus*

B1-4 Gnathotectum of nymphae:-

B1: *R. pravus* & *R. oculatus*;

B2: *R. appendiculatus* ;

B3: *B. decoloratus*;

B4: *B. microplus*.

Z: Composition of ambulacrum

2. Chelicerae

2.1 Cheliceral sheaths

1. Outer cheliceral sheaths covered about two-thirds the length with teeth;
2. Covered about three quarters;
3. Almost entirely covered.

2.2 Chelicerae

1. About equal in length with the palps;
2. Longer than the palps.

3. Hypostome

3.1 Dentition

1. 2/2;
2. 3/3.

3.2 Number of denticles per longitudinal files

1. 9-10;
2. 8-9.

4. Palps

4.1 Shape

1. Tapering towards the tips;
2. Becoming broader to the tips;
3. Almost rectangular.

4.2 VSM-setae

1. Two on the femur; one on the femur.

4.3 Structure of VSM1-seta

1. Large, multi-barbed ventrally;
2. Relatively large but lesser profusely barbed;
3. Small with a few barbs apically.

5. Idiosoma

5.1 Shape

1. Elongate oval;
2. Broadly ovate;
3. Ovate;
4. Narrowly ovate.

6. Scutum

6.1 Scapulae

1. Covered by the gnathotectum; 2. Partially covered by the gnathotectum.

6.2 Posterior margin

1. Relative broadly rounded; 2. Broadly rounded;
3. Relative narrowly rounded; 4. Narrowly rounded.

6.3 Cervical pits

1. Deep; 2. Shallow or absent; 3. Absent.

6.4 Cervical grooves

1. Relative deep at first, becoming shallower and fading out at about eye-level; 2. Relative shallow and almost reaching the posterior margin of the scutum; 3. Faint and reaching the posterior margin of the scutum; 4. Faint and reaching half-way down the scutum.

6.5 Lateral grooves

1. Sharply defined, arcuate, closely located to the lateral margins of the scutum and almost reaching the posterior margin of the scutum; 2. Extremely sharply defined, closely located to the lateral margins of the scutum and almost reaching the posterior margin of the scutum; 3. Faintly defined and not closely located to the lateral margins of the scutum; 4. Absent.

6.6 Scutal setae

6.6.1 Sc-setae (Scutal setae)

1. Sc1-4; 2.Sc1-5; 3.Sc1-3.

6.6.2 Scapular setae

1. Three pairs; 2. One pair; 3. Two pairs.

6.6.3 Setae between the scapulae and the eyes

1. Two pairs; 2. 1-2 setae; 3. One seta.

6.6.4 Medio-lateral row to the eyes

1. Four setae; 2. Two setae; 3. Nil.

6.6.5 Between the eyes and Sc-serie

1. One pair; 2. Two pairs; 3. Absent.

6.7 Punctations

1. Large to medium size punctations, more abundant outside the lateral grooves; 2. A few, small and shallow scattered punctations.

6.8 Reticulation

1. Inner section between lateral grooves markedly reticulated, with the outer parts vaguely reticulated, except for a narrow strip anteriorly and medianly to they eyes; 2. Inner section between the lateral grooves and outer parts almost reticulate to the same extent; 3. Surface smooth.

7. Eyes

1. Elongate oval, edged anteriorly and mesially by a reticulate strip. 2. Circular, limited mesially by a deep reticulate furrow which becomes shallower antero-laterally and postero-laterally; 3. Oval, limited mesially by a shallow groove without any reticulations; 4. Inconspicuous and when present, oval and slightly bulging beyond the posterior scutal margin.

8. Alloscutum

8.1 Festoons

1. Nine; 2. Nine well-developed and two lesser developed; 3. Absent.

8.2 Setae

8.2.1 Cd-setae (Central-dorsal)

1. Five pairs; 2. Six pairs; 3. Two pairs.

8.2.2 Md-setae (Marginal dorsal)

1. 36 with 11 anterior to the festoons, two on each of the festoons I-III and one on the fourth festoon; 2. 42 with 12 anterior to the festoons, two on each of the festoons I-IV and one on the fifth festoon; 3. About 30 on the posterior and lateral margins of the alloscutum; 4. About 38 on the posterior and lateral margins of the alloscutum.

8.3 Unknown structure

1. Bear three slit-like apertures; 2. Bear 3-4 slit-like apertures.

9. Idiosoma ventrally

9.1 Genital grooves

1. Deep and narrow, originating just behind the third coxae, widely "S"-shaped; 2. Vague and shallow, extending from the level of the first intercoxal space to the posterior margin of the body.

9.2 Chaetotaxy

9.2.1 St-setae (Sternal setae)

1. One pair posterior to coxa I and two pairs on level or just posterior to coxae II-IV; 2. One pair at the level of first intercoxal space and one pair on level or just posterior to coxae II-IV.

9.2.2 Pre-anal setae

1. Four pairs; 2. Two pairs.

9.2.3 Lateral anal setae

1. Lacking;
2. Two pairs;
3. One pair.

9.2.4 Pre-marginal setae

1. 7-8 pairs;
2. 8 pairs;
3. 5-7 pairs;
4. Four pairs.

9.2.5 Marginal ventral setae

1. Eight pairs;
2. Ten pairs;
3. Five pairs.

9.2.6 Circumspiracular setae

1. Usually five;
2. Three pairs;
3. Ten pairs;
4. Variable in numbers;
5. 10-14 pairs.

10. Spiracles

10.1 Shape

1. Oval;
2. Elongate oval;
3. Circular.

10.2 Number of apertures

1. 99-131;
2. 60-90;
3. 160-185;
4. 12-15.

11. Anus

11.1 Grooves

1. Anal and post-anal grooves present;
2. Absent.

11.2 Setae on anal-valves

1. Three setae;
2. Two setae.

12. Coxae

12.1 Spurs on coxa I

1. Triangular internal and external spurs of about equal dimensions;
2. Triangular internal and external spurs with the internal spur smaller;
3. Triangular internal and external spurs with the

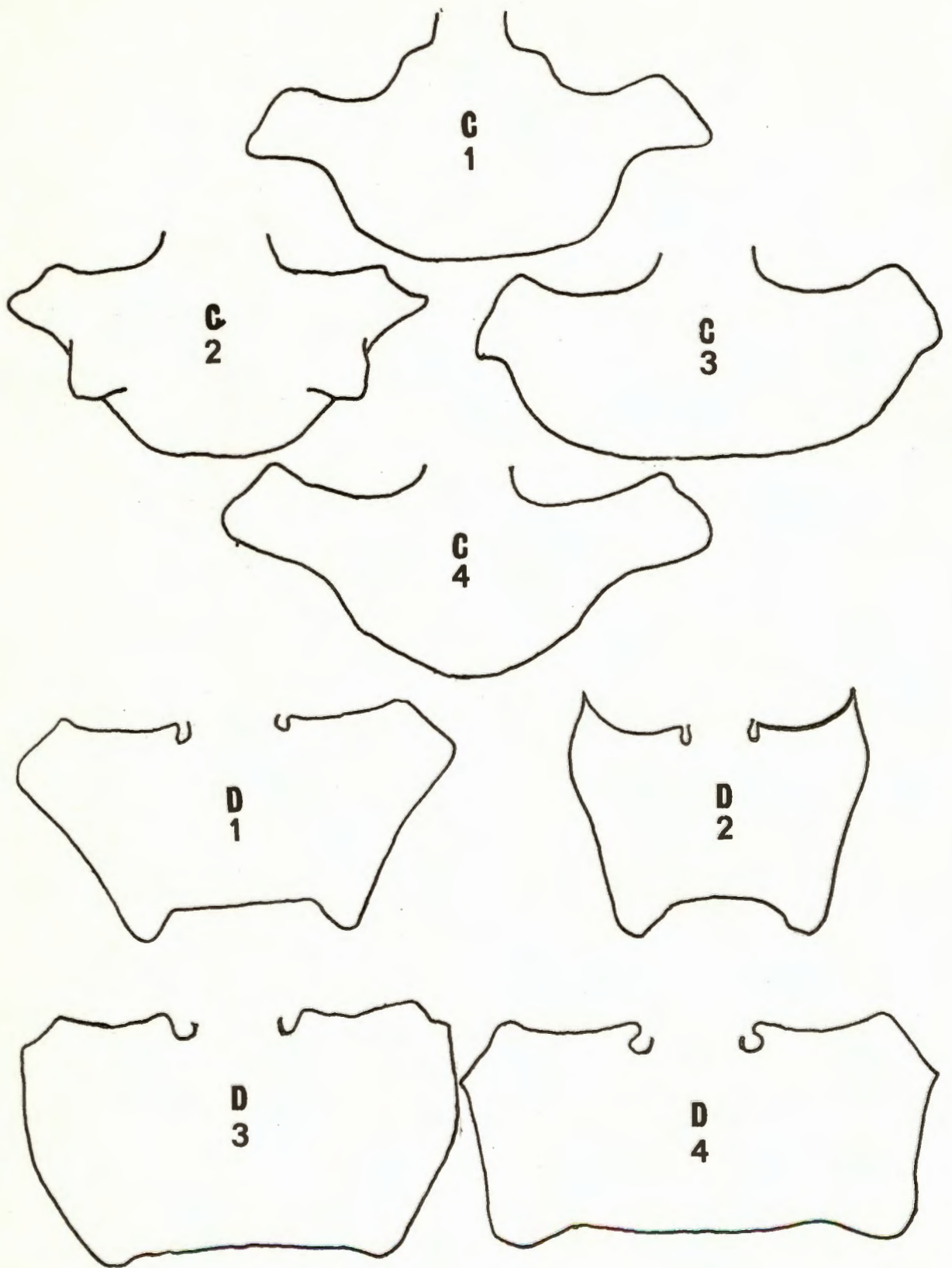


FIGURE 5

FIGURE 5

C1-4: Ventral aspect of the gnathothecum of the nymphae:-

C1: *Rhipicephalus pravus* and *R. oculatus*;

C2: *R. appendiculatus*;

C3: *Boophilus decoloratus*;

C4: *B. microplus*.

D1-4: Gnathotectum of males:-

D1: *R. pravus* and *R. oculatus*;

D2: *R. appendiculatus*;

D3: *B. decoloratus*;

D4: *B. microplus*

- external spur narrowly elongate; 4. Broad internal spur and narrowly tapering external spur.
5. Narrowly rounded external spur with a broadly rounded external spur.

12.2 Spurs on coxae II-IV

1. Internal spurs triangular with a vague indication of the external spurs, both decline progressively on the succeeding coxae from II-IV; 2. Slight indications of internal spur on coxa II and lacking on coxa III with the external spurs on coxae II and III broadly rounded. Coxa IV lacks any spurs; 3. Broadly rounded internal and external spurs on coxae II and III with the external spurs smaller. Coxa IV spurless.

13. Haller

13.1 Halleral setae (number of)

1. Two; 2. One.

13.2 Shape of aperture

1. (Fig. 9, M1); 2. (Fig. 9, M2); 3. (Fig. 9, M3).

13.3 Post-halleral setae

1. A complex of four centro-median setae posterior to the post-halleral setae; 2. Absent.

Males

1. Gnathothecum (dorsally)

1.1 Shape of gnathotectum

1. (Fig. 5, D1); 2. (Fig. 5, D2); 3. (Fig. 5, D3);
4. (Fig. 5, D4).

1.2 Alae

1. Prominent; 2. Present but lesser prominent;
3. Obtuse or lacking.

- 1.3 Cornua
 - 1. Prominent; 2. Lesser prominent.
- 1.4 Posterior transverse row of setae
 - 1. Four but rarely five; 2. Four but more often five; 3. 4-6; 4. A posterior arch of 6-7.
 - 5. Two pairs of sub-mesial setae.
- 1.5 Postero-lateral row of setae
 - 1. Two pairs; 2. Three pairs.
- 1.6 Antero-lateral row of setae
 - 1. Two pairs; 2. 3-4 pairs; 3. Four pairs.
- 2. Gnathothecum (ventrally)
 - 2.1 Shape
 - 1. (Fig. 6, E1); 2. (Fig. 6, E2); 3. (Fig. 6, E3);
 - 4. (Fig. 6, E4).
 - 2.2 Setae at junction of posterior and postero-lateral row
 - 1. Five; 2. Six; 3. 8-9; 4. 6-10; 5. 9-13;
 - 2.3 On posterior steep face of allae
 - 1. One pair; 2. Absent.
 - 2.4 Setae on antero-lateral margins
 - 1. Two; 2. 3-4.
 - 2.5 Setae on socket ventrally
 - 1. 2-3; 2. 3-4; 3. ⁺ 5; 4. 6-7.
- 3. Chelicerae
 - 3.1 Visibility
 - 1. Almost entirely covered by the palps; 2. Clearly visible.
 - 3.2 Outer cheliceral sheaths
 - 1. Two-thirds the length covered by teeth; 2. Almost

entirely covered.

3.3 Length

1. About equal in length to the palps;
2. Longer than the palps.

4. Hypostome

4.1 Dentition

1. 3/3; 2. 4/4.

4.2 Dimensions of denticles

1. Large; 2. Small.

4.3 Denticles per longitudinal files

1. 7-9; 2. 7-8.

4.4 Corona

1. Contain six rows; 2. Contain five rows.

4.5 Corona denticles per row

1. (9/9), (9/9), (5-6/6), (7/7), (6/6), (3-4/4);
2. (12/2), (8/8), (1-2/1), (4/4), (4-5/4), (5-4/4);
3. (14-15/14), (8/8), (9-10/9), (7-8/7), (9-10/9), (4-5/4);
4. (9/9), (8/8), (5/5), (4/4), (2/2);
5. (9/9), (6/6), (6/6), (5/5), (3/3).

5. Palps

5.1 Bristle-bearing structure

1. Well-developed and triangular; 2. Broad, thickened protruberance.

5.2 Chaetotaxy

1. 2M, 5SM, 6DSM, 2L;
2. 2M, 5SM, 6DSM, 3L;
3. 4M, 6SM, 5DSM, 1L.

5.3 Ventral mesial serie of setae on the femur

1. Strongly barbed; 2. Finely barbed; 3. Slight=

ly barbed apically.

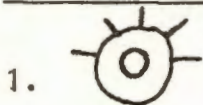
5.4 Spur on ventral margin of tibia-tarsus complex

1. Well-defined, large, triangular in shape;
2. Broad, large, triangular but elongate.
3. Small, triangular; 4. Protruberant.

5.5 Chaetotaxy

1. 7 + 6 + 3VM, 3SM, 5VSM, 3L;
2. (5-6) + (3-4) + 2VM, 3SM, 5VSM, 3L;
3. 5 + (4-5) + 2VM, 3SM, 5VSM, 3L;
4. 1 + 2 + 2VM, 4SM, 3VSM, 2L;
5. 0 + 2 + 2VM, 4SM, 3VSM, 2L.

6. Tibia-tarsus complex



7. Conscutum

7.1 Cervical pits

1. Deep; 2. Shallow.

7.2 Cervical grooves

1. Relatively deep, convergent at first, becoming divergent and fading out beyond level of the eyes;
2. Shallow and broad, fading out beyond eye-level.

7.3 Lateral grooves

1. Very short; 2. Very shallow, if present;
3. Absent.

7.4 Marginal grooves

1. Conspicuous; 2. Conspicuous with pronounced outer edge; 3. Very well developed.

7.5 Fovea

1. Well-developed; 2. Lesser developed; 3. Absent.

7.6 Posterior grooves

1. A prominent postero-median groove, two times the length of the postero-lateral grooves; 2. As in 1, but more prominent; 3. Postero-median groove one-third the length of postero-lateral grooves, longer.

7.7 Festoons

1. Eleven present; 2. Absent.

7.8 Longitudinal depressions

1. Vague longitudinal depressions, mesial to the marginal grooves; 2. Absent.

8. Eyes

1. Convexally, oval and obliquely set with confluent punctations dorsally which may coalesce to form a groove.
2. Strongly convex circular and oculated or nearly oculated by a groove of punctations conspicuous; 3. Slightly convex and oval, a groove absent; 4. Flattened to slightly elevated, circular and inconspicuous; 5. Flattened, small and inconspicuous.

9. Unknown structure

1. Present; 2. Absent.

10. Genitalia

10.1 Shape

1. (Fig. 8, I1); 2. (Fig. 8, I2); 3. (Fig. 8, I3); 4. (Fig. 8, I4).

10.2 Number of setae in anterior and antero-lateral complexes

1. 11-12; 2. \pm 10; 3. \pm 14; 4. \pm 16; 5. \pm 16-22.

10.3 Number of setae in lateral complex

1. Two;
2. 5-6.

11. Spiracles

11.1 Shape

1. (Fig. 7, H1);
2. (Fig. 7, H2);
3. (Fig. 7, H3);
4. (Fig. 7, H4).

11.2 Numbers of small apertures (s) and large apertures (1)

1. S(350-400) + 1(40-70);
2. S(220-280) + 1(40-60);
3. S(150-200) + 1(120-200);
4. 1(40-50);
5. 1(8-40).

12. Anus

12.1 Anal grooves

1. Present;
2. Absent.

12.2 Setae on anal-valves

1. Four pairs;
2. Three pairs;
3. One pair.

12.3 Adanal plates

12.3.1 Shape

1. (Fig. 9, O1);
2. (Fig. 9, O2);
3. (Fig. 9, O3);
4. (Fig. 9, O4);
5. (Fig. 9, O5).

12.3.2 Length

1. Never reach posterior body margin;
2. Reach or fail to.

12.3.3 Numbers of setae

1. 18-24;
2. 14-20;
3. 17-22;
4. 30-35;
5. 35-40.

12.4 Accessory anal plates

12.4.1 Shape

1. Represented by ventricular folds;
2. Small to rather well-developed;

3. Well-developed protruding in some cases beyond the posterior body margin;
4. Well-developed but never protrude beyond body margin.

12.4.2 Setae

1. Not any setae occur;
2. About 13 setae;
3. About 40.

13. Coxae

13.1 Shape of coxa I

1. Triangular to sub-triangular;
2. Sub-rectangular.

13.2 Spurs on coxa I

1. Internal and external spurs about equal in length, with the internal spur broadly elongate and the external spur narrowly elongate;
2. Internal and external spurs about equal in length with the internal spur narrowly rounded and the external spur relative small, broad and triangular.

13.3 Coxae II-IV

1. Provided with small, broadly rounded, triangular internal and external spurs.
2. External spurs as in (1) but internal spurs weakly defined or lacking;
3. Provided with small, broadly rounded spurs, with the external spur on coxa III broader. Coxa IV lacking a external spur;
4. Provided with small, broadly rounded internal and external spurs with the spurs on coxa III broader than in II, while coxa IV lacks any spurs.

14. Haller

14.1 Shape of aperture

1. (Fig. 9, N1);
2. (Fig. 9, N2);
3. (Fig. 9, N3).

14.2 Halleral setae

1. One present; 2. Two present.

14.3 Post-halleral setae

1. Post-halleral setae followed up by a complex of four medio-dorsal setae, then by six pairs of widely separated setae; 2. As in (1), but the complex followed up by four pairs of widely separated setae; 3. Post-halleral setae followed up by 3-4 pairs of widely separated setae; 4. Post-halleral setae followed up by five pairs of widely separated setae with the second pair closely located anteriorly or between the third pair.

14.4 Circular sense organ in anterior pit

1. Present; 2. Absent.

Females

1. Gnathothecum (dorsally)

1.1 Shape of gnathotectum

1. (Fig. 6, F1); 2. (Fig. 6, F2); 3. (Fig. 6, F3);
4. (Fig. 6, F4).

1.2 Alae

1. Prominent; 2. Less prominent.

1.3 Cornua

1. Well-developed and relatively broadly rounded;
2. Well-developed and broadly rounded; 3. Well-developed and narrowly rounded; 4. Small to moderate in size and widely rounded; 5. Faintly indicated or absent.

1.4 Setae (dorsally)

1.4.1 Porose areas

1. Two setae present with one inside and one outside the area; 2. Absent.

1.4.2 Postero-lateral row

1. Two; 2. Three; 3. Lacking.

1.4.3 Antero-lateral row

1. Two; 2. 1-2.

1.5 Setae (ventrally)

1.5.1 Setae at postero-lateral junction

1. 3-4; 2. Four; 3. Five; 4. 1-3; 5. 4-6.

1.5.2 Allae

1. Two; 2. Three; 3. Possibly one; 4. Possibly three.

2. Gnathothecum (ventrally)

2.1 Shape

1. (Fig. 7, G1); 2. (Fig. 7, G2); 3. (Fig. 7, G3); 4. (Fig. 7, G4).

2.2 Setae on socket ventrally

1. 3-7; 2. 3-5.

3. Porose areas

3.1 Shape

1. Oval; 2. Sub-circular; 3. Almost circular; 4. Relative broadly elongate oval; 5. Elongate oval to perriform.

3.2 Topography

1. Slightly sunken in gnathotectum; 2. Elevated above surface of gnathotectum; 3. Not depressed or elevated.

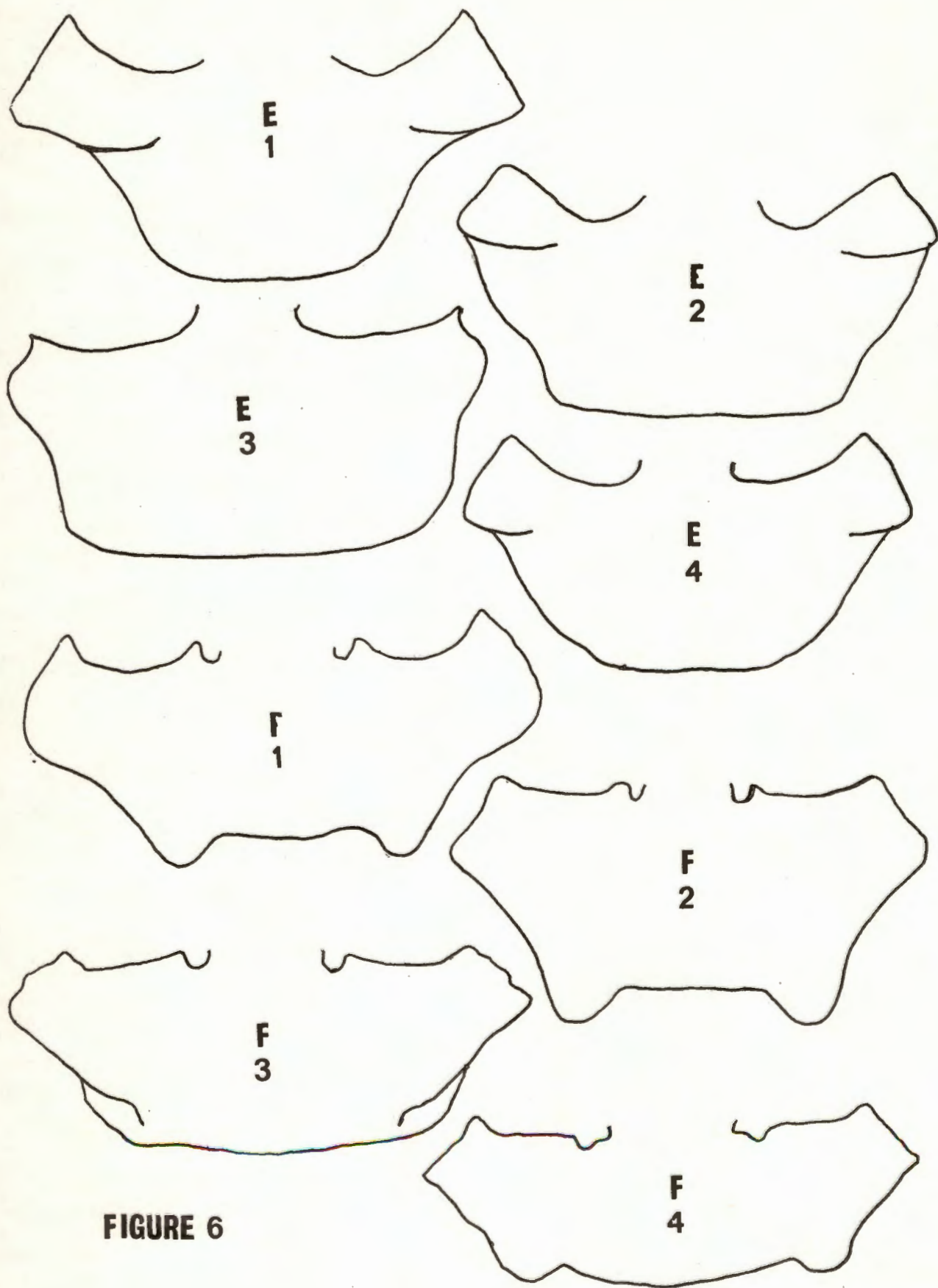


FIGURE 6

FIGURE 6

E1-E4: Ventral aspect of the gnathothecum of the males:-

E1: *Rhipicephalus pravus* and *R. oculatus*;

E2: *R. appendiculatus*;

E3: *Boophilus decoloratus*

E4: *B. microplus*

F1-F4: Gnathotectum of the females:-

F1: *R. pravus* and *R. oculatus*;

F2: *R. appendiculatus*;

F3: *B. decoloratus*;

F4: *B. microplus*.

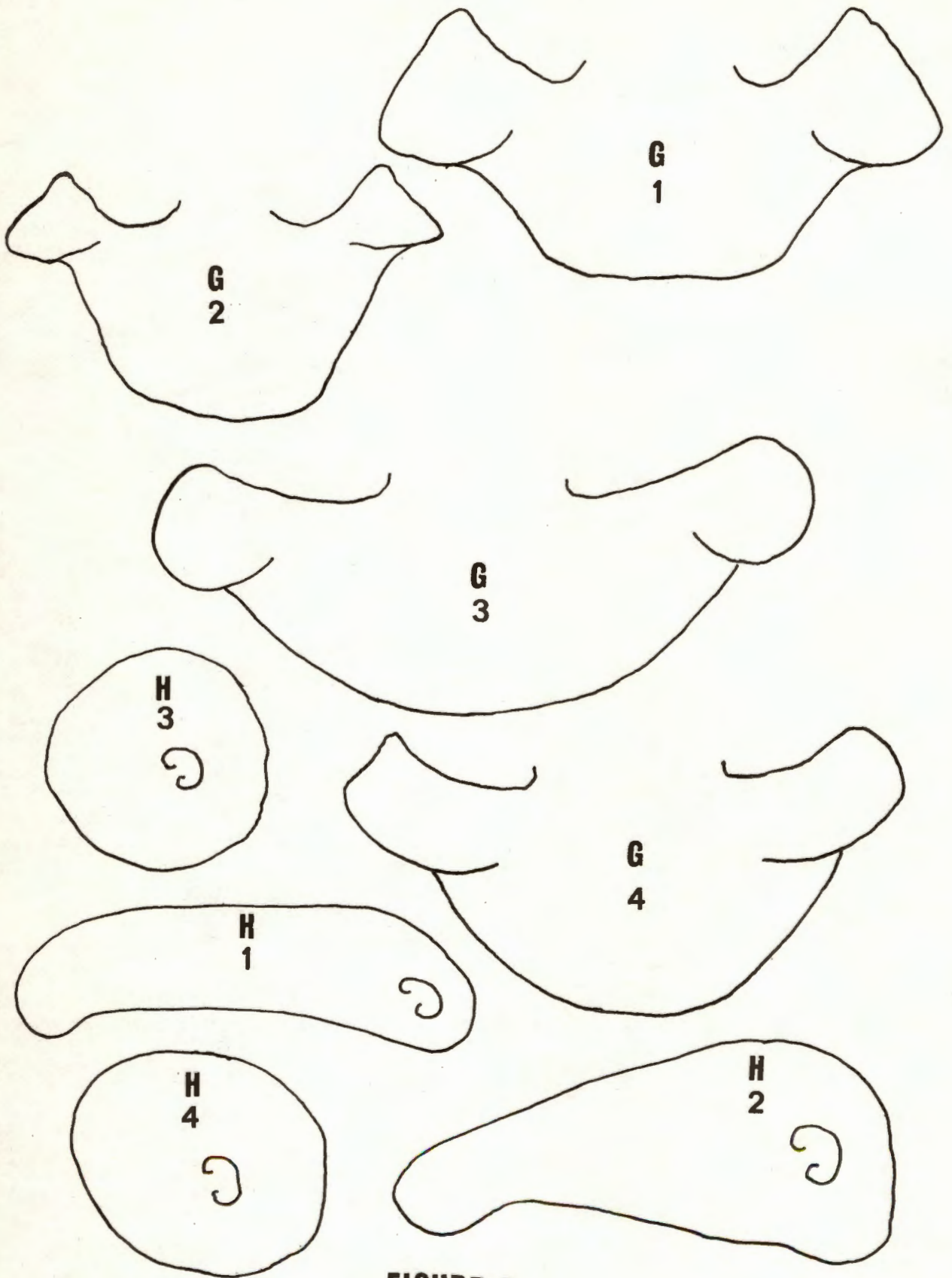


FIGURE 7

FIGURE 7

G1-4: Ventral aspect of the gnathothecum of the females:-

G1: *Rhipicephalus pravus* and *R. oculatus*;

G2: *R. appendiculatus*;

G3: *Boophilus decoloratus*;

G4: *B. microplus*.

H1-4: Spiracles of males:-

H1: *R. pravus* and *R. ocellatus*

H2: *R. appendiculatus*;

H3: *B. decoloratus*;

H4: *B. microplus*.

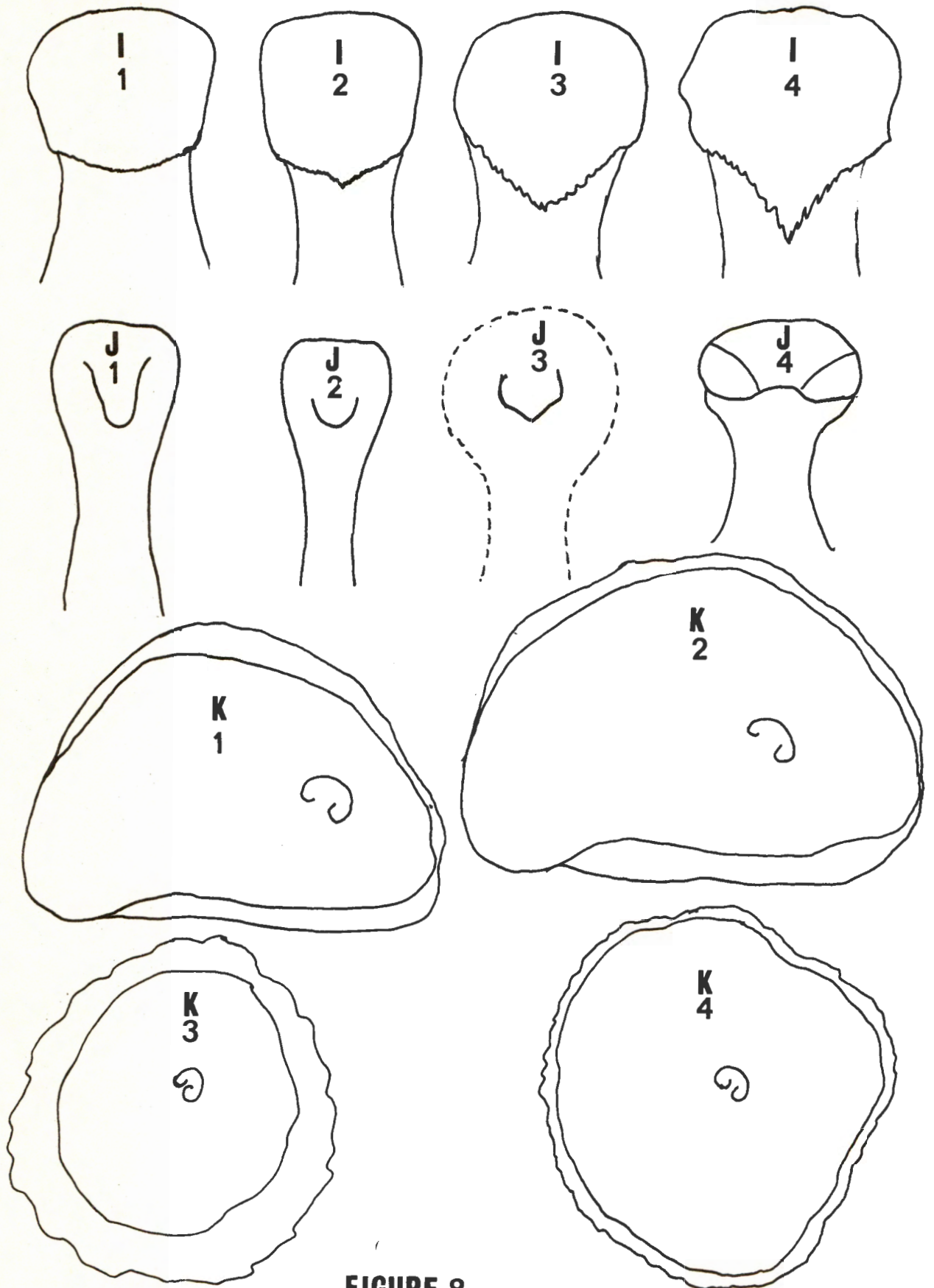


FIGURE 8

FIGURE 8

I1-4: Genitalia of males:-

I1: *Rhipicephalus pravus* and *R. oculatus*;

I2: *R. appendiculatus*;

I3: *Boophilus decoloratus*;

I4: *B. microplus*.

J1-4: Genitalia of females:-

J1: *R. pravus* and *R. oculatus*;

J2: *R. appendiculatus*;

J3: *B. decoloratus*;

J4: *B. microplus*;

K1-4: Spiracles of females:-

K1: *R. pravus* and *R. oculatus*;

K2: *R. appendiculatus*;

K3: *B. decoloratus*;

K4: *B. microplus*.

3.3 Number of apertures

1. 40-80;
2. 50-80;
3. 60-80;
4. 55-65.

4. Hypostome

4.1 Size of denticles

1. Moderate in size;
2. Relative small;
3. Relative large.

4.2 Dentition

1. 3/3;
2. 4/4

4.3 Number of denticles per longitudinal files

1. 11-12;
2. 9-10;
3. 7-8, rarely nine.

5. Corona

1. (12/12), (10/10), (9/9), (6/6), (5/5);
2. (12/12), (9/9), (7/7), (4/4);
3. (12/12), (14/14), (15-16/16), (12-13/13), (13/13);
4. (9/9), (9/9), (9/9), (7/7);
5. (9-10/10), (10/10), (8/8), (7-6/7), (2-3/3).

6. Palps

6.1 Mesial serie on the femur and genu, excluding setae on apex of genu

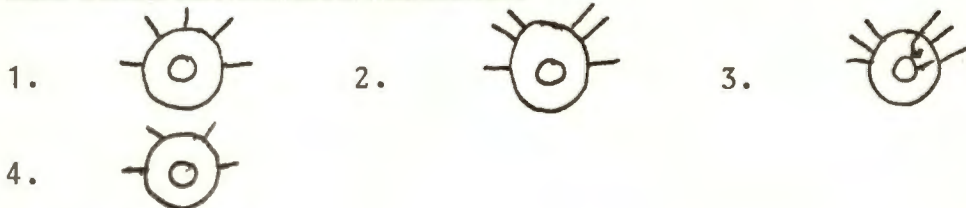
1. (8-9) + (5-8) + 3;
2. (5-8) + (4-6) + 3;
3. (6-8) + (5-7) + 3;
4. (1-2) + (2-3) + 2;
5. (0-1) + (3) + 2.

6.2 Bristle-bearing structure

1. Prominent, triangular structure;
2. Short, protruberance of mesial wall of femur;
3. Lacking.

7. Tibia-tarsus complex

7.1 Setal arrangement on column



7.2 Setae on apex

1. Ventral serie with 1-2 setae; 2. Ventral serie with two setae; 3. As in the males; 4. With one in dorsal and ventral series and three in supra-ventral and sub-dorsal series.

8. Scutum

8.1 Shape

1. (Plate XIV, 5); 2. (Plate XIV, 6);
3. (Plate XIV, 7); 4. (Plate XIV, 9).

8.2 Cervical pits

1. Small and deep; 2. Relative large and deep;
3. Absent.

8.3 Cervical grooves

1. Fairly well-developed, converging at first and then divergent and fading out at eye-level; 2. Relative short, converging at first and then divergent, fading out anterior to eye-level; 3. Shallow and less prominent, almost reaching posterior margin; 4. Broad and shallow, converging at first and then divergent, reaching halfway down the scutal length; 5. Long, broad, shallow, converging at first and then divergent, reaching the posterior margin of the scutum.

8.4 Lateral grooves

1. Very short or absent. Usually replaced by a row of medium size punctations which indicate an arcuate shape; 2. Present but without a clear-cut outer

edge; 3. Very short and inconspicuous and often marked by punctations; 4. Absent.

8.5 Emargination

1. Relative wide and deep; 2. Broad and deep.

8.6 Setae

1. Numerous very small scattered setae; 2. Quite a lot of setae of moderate length along antero-lateral margins, between cervical grooves and a postero-median group; 3. A few setae of moderate length scattered over scutal surface.

9. Eyes

9.1 Shape

1. Large, conspicuous, relatively elevated above the scutal surface, oval in shape, with a groove of punctations bounding it anteriorly and mesially; 2. Small, conspicuous, hemispherically elevated, almost encircled by a groove which is sometimes incomplete; 3. Large, oval and slightly elevated above surface of scutum, lacking a bounded groove; 4. Large and elevated above scutal surface, oval; 5. Inconspicuous, oval and slightly raised above scutal surface.

9.2 Setae

1. Two setae mesial to the eyes; 2. Three setae anterior to the eyes; 3. Two setae antero-laterally and three mesially; 4. About four mesial setae occur; 5. Several setae anterior and antero-mesially.

10. Alloscutum

10.1 Setae

1. Relative few, very small scattered setae within or outside the punctations; 2. Numerous setae of

moderate length; 3. More than in (2) with about the same length.

10.2 Marginal grooves

1. Broadly arcuate and well-defined; 2. Absent.

10.3 Posterior grooves

1. Postero-median and postero-lateral grooves about equal in length and reaching about two-thirds the length of the alloscutum anteriorly; 2. Postero-lateral grooves stretched over the entire length of the alloscutum, with the postero-median groove about half the length of the postero-lateral grooves.

11. Genitalia

11.1 Shape

1. (Fig. 8, J1); 2. (Fig. 8, J2); 3. (Fig. 8, J3);
4. (Fig. 8, J4).

11.2 Genital grooves

1. Conspicuous; 2. Inconspicuous.

11.3 Setae in a anterior (a), antero-lateral (al) and lateral complexes (1)

1. a (13-15) + 21; 2. a (12-14) + 21;
3. a (9-10) + 2-31; 4. 26 al; 5. 30 al.

12. Spiracles

12.1 Shape

1. (Fig. 8, K1); 2. (Fig. 8, K2); 3. (Fig. 8, K3);
4. (Fig. 8, K4);

13. Anus

13.1 Annulus

1. Relative broader anteriorly; 2. About equal in dimensions anteriorly and posteriorly; 3. Broad anteriorly.

13.2 Setae on anal-valves

1. Four pairs; 2. Three pairs; 3. Two pairs.

13.3 Post-anal median groove

1. Deep and well-defined ; 2. Vague shallow depressions.

13.4 Anal grooves

1. Stretching antero-laterally and well-defined;
2. Absent.

14. Coxae

14.1 Spurs on coxa I

1. Internal and external spurs about equal in length with the internal spurs broadly elongate and the external spur narrowly elongate; 2. External spur broader and shorter than the internal spur;
3. Nearly equal rounded internal and external spurs with the external spur a little broader than the internal spur.

14.2 Coxae II-IV

1. Provided with small, broadly rounded triangular internal and external spurs; 2. Broadly rounded external spur on coxa II, a slight salience on coxa II and lacking on coxa IV; 3. A broadly rounded external and internal spurs on coxae II & III with the external spur a salience on coxa IV.

15. Haller

As in the males.

8.3 Species used in the analysis

1. *Rhipicephalus pravus*
2. *R. oculatus*

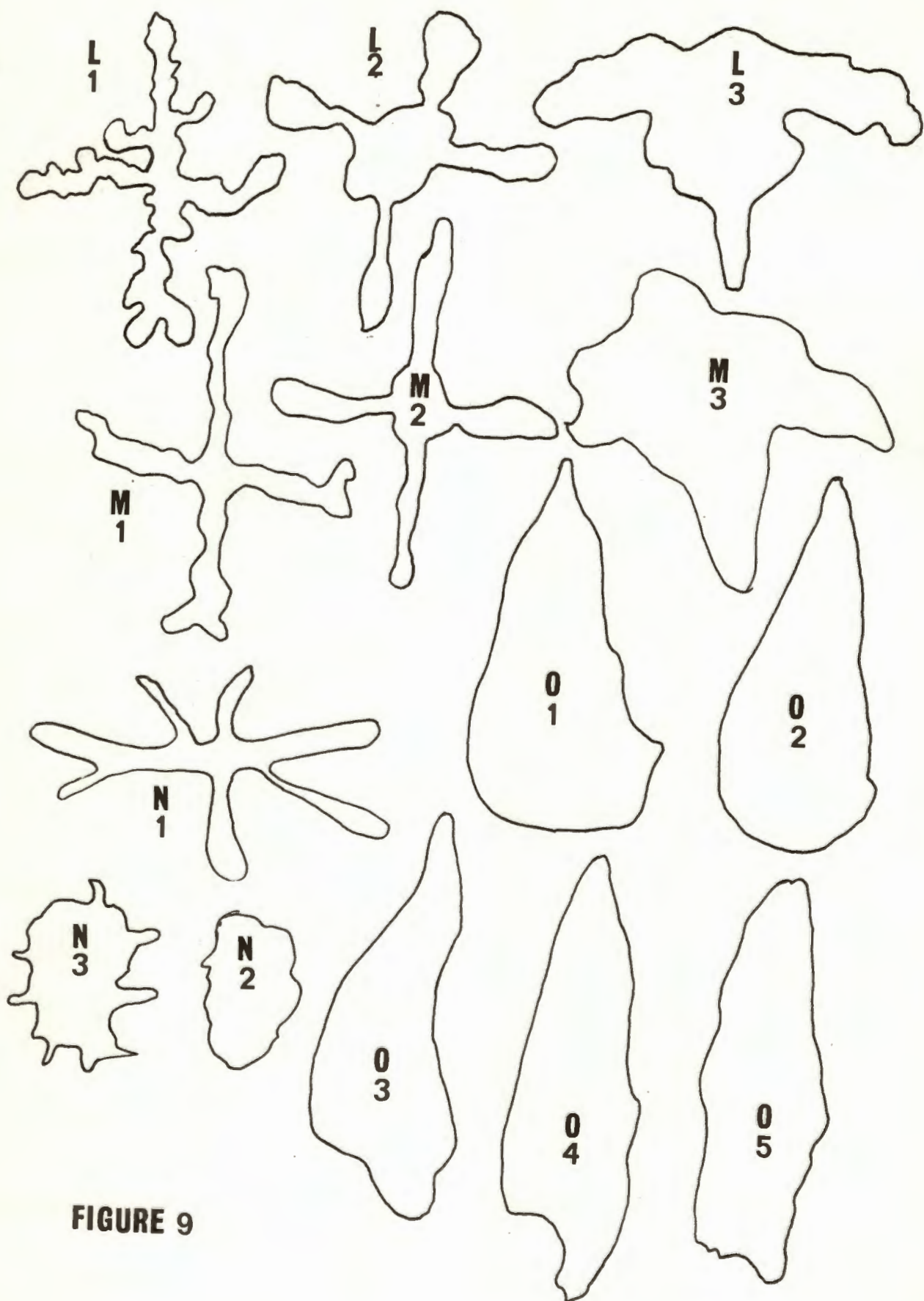


FIGURE 9

FIGURE 9

L1-3: Aperture of Haller's organ of larvae:-

L1: *Rhipicephalus pravus* and *R. oculatus*;

L2: *R. appendiculatus*;

L3: *Boophilus decoloratus* and *B. microplus*.

M1-3: Aperture of Haller's organ of nymphae:-

M1: *R. pravus* and *R. oculatus*;

M2: *R. appendiculatus*;

M3: *B. decoloratus* and *B. microplus*.

N1-3: Aperture of Haller's organ of males:-

N1: *R. pravus* and *R. oculatus*;

N2: *R. appendiculatus*;

N3: *B. microplus*.

Q1-5: Sub-anal plates:-

Q1: *R. pravus*;

Q2: *R. oculatus*;

Q3: *R. appendiculatus*;

Q4: *B. decoloratus*;

Q5: *B. microplus*.

3. *R. appendiculatus*.
4. *Boophilus decoloratus*.
5. *B. microplus*.

The data fed into the computer contain the resemblances and differences between the five species as indicated in Table 2. The rows indicate the variation of each of the characteristics displayed by each species. The columns indicate the variation of the characters in each of the five species and in the different life-stages of the studied species.

8.4 Determination of similarity

To determine the similarity coefficient (Table 2), each of the five species is compared with each other in respect of the varying characteristics with the aid of the information presented in Table 3. The organisms concerned are arranged so that types displaying the highest percentage of relationship or similarity are grouped together. This grouping together of types with the highest similarity coefficients is known as cluster analysis (Sneath, 1957; Gower, 1969).

Due explanation of cluster analysis is that used by Sneath, (1957). According to this method a nuclear group consisting of the two taxons with the highest coefficients of similarity are selected. Thereupon the taxons with the next highest relationship are added to the nuclear group. In this way clusters or groups are assembled. When the similarity coefficients decrease new higher taxons are obtained.

A computer is used to determine the similarity coefficients and work units for cluster analysis. The programme (fig. 13) compiled for this purpose, consist of two phases viz. the determination of the similarity coefficient (Table 2) and the determination of the work units (Table 4) for the compilation of the cluster analysis.

FIGURE 13

**BASIC COMPUTER PROGRAMME TO CALCULATE
THE SIMILARITY COEFFICIENT AND WORK UNITS
FOR CLUSTER ANALYSIS**

```

V2 M11  ACTUAL 16K  CONFIG 16K

// FOR
*ONE WORD INTEGERS
*EXTENDED PRECISION
*IOCS(CARD,1403 PRINTER,DISK)
*LIST SOURCE PROGRAM
C NUMERIESE TAKSONMIE - PERSENTASIE OOREENKOMSTE
C GEGEWENS VERWERK OM N DENDOGRAM TE STEL
C PROGRAM KAN 80 SPESIES EN 80 KENMERKE HANTEER
  INTEGER TABLE(5,160),SPESI,DEEL(160)
  455 CONTINUE
  WRITE(5,1001)
1001 FORMAT('1')
  READ(2,456) KENMR,SPESI
  456 FORMAT(2I4)
  DO 222 I=1,SPESI
  READ(2,2) (TABLE(I,J),J=1,KENMR)
  2 FORMAT(80I1/80I1)
  222 CONTINUE
  WRITE(5,1)
  1 FORMAT(9X'BASIESE GEGEWENS WAAROP BEREKENINGS
  GEDOEN WORD'///20X'K 1ENMERKE.....'//)
  DO 3 I=1,SPESI
  3 WRITE(5,4)I,(TABLE(I,J),J=1,KENMR)
  4 FORMAT(3X'SP',I2'-'2X,80I1/10X,80I1)
  N=SPESI-1
  DO 8 I=1,N
  M=I+1
  DO 8 J=M,SPESI
  PERS=0.0
  DO 10 K=1,KENMR
  IF(TABLE(I,K)-TABLE(J,K))10,12,10
  12 PERS=PERS+1.0
  10 CONTINUE
  PERS=PERS/KENMR*100
  8 TABLE(I,J)=PERS
  DO 7 I=1,SPESI
  DO 9 J=1,SPESI
  9 TABLE(J,I)=TABLE(I,J)
  TABLE(I,I)=0
  7 DEEL(I)=1
  WRITE(5,13)
  13 FORMAT(///10X'PERSENTASIE OOREENKOMS'///)

```

PAGE 2 CONTINUE

```
M=0
19 M=M+20
   IF(SPESI-M)16,15,15
15 N=M-20+1
   GO TO 5
16 N=M-20+1
   M=SPESI
   5 WRITE(5,17)N,M
   DO 14 I=1,SPESI
14 WRITE(5,11)I,(TABLE(I,J),J=N,M)
17 FORMAT(1H0,3X'VIR KENMERKE'I2'TOT'I2'///)
   IF(M-SPESI)19,18,19
18 WRITE(5,119)
119 FORMAT(///13X'GEGEWENS VIR DENDOGRAM'///3X,
   .RY..KOLOM.PERSENTASIE 1 OOREENKOMS...GROEPE'///)
40 IHOU=0
   N=SPESI-1
   DO 20 I=1,N
   M=I+1
   DO 20 J=M,SPESI
   IF(TABLE(I,J)-IHOU)20,20,24
24 IHOU1=I
   IHOU2=J
   IHOU=TABLE(I,J)
20 CONTINUE
   IF(IHOU)101,101,38
38 DO 34 J=1,SPESI
   PERS=(FLOAT(TABLE(J,IHOU1))*DEEL(IHOU1)+FLOAT
   (TABLE(J,IHOU2))*DEEL(IHOU2))/(DEEL(IHOU1)+DEEL(IHOU2))
34 TABLE(J,IHOU1)=PERS
   DO 35 J=1,SPESI
   TABLE(IHOU1,J)=TABLE(J,IHOU1)
   TABLE(J,IHOU2)=0
35 TABLE(IHOU2,J)=0
   TABLE(IHOU1,IHOU1)=0
   WRITE(5,26)IHOU1,IHOU2,IHOU,DEEL(IHOU1),DEEL(IHOU2)
26 FORMAT(3X,I4,2X,I4,8X,I4,12X,2I4)
   DEEL(IHOU1)=DEEL(IHOU1)+DEEL(IHOU2)
   GO TO 40
11 FORMAT(3X,I2,2X,20I5'')
101 GO TO 455
END
```

FEATURES SUPPORTED
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CORE REQUIREMENTS FOR
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END OF COMPILATION

		SP 1	2	3	4	5
IMMATURE & MATURE STAGES	SP 1	0	73	55	1	2
	.. 2	73	0	53	2	3
	.. 3	55	53	0	3	5
	.. 4	1	2	3	0	53
	.. 5	2	3	5	53	0
MALES	SP 1	0	74	55	1	3
	.. 2	74	0	53	1	3
	.. 3	55	53	0	5	11
	.. 4	1	1	5	0	50
	.. 5	3	3	11	50	0
FEMALES	SP 1	0	68	57	4	2
	.. 2	68	0	57	6	4
	.. 3	57	57	0	4	4
	.. 4	4	6	4	0	40
	.. 5	2	4	4	40	0
NYMPHAE	SP 1	0	77	53	0	2
	.. 2	77	0	53	0	2
	.. 3	53	53	0	0	2
	.. 4	0	0	0	0	66
	.. 5	2	2	2	66	0
LARVAE	SP 1	0	82	47	0	0
	.. 2	82	0	47	0	0
	.. 3	47	47	0	0	0
	.. 4	0	0	0	0	70
	.. 5	0	0	0	70	0

TABLE 3 Matrix to show the similarity coefficients

DATA FOR DENDROGRAM

RQW	COLUMN	PERCENTAGE SIMILARITY	GROUPS	
1	2	73	1	1
1	3	54	2	1
4	5	53	1	1
1	4	2	3	2
1	2	74	1	1
1	3	54	2	1
4	5	50	1	1
1	4	3	3	2
1	2	68	1	1
1	3	57	2	1
4	5	40	1	1
1	4	3	3	2
1	2	77	1	1
4	5	66	1	1
1	3	53	2	1
1	4	1	3	2
1	2	82	1	1
4	5	70	1	1
1	3	47	2	1

TABLE 4 Work units from which the dendrograms are compiled

The groups produced by cluster analysis can be arranged in a specific pattern (figg. 10A, B; 11A, B & 12A) with the aid of the information in Table 4. This diagrams or dendrograms displays the specific levels of similarity. If, for example, a horison-tal line, or "phenon"line is drawn right opposite the 70% level of similarity, all the representatives of the clusters or groups above this phenon line correspond at least 70% with each other. In this manner groups of organisms can be assigned to phenons on different levels. Phenons, according to Sokal & Sneath (1963) are groups which approach natural taxa more or less closely and like the term taxon, they can be of any hierarchic rank or of indeterminate rank. If, for example a horixontal line or phenon-line, is drawn right opposite the 70% value, all the representatives of the clusters or groups above this phenon-line correspond at least 70% with each other. In this manner groups of organisms can be assigned to taxons on different levels. For example, 10A, indicates the existance of two phenons on the 70% phenon-line. Numeric taxonomists, as already mentioned, used the term phenon instead of genera, families, etc., because the latter might contain phylogenetic or nomenclaturistic implications.

The work unit or information in Table 4 indicates that *R. pravus* and *R. oculatus* have a similarity coefficient of 73, in other words these species display the greatest similarity. These two species form a group on the 73% phenon-line. On the 54% phenon-line *R. appendiculatus* joins them. Likewise each species with the next highest similarity is attached. A new group can also be formed, however, *B. microplus* and *B. decoloratus* form a different group on the 54% phenon line. Much lower on the 2% phenon line this group attaches to the group consisting of *Rhipicephalus pravus*, *R. oculatus* and *R. appendiculatus*.

Furthermore the dendrogram indicates that the genus *Boophilus* is not, or nearly not related to the genus *Rhipicephalus*. The same above mentioned conclusions can be drawn from the dendrograms drawn up from the similarity coefficients of the larvae, nymphae, males and females. In fig. 12A, the genus *Boophilus* seemed not to be

related to the *Rhipicephalus* genus, but one must bear in mind that only 17 characters were used in this investigation.

Although this quantitative investigation did not bring any new facts to light, it serves as a good control of conventional methods and also indicates the use of phenons to indicate related taxons. For example *Rhipicephalus pravus*, *R. oculatus* and *R. appendiculatus* are described as different species by conventional methods and *R. pravus* and *R. oculatus* are regarded to be representatives of the same group and *R. appendiculatus* from another, numerical taxonomy can prove this statement.

8.5 Dimensional analysis

Whereas some users of biometrical techniques assume that the variance or standard deviation of a sample is useful only as a tool for determining the error with which the mean is estimated, a measurement of variability is of interest in itself. The fact that one population is more variable than another is biological information of just as great significance to the systematist and the morphologist. The variance of a population conveys a kind of information about the relation of the group to other groups and to the forces of the environment, which cannot be extracted from the mean alone.

If enough characters were available in a given study, one might segregate all those characters which manifest a size trend and compute distances between unit characters on the basis of these characters only. According to Sokal & Sneath (1963) one could then partition these distances into shape and size components which should give some insight into the pattern of evolutionary change within the groups. It is not likely that the size component will be very large. The rules for treating empirical correlations would probably have reduced the importance of a general size factor even if many characters had shown its effects. To illustrate this problem, suppose a study of a number of different but approximately equal sized unengorged ticks is included,

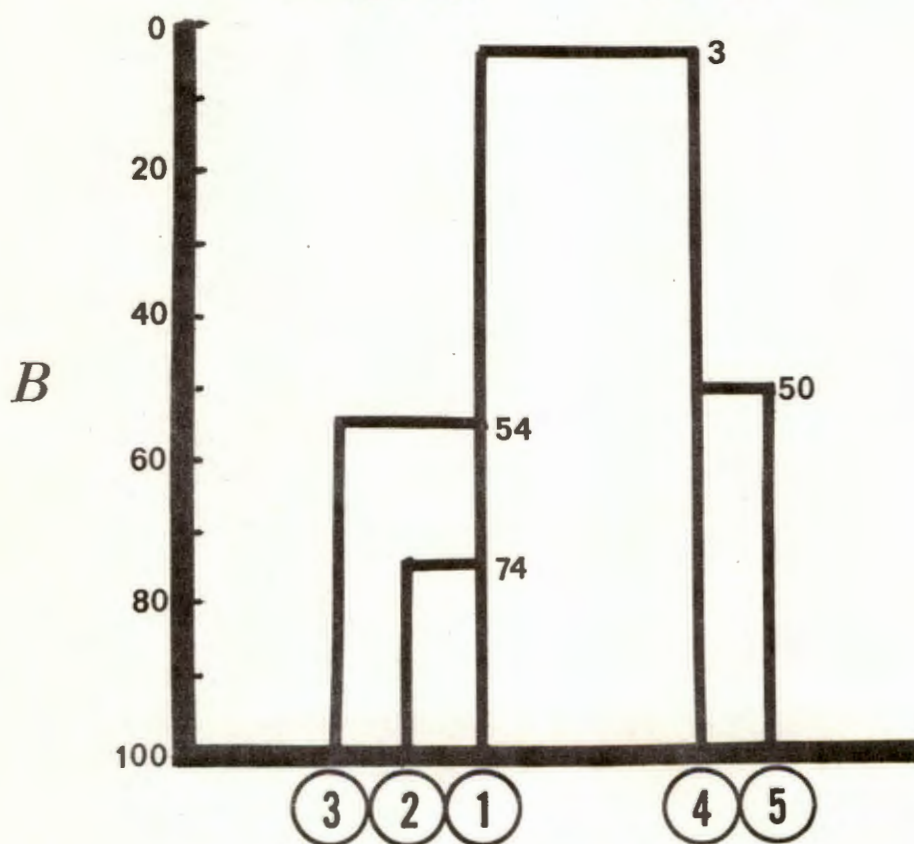
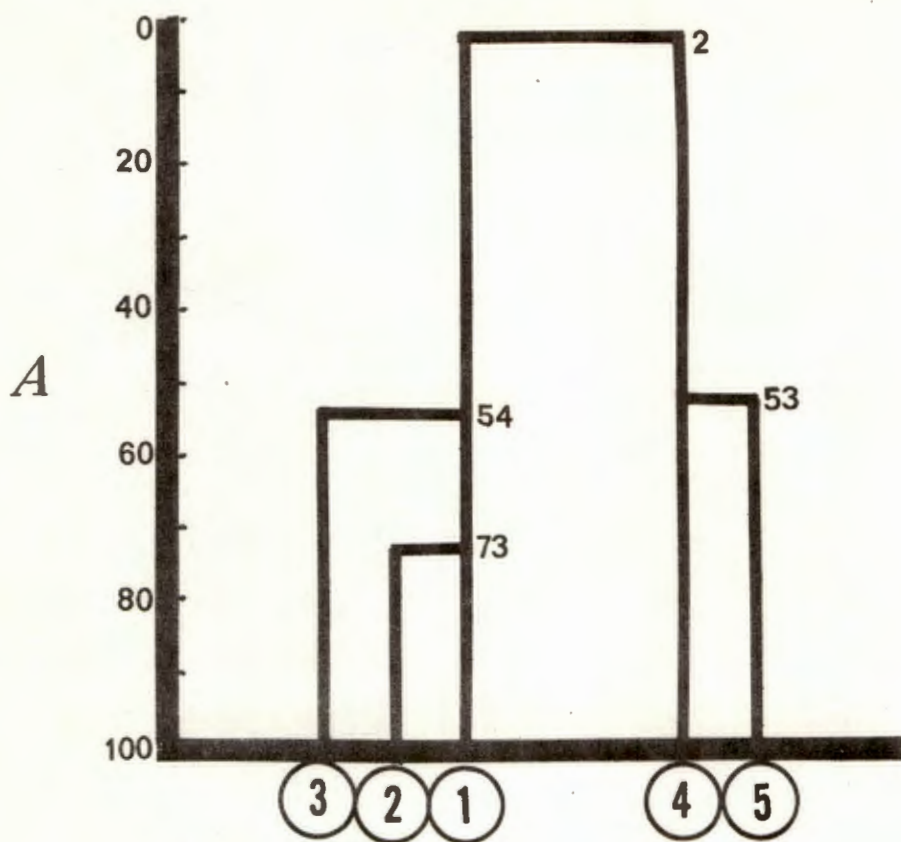


FIGURE 10

FIGURE 10

- A. Dendrogram to show the phenetic relationships of both the immature and mature stages of the studied species.
- B. Dendrogram to show the phenetic relationships of the males of the studied species.

- 1 = *Rhipicephalus praeus*
- 2 = *R. oculatus*
- 3 = *R. appendiculatus*
- 4 = *Boophilus decoloratus*
- 5 = *B. microplus*

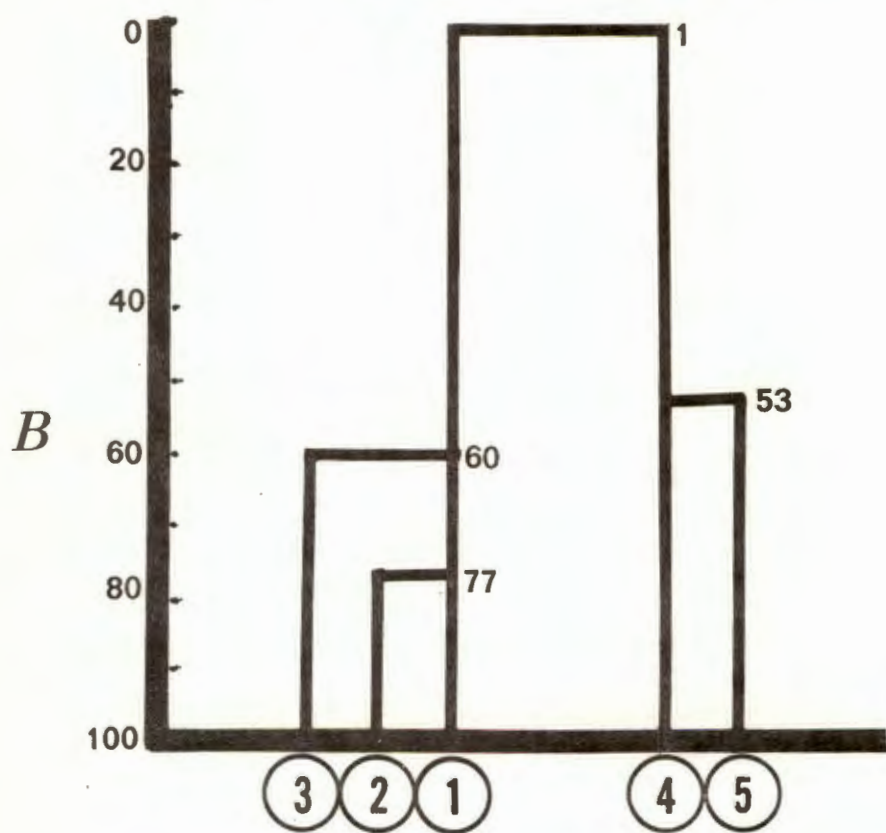
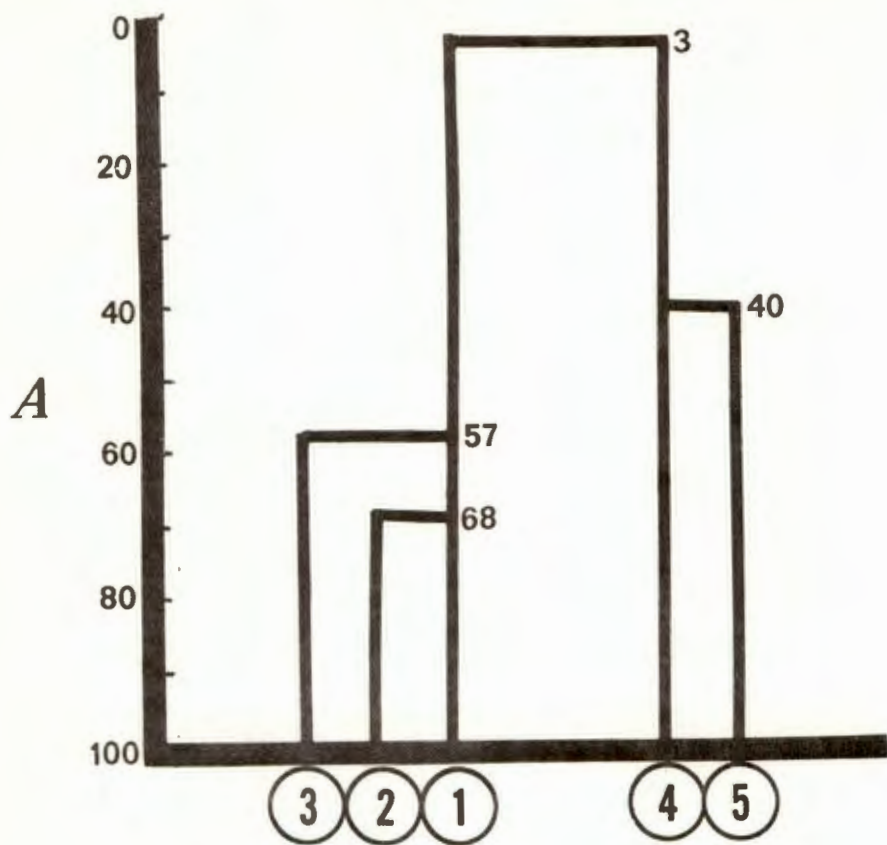


FIGURE 11

FIGURE 11

- A. Dendrogram to show the phenetic relationships of the females of the studied species.
- B. Dendrogram to show the phenetic relationships of the nymphae of the studied species.

- 1 = *Rhipicephalus pravus*
- 2 = *R. oculatus*
- 3 = *R. appendiculatus*
- 4 = *Boophilus decoloratus*
- 5 = *B. microplus*

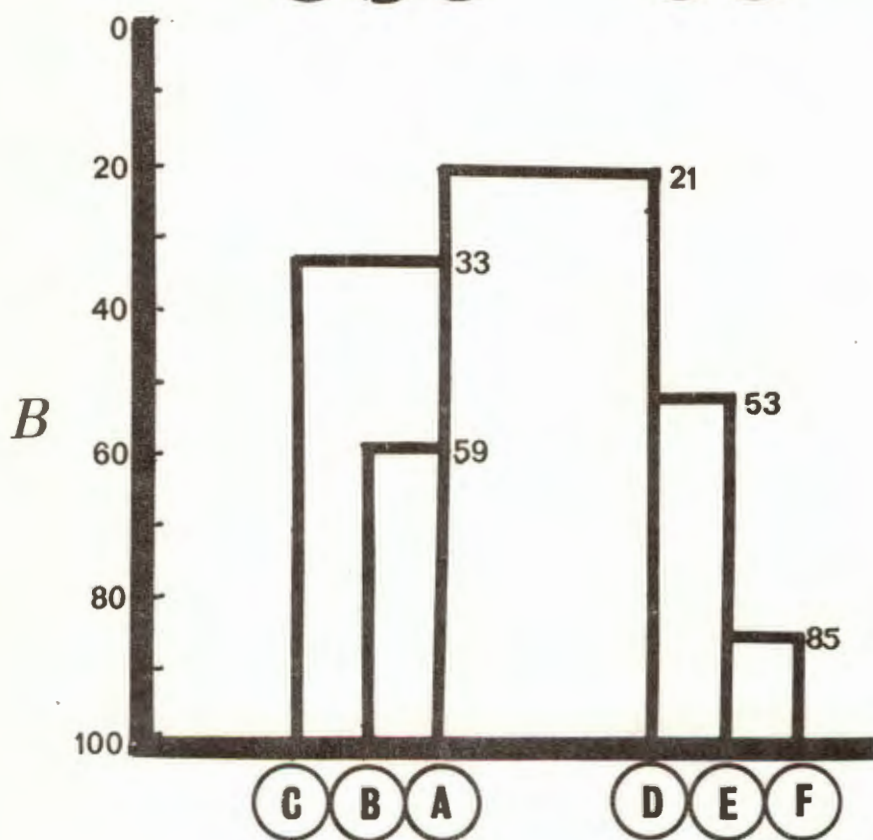
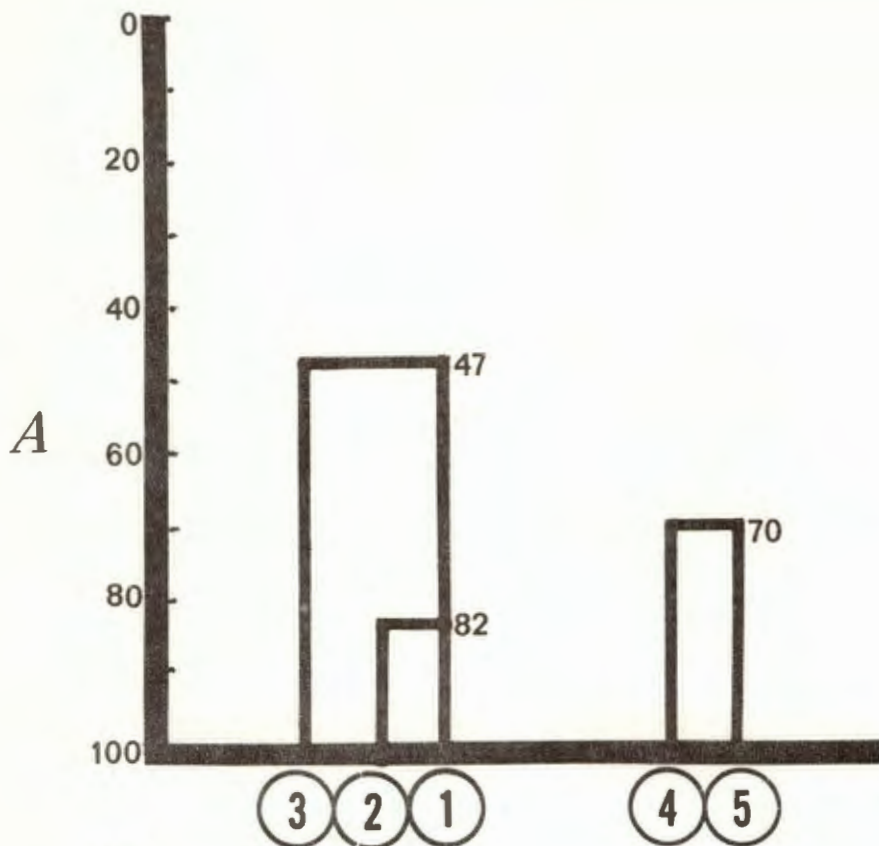


FIGURE 12

FIGURE 12

- A. Dendrogram to show the phenetic relationships of the larvae of the studied species.
- B. The classification (dendrogram) of the studied six groups based on the indices of dimensional similarity between them.

A = *Rhipicephalus pravus*
B = *R. oculatus*
C = *R. appendiculatus*
D = *Boophilus decoloratus*
E = *B. microplus* (South African strain)
F = *B. microplus* (Australian strain)

1 = *R. pravus*
2 = *R. oculatus*
3 = *R. appendiculatus*
4 = *B. decoloratus*
5 = *B. microplus*

whose resemblances are computed from, say 100 characters. If species A was added, which is apparently identical to a species A already involved in the study, but several times as large, a number of new characters should have to be added to express size differences of various parts of the body. For all these new characters all the old species (including A) will exhibit the small state, while A(1) will show the large state. Since these new characters will therefore be identical to each other, one must show cause. If a single size factor is responsible for the enlargement of the various parts of the body in species A(1), the new characters are reduced to a single one, because general size in this case is ab initio an unimportant component of the distance coefficient.

8.5.1 F-test (variance analysis)

The information derived from the dimensions from the different species was subjected to a variance analysis, also known as the F-test. (Moronay, 1965; du Toit, 1966), Sokal & Rohlf, 1969).

This test is an improvement on the t-test, as in the latter case, like with the naught hypothesis, it is assumed that not only the mean values of the dimensions treatments are identical but also the variances. In the case of the F-test, it is first determined whether the variances between the treatments dimensions correspond or differ, before the differences between the mean values of treatment dimensions are examined. In the latter examination the S.S.D. (Smallest significant difference) analysis is used. In this analysis any reliability level can be used but in the F-test only the 95% and 99% levels are used. For the F-test and S.S.D.-analysis, the 99% reliability level was always employed during this investigation. The results are summarized in Tables 5-9.

From the data in Tables 5-9 a dendrogram was drawn up by using an index of similarity - Mountford (1962) as described by Sokal & Sneath (1963). The series of indices between the studied groups

are determined, from which a classification is derived. The analysis is based on 65 of the total amount of 96 characters, because only 65 characters show variances. Such characters are used since characters that are similar will increase the similarity indices artificially.

Index of similarity

Let groups be A, B, C, D, E and F with indices of similarity:
(Data obtainable in Table 9, last column.)

	B	C	D	E	F
A	59	37	25	20	17
B		29	23	15	17
C			28	23	23
D				51	52
E					85

The highest index is that between groups E and F, therefore E and F are grouped together and the indices of similarity worked out between this group and the remaining groups.

$$\begin{aligned}
 I(EF:A) &= \frac{I(AE) + I(AF)}{2} & I(EF:C) &= \frac{I(EC) + I(FC)}{2} \\
 &= \frac{20 + 17}{2} & &= \frac{23 + 23}{2} \\
 &= 18,5 & &= 23 \\
 \\
 I(EF:B) &= \frac{I(EB) + I(FB)}{2} & I(EF:D) &= \frac{I(ED) + I(FD)}{2} \\
 &= \frac{15 + 17}{2} & &= \frac{51 + 52}{2} \\
 &= 16 & &= 51,5
 \end{aligned}$$

TABLE 5

Smallest significant differences of the gnathotectum

Species	Combinations	Larvae			Nymphae		Males			Females		
		G1	Gb	Sb	G1	Sb	G1	Gb	Sb	G1	Gb	Sb
<i>R. pravus</i>	<i>R. oculatus</i>	-	+	+	-	+	-	-	-	-	-	+
" "	<i>R. appendiculatus</i>	+	+	+	-	+	+	+	+	-	-	+
" "	<i>B. decoloratus</i>	-	+	+	+	+	+	+	+	+	+	+
" "	<i>B. microplus</i> (S)	+	+	+	+	+	+	+	+	-	+	+
" "	<i>B. microplus</i> (A)	-	+	+	+	+	+	+	+	-	-	+
<i>R. oculatus</i>	<i>R. appendiculatus</i>	-	+	+	-	+	+	+	+	-	+	+
" "	<i>B. decoloratus</i>	-	+	+	+	+	+	+	+	+	+	+
" "	<i>B. microplus</i> (S)	+	+	-	+	+	+	+	+	+	+	+
" "	<i>B. microplus</i> (A)	+	+	-	+	+	+	+	+	+	+	+
<i>R. appendiculatus</i>	<i>B. decoloratus</i>	+	+	+	+	+	+	+	+	+	+	-
" "	<i>B. microplus</i> (S)	+	+	+	+	+	+	+	+	+	+	+
" "	<i>B. microplus</i> (A)	+	+	+	+	-	+	+	+	+	+	+
<i>B. decoloratus</i>	<i>B. microplus</i> (S)	+	+	-	+	-	-	-	-	-	+	+
" "	<i>B. microplus</i> (A)	+	+	-	+	-	-	-	-	-	+	+
<i>B. microplus</i> (S)	<i>B. microplus</i> (A)	-	-	-	-	-	-	-	-	-	-	-

G1 = gnathotectum length Sb = Socket breadth

Gb = gnathotectum breadth S = South African

A = Australian strain

+ difference

- no difference

No significant difference between groups
of the gnathotectum breadth of the nymphae.

TABLE 6.

Smallest significant differences of the palp segments

Species	Combinations	Larvae				Nymphae	Males					Females				
		F1	Fb	G1	Gb		P1	P1	F1	Fb	G1	Gb	P1	F1	Fb	G1
<i>R. pravus</i>	<i>R. oculatus</i>	+	+	+	+	+	+	+	-	+	-	-	-	-	-	-
" "	<i>R. appendiculatus</i>	+	+	-	-	+	+	+	+	+	+	-	+	-	-	-
" "	<i>B. decoloratus</i>	+	-	-	-	+	+	+	+	+	+	+	+	-	+	+
" "	<i>B. microplus (S)</i>	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+
" "	<i>B. microplus (A)</i>	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
<i>R. oculatus</i>	<i>R. appendiculatus</i>	+	+	-	-	+	+	+	+	+	+	+	+	+	-	+
" "	<i>B. decoloratus</i>	+	+	+	-	+	+	-	+	+	+	+	+	+	+	+
" "	<i>B. microplus (S)</i>	-	+	-	+	+	+	+	-	+	+	+	+	+	+	+
" "	<i>B. microplus (A)</i>	+	-	-	+	+	+	+	-	+	+	+	+	+	+	+
<i>R. appendiculatus</i>	<i>B. decoloratus</i>	-	-	+	-	+	+	+	+	+	+	+	+	+	+	+
" "	<i>B. microplus (S)</i>	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
" "	<i>B. microplus (A)</i>	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
<i>B. decoloratus</i>	<i>B. microplus (S)</i>	-	-	+	+	+	+	+	-	-	-	+	-	-	-	-
" "	<i>B. microplus (A)</i>	-	+	-	+	+	+	+	-	-	-	+	-	-	-	-
<i>B. microplus (S)</i>	<i>B. microplus (A)</i>	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-

P1 = Palpal length F1 = Femur length G1 = Genu length Fb = Femur breadth Gb = Genu breadth
 S = South African strain + = difference No significant difference between the groups in
 A = Australian strain - = No difference the palpal length of the larvae; femur and genu
 length; femur and genu breadth of the nymphae.

TABLE 7.

Smallest significant differences of the hypostome and scutum

Species	Combination	Larvae			Nymphae	Males	Females	Larvae		Nymphae		Females
		Hl.	Hmb.	Hb.	Hb.	Hl.	Hl.	Sb.	Eb.	Sl.	Sb.	Sb.
<i>R. pravus</i>	<i>R. oculatus</i>	-	-	-	+	+	-	+	+	+	+	-
" "	<i>R. appendiculatus</i>	+	+	-	+	+	-	+	+	+	+	-
" "	<i>B. decoloratus</i>	-	+	+	+	-	+	+	+	+	-	+
" "	<i>B. microplus</i> (S)	-	+	+	+	+	+	+	-	+	-	+
" "	<i>B. microplus</i> (A)	-	+	+	+	-	+	+	+	+	+	+
<i>R. oculatus</i>	<i>R. appendiculatus</i>	+	+	+	-	+	+	+	+	+	+	+
" "	<i>B. decoloratus</i>	-	+	+	+	+	+	+	+	+	+	+
" "	<i>B. microplus</i> (S)	-	+	+	+	+	+	+	+	-	+	+
" "	<i>B. microplus</i> (A)	-	+	+	+	+	+	+	+	-	+	+
<i>R. appendiculatus</i>	<i>B. decoloratus</i>	-	+	+	+	+	+	-	+	+	+	+
" "	<i>B. microplus</i> (S)	+	+	+	+	-	+	-	-	+	+	+
" "	<i>B. microplus</i> (A)	+	+	+	-	-	+	-	-	+	+	+
<i>B. decoloratus</i>	<i>B. microplus</i> (S)	-	-	-	+	+	-	-	+	+	+	-
" "	<i>B. microplus</i> (A)	+	-	-	+	+	-	-	+	+	+	-
<i>B. microplus</i> (S)	<i>B. microplus</i> (A)	-	-	-	-	-	-	-	-	-	-	-

Hl = Hypostome length; Hmb = Hypostome minimum breadth; Hb. = Hypostome maximum breadth
 Sl = Scutum length; Sb = Scutum breadth; Eb = Emargination breadth; S. = South African strains;
 A = Australian strains; + = difference; - no difference.

No significant difference between the groups in hypostomal length of the nymphae; hypostomal minimum and maximum breadth of the adults and the minimum breadth in the nymphae; the emargination breadth of the nymphae and adults; scutal length of the larvae and adults and scutal breadth in the males.

TABLE 8.

Smallest significant differences of the idiosoma, alloscutum, spiracles and anus

Species	Combinations	Larvae			Nym= phae	Males	Females		Nymphae		Males	Females		Larvae	
		I1	Ib	A1	Ib	Ib	I1	Ib	S1	Sb	S1	S1	Sb	Ab	A1
<i>R. pravus</i>	<i>R. oculatus</i>	+	+	+	-	-	-	-	-	-	-	+	-	+	-
" "	<i>R. appendiculatus</i>	+	+	-	+	+	-	-	+	+	+	+	+	-	-
" "	<i>B. decoloratus</i>	+	+	+	+	-	+	+	+	-	+	+	+	+	+
" "	<i>B. microplus (S)</i>	+	+	-	+	-	+	+	-	+	+	+	-	+	+
" "	<i>B. microplus (A)</i>	+	+	-	+	-	+	+	-	+	+	+	-	+	+
<i>R. oculatus</i>	<i>R. appendiculatus</i>	+	+	+	+	-	-	-	+	+	+	+	+	+	-
" "	<i>B. decoloratus</i>	+	+	+	+	-	-	+	+	+	+	+	-	-	+
" "	<i>B. microplus (S)</i>	+	+	+	+	+	+	+	+	+	+	+	-	+	+
" "	<i>B. microplus (A)</i>	+	+	+	+	+	+	+	+	+	+	+	-	-	+
<i>R. appendiculatus</i>	<i>B. decoloratus</i>	+	-	-	-	+	-	+	+	+	+	+	+	+	+
" "	<i>B. microplus (S)</i>	+	-	-	+	+	+	+	+	+	+	+	+	+	-
" "	<i>B. microplus (A)</i>	+	-	-	+	+	+	+	+	+	+	+	+	+	+
<i>B. decoloratus</i>	<i>B. microplus (S)</i>	+	-	+	+	-	+	+	+	+	-	-	-	-	+
	<i>B. microplus (A)</i>	+	-	+	+	-	+	-	+	+	-	-	-	-	-
<i>B. microplus (S)</i>	<i>B. microplus (A)</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-

I1 = Idiosoma length; Ib = Idiosoma breadth; A1 = Alloscutum length; S1 = Spiracle length; Sb = Spiracle breadth; Ab = Anus breadth; A1 = Anus length; S = South African strains; A. = Australian strains; + = difference; - = no difference.

No significant difference between the groups in idiosoma length of the nymphae and adults and spiracle breadth of the males.

TABLE 9

Smallest significant differences of the aperture of Haller's organ, setae of Haller's organ, setae of tibia-tarsus complex and sensillae on the gnathotectum

Species	Combinations	Larvae										All lifestages % similarity
		Ap1	Apb	A11	A21	VS21	SS1	LS	Ds	VS	A2b	
<i>R. pravus</i>	<i>R. oculatus</i>	-	+	-	+	+	+	+	+	+	-	50,77
" "	<i>R. appendiculatus</i>	-	+	-	-	+	+	+	+	+	-	36,92
" "	<i>R. decoloratus</i>	+	-	-	+	-	+	+	+	+	+	24,62
" "	<i>B. microplus</i> (S)	+	+	-	+	+	+	+	+	+	+	20,00
" "	<i>B. microplus</i> (A)	+	+	-	+	+	+	+	+	+	+	16,92
<i>R. oculatus</i>	<i>R. appendiculatus</i>	-	+	-	+	+	+	-	+	--	-	29,23
" "	<i>B. decoloratus</i>	+	+	-	-	+	+	-	+	-	+	23,08
" "	<i>B. microplus</i> (S)	+	+	+	-	+	+	+	+	+	+	15,38
" "	<i>B. microplus</i> (A)	+	+	+	-	+	+	+	+	+	+	16,92
<i>R. appendiculatus</i>	<i>B. decoloratus</i>	+	+	-	+	-	+	-	+	-	-	27,69
" "	<i>B. microplus</i> (S)	+	+	+	+	-	+	+	-	+	-	23,08
" "	<i>B. microplus</i> (A)	+	+	+	+	-	+	+	-	+	-	23,08
<i>B. decoloratus</i>	<i>B. microplus</i> (S)	+	+	+	+	-	+	+	-	+	-	50,77
" "	<i>B. microplus</i> (A)	+	+	+	-	-	+	+	-	+	-	52,31
<i>B. microplus</i> (S)	<i>B. microplus</i> (A)	+	+	+	-	-	-	-	-	-	-	84,62

Ap1 = Aperture of Haller's length; Apb = Aperture of Haller's breadth; A1 = Setae of Haller's length
 VS21 = seta on tibia-tarsus complex length; SS1 = length between sensillae; LS = distance from
 lateral margins; DS = distance from anterior margin; VS = distance from posterior margin; A2b =
 basal diameter of Haller's setae; S. = South African strains; A = Australian strains; + = difference;
 - = no difference.

No significant difference between the groups in length of A3, A4, A5 and A6 setae; basal diameter of
 A1, A3, A4, A5 and A6 setae; length of VS1, SV1, SV2, SD1, SD2, SD3, DS1 setae.

A new table is formed:

	B	C	D	EF
A	59	37	25	18,5
B		29	23	16
C			28	23
D				51,5

The highest value being between A and B, these are combined to form a new group and indices between this group and A and B are found.

$$\begin{aligned}
 I(AB:C) &= \frac{I(AC) + I(BC)}{2} \\
 &= \frac{37 + 29}{2} \\
 &= 33
 \end{aligned}$$

$$\begin{aligned}
 I(AB:D) &= \frac{I(AD) + I(BD)}{2} \\
 &= \frac{25 + 23}{2} \\
 &= 24
 \end{aligned}$$

$$\begin{aligned}
 I(AB:EF) &= \frac{I(EA) + I(EB)}{2} \\
 &+ \frac{I(AF) + I(BF)}{4} \\
 &= \frac{69}{4} \\
 &= 17,25
 \end{aligned}$$

A new table is formed

	AB	C	D
C	33		
D	24	28	
EF	17,25	23	51,5

The highest value being between D and EF, these combined form a new group and indices between D and EF must be found.

$$\begin{aligned}
 I(DEF:AB) &= \frac{I(AD) + I(DB) + I(EA) + I(EB) + I(FA) + I(FB)}{6} \\
 &= \frac{25 + 23 + 20 + 15 + 17 + 17}{6} \\
 &= 17,16
 \end{aligned}$$

$$\begin{aligned}
I(DEF:C) &= \frac{I(CD) + I(CE) + I(CF)}{3} \\
&= \frac{28 + 23 + 23}{3} \\
&= 24,66
\end{aligned}$$

A new table is formed.

	DEF	AB	C
AB	17,16		
C	24,66	33	

The indices between AB and C is the highest, and so these form a third group and therefore the final stage is a comparison of the two groups given by:

$$\begin{aligned}
I(CAB:DEF) &= \frac{I(CD)+I(CE)+I(CF)+I(AD)+I(AE)+I(AF)+I(BD)+I(BE)+I(BF)}{9} \\
&= \frac{28 + 23 + 23 + 25 + 20 + 17 + 23 + 15 + 17}{9} \\
&= \frac{191}{9} \\
&= 21,22
\end{aligned}$$

Now for the final classification (fig. 12, B).

E and F are the first groups taken out; D is arranged on the apex line next to E and F on the 52 level, because D in comparison with E and F show an indices of 52. Similar considerations govern the positions of the other groups.

The present opinions of conventional and numerical taxonomist are largely irreconcilable, but there are indications that a combination of conventional and numerical methods are to become standard practice in future taxonomic studies since cluster analysis has a bearing on the construction of hierarchies, which offers an explanation for the validity and usefulness of hierarchic classifications in systematics.

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