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THE STRUCTURE AND IDENTIFICATION OF THE HAIRS OF THE MAMMALS OF SRI LANKA

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(With 10 Plates)

INTRODUCTION

Hair is one of the most conspicuous and characteristic features of mammals, being present as a general body covering in almost all members of this group. Modifications of hair are seen in the quills of porcupines and the scales of pangolins.

All mammalian hairs have a basic structural similarity, being composed of a cuticle, cortex and medulla, the last two components usually containing pigment particles (Fig. 1). These structural elements have been shown to possess definite and constant features that are useful in identification (Hausman 1920, 1930). Much of the early impetus for the study of hair came from the animal textile industry (eg. Hausman 1944; Wildman 1954; Stains 1958; Appleyard 1960), and the study of the food habits of predatory animals by the identification of prey hairs in faeces (eg. Williams 1938; Mathiak 1938b; Mayer 1952; Day 1966). More recent contributions in this field include the publications of Collins (1971), Dziurdzik (1973, 1978), Brunner & Coman (1974), Feder (1975), Moore (1975), Weingart (1975), Koppiker & Sabnis (1976, 1977) and Keller (1978,1980).

The microscopic structures of the hairs of the mammals of Sri Lanka have not been investigated previously, nor is there much information on similar or related species in the Oriental and South-east Asian Regions. To the authors knowledge, the only relevant contributions are those of Hausman (1920) and Koppiker & Sabnis (1976, 1977). The present work provides information on the hair characters of Sri Lankan mammals and a system of hair identification that should aid in food habits analyses of predatory animals.

MATERIALS AND METHODS

A. Collection of Samples.

A reference collection of hairs from 108 species and sub-species of wild mammal occurring on Sri Lanka was examined, the

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material being obtained mainly from the Sri Lanka National Museum, Colombo. In the majority of species, additional samples, obtained from various sources, were also examined. The pangolin *(Manis crassicaudata)* and the Dugong *(Dugong dugon)* have not been included in this study.

Samples of hair were taken separately from the dorsal and ventral regions of the main body trunk, care being taken to ensure that both coarse and fine hairs were included.

B. Microscopical Technique.

(1) Cuticular Scales: The hairs were cleaned by washing in warm water, drying, and rinsing in ether. Since the scales are often difficult to observe on the hairs themselves, casts of the outer surface of the hairs were made. Previous workers have used media such as gelatine, celloidin and resins (Day 1966), spray lacquer (Carter & Dilworth 1971) and nail polish (Weingart 1973), but in the present study, a thin solution of canada balsom in xylene gave satisfactory results. A film of the balsom solution was spread on a microscopical slide in a manner similar to the making of a blood smear. After allowing several minutes for the film to become firm (but not hard), the cleaned hairs were placed transversely across the slide, with their tips protruding from one side. After covering with another slide, pressure was applied for a few seconds using a press (Korschgen 1969). The covering slide was then removed, and the hairs carefully peeled off using their protruding tips, thus leaving a permanent impression of the cuticular scales on the balsom film.

(2) Medulla and Hair Profile: The hairs were cleaned by washing in a 1:1 mixture of ether and 95% ethanol, and rinsing in pure ether or chloroform to ensure complete drying. For permanent preparations, these hairs were mounted directly in canada balsom on a microscopical slide. 70% ethanol was used in the case of temporary mounts.

(3) Cross-sections: Hairs were sectioned according to the technique of Mathiak (1938a), but using "botanical pith" instead of balsa wood. Thin strips of pith, about 6 cm long, were cut, and

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one flat surface coated with a solution of celloidin in acetone. The hairs to be sectioned were placed on this coating, parallel to the longitudinal axis of the strip. Additional cellodin was applied over the hairs. After drying for 15-20 mts, thin transverse sections of the strip and hairs were cut using a sharp razor blade, in a manner similar to the obtaining of hand-cut botanical sections. The sections were dipped in clove oil to eliminate air bubbles from the spongy pith, arranged in serial order on a slide, and mounted in canada balsom under a cover glass.

(4) Hair Dimensions: The lengths (in millimetres) of the dorsal and ventral guard hairs of each specimen were measured, using a minimum of 20 hairs. The width or diameter (in micrometres) was measured in a minimum of 20 guard hairs per sample, a series of readings being taken of the broadest region of each hair, and the average calculated. The values are given in the form of a range, the upper and lower limits corresponding to the largest and smallest hairs measured. Owing to the obvious variability of hair size both on an individual pelt and in a species population, and considering the limited number of samples examined in the present work, these values have a very limited use in identification.

GENERAL REVIEW OF HAIR STRUCTURE

The features of primary importance in hair identification are the cuticular scales, medulla, cross-section and hair profile. Characters such as pigmentation and hair dimensions appear to be more variable, and their usefulness is correspondingly more limited.

A. Hair Profile.

The most useful classification of hair types, as far as the present work is concerned, is that of Williams (1938), according to which mammal hairs divisible into (a) sensory hairs, and (b) all other hairs. The former group includes specialized nasal hair and whiskers, while the latter group includes the hair of the body trunk and extremities, generally referred to as coat hair.

Coat hairs can be of three types: (a) Fine Hairs, which are weak and flexible along their entire length (Figs. 2 & 3); (b) Intermediate Hairs, which are weak and curly in the proximal or "shaft" region, and, broad and stiff in the distal or "shield" region (Fig. 4); (c) Guard Hairs, which are usually the longest, straightest and most robust hairs of the coat. Typically, they have a straight, narrow shaft region, followed by an expanded, often

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flattened, shield region (Fig. 5). Most guard hairs have roughly equally long shaft and shield regions, but in some rodents, the shaft region is highly reduced and the hairs are short and "spinous" (Fig. 6). In the case of fine hairs, two types are recognized: those with distinct constrictions at points of bending (Fig. 2), and those without such constrictions (Fig. 3), usually referred to as curly hairs.

B. Cuticular Scales and Scale Patterns.

Cuticular scales are of two main types, coronal and imbricate. Coronal scales completely encircle the hair shaft, and have been classified according to the nature of their distal edges as simple, serrate and dentate (Hausman 1920). Imbricate scales do not encircle the hair, but overlap one another. They have been classified according to shape by Hausmann (1920), but this classification is of rather limited value since it has been shown that the shape of the scales bears a relationship not so much to the species of mammal bearing the hair, but to the diameter of the hair bearing the scales (Hausman 1930). Thus scales at the base of the hair are longer than they are broad, and the converse is true nearer the tip.

The pattern of arrangement of the scales in the shaft region of the hair appears to be a more useful identifying criterion. The nomenclature of Wildman (1954) in Day (1966) has been used here. Two main types of scale pattern are recognized. In one, there is the impression of definite, individual scales making up the pattern, while in the other, the pattern is formed of a series of wavy, irregular lines rather than by individual scales. The former group includes the lanceolate (Figs. 7, 8 & 9) and diamond-petal (Fig. 10) patterns, while the latter group includes the chevron (Figs. 12 & 13) and mozaic (Figs. 11, 16 & 17) patterns. The shield regions of the hairs generally show a mozaic pattern. Scale patterns intermediate between the clearcut extremes mentioned above occur frequently.

According to Day (1966), both guard and fine hairs of the same species have the same basic type of scale pattern, though usually that of the fine hair is a simplified version of the guard hair pattern. This was found to be true for most of the species examined in the present study. For example, figures 8 and 9 show the lanceolate scalation on the fine and guard hairs, respectively, of the Otter *(Lutra lutra nair)*. The fine hairs of the Giant squirrel *(Ratufa macroura)* show a diamond-petal scale pattern (Fig. 14), while on the guard hairs the scalation is less regular, but the basic diamond-petal configuration can still be distinguished (Fig. 15). However, in the Leopard *(Panthera pardus)*, the Brown Mongoose *(Herpestes fuscus)* and the Jackal *(Canis aureus)*, the guard and fine hair scalation differs, that of the former being mozaic, while in the latter it is basically diamond-petal.

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C. Medullas.

The classification of Wildman (1954) has been used in the present work. Two basic types of medulla are recognized: ladder and lattice. In the ladder type, the medullary cells are distinct and arranged either in a single row, "uniseriate" (Fig. 45), or in several longitudinal rows, "multiseriate" (Fig. 47). In the lattice types, discrete cells cannot be distinguished, and the medulla has a hazy, net-work like appearence. In some cases, however, the medullary pigment may be organized into distinct transverse bands (Fig. 53), or present a honeycomb appearence (Fig. 52 & 57). In some hairs, the medulla is discontinuous, and is termed a fragmental type.

As a rule, fine hair medullas are of the uniseriate ladder type, while guard hairs possess variations of the multiseriate ladder and lattice types. The medullary column usually contains air, and this often gets trapped in the hair when mounted on a microscopical slide. The presence or absence of air may alter the appearance of the medulla. For example, a multiseriate ladder medulla appears as in figure 47 whenair is absent, and as in figure 50 when present. Similarly, figures 52-54 and figure 57 show different lattice medullas, the dark upper region showing the appearence when air is present, and the light lower region the appearence when air is displaced.

D. Cross-sectional Shape.

Fine hairs are generally circular or oval in cross-section, and are not of much use in identification. It is the guard hairs that show variations in shape in different mammals. These hairs normally do not show a constant cross-sectional shape along their entire length. Usually, the base and tip of the hair are circular, but the region in-between shows a range of shapes, from circular to oval, flattened, kidney and dumb-bell shapes. These changes in appearance are well marked in the region between the shield-base and tip. Figures 33-44 show the variations in cross-sectional shape in this region in the hairs of the mammals studied.

It must be noted that the important factor in identification is the sequence of shapes along the hair, rather than the shape at any particular point along its length. For instance, figures 33, 34 and 35 show three variants of a basic kidney-shaped sequence. It is possible to pick out sections of similar appearence in the three sets, but the overall sequences of shapes differ sufficiently for distinctions to be made between them.

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E. Pigmentation.

The colours (or colour patterns) of hairs and the appearance and distribution of the pigment masses may also serve as aids to identification. In considering hair colour, it is desirable that the entire pelt be examined, since hairs of different colours may be present on different body regions in some species. Even in unicoloured types, the ventral hairs are usually much lighter than the dorsal ones. In some species, all or most of the hairs may be banded, and in this case, the number of bands and their location along the hairs can be useful identifying features. Under the microscope, the pigment masses are seen to be deposited in the cortex and medulla. They may appear as fine or coarse granules, or streaks, or combinations of these. The distribution of the cortical pigment may also be useful - the pigmentation being dense or sparse, uniform or uneven.

The value of pigmentation in hair identification is, however, limited by its possible variability with age, season and nutrition. In addition, it may undergo deterioration when subjected to weathering or the action of the digestive juices of predators (Mathiak 1938b).

HAIR CHARACTERISTICS OF THE MAMMALS INVESTIGATED

The general hair characters of each order of mammals are presented below, followed by brief descriptions of the various genera and species. The nomenclature follows that of Eisenberg & McKay (1970), except where superseded by McKay (1972).

The following abbreviations are used in the case of hair dimensions: DGH = Dorsal Guard Hair; VGH = Ventral Guard Hair; DFH = Dorsal Fine Hair. Hair length is in millimetres (mm), and the width (diameter) at the broadest region of the hair, in micrometres (μm). Except where otherwise stated, all references to scalation are for the shaft region of the hairs.

A. Order Insectivora

Four genera and 6 species of shrews (Fam. Soricidae) occur On Sri Lanka. Five sub-species of the Musk Shrew *(Suncus murinus)* are recognized. Museum samples of all these were examined, together with additional field-collected samples of *Suncus murinus* *Crocidura horsfieldi*.

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Insectivore pelages are quite distinct from those of most other mammals. The fur is soft, plush-like, and composed of short, interwoven hairs. The fine and intermediate hairs are constricted at points of bending, and far outnumber the straight, unconstricted, guard hairs.

Because of their extremely small size, insectivore hairs can be confused only with those of the Chiroptera and the smaller Rodentia (mice). These types of hair can be distinguished as follows: (1) The hairs of insectivores and mice contain a medulla, while most bats lack this structure. (2) Mouse guard hairs usually have 3 or more rows of medullary cells, or a lattice medulla, in the shield region, while in shrews, only one row of cells is present in the shield region (Williams 1938). Another useful distinguishing feature is that insectivore fine hairs have long, whip-like tips, which are lacking in the other two groups of mammals. Day (1966) found that in British insectivores, the cuticular scales protrude very obviously to one side of a fine hair before a constriction, and "cross-over" to the other side after the constriction. This feature, however, is not prominent in the hairs of the Sri Lankan shrews.

The cuticular scale patterns of insectivore hairs are of the lanceolate type and the medullas of the uniseriate ladder type in Soricids and multiseriate ladder in Talpids (Day 1966; Keller 1978). Guard hair cross-sections are circular, while the predominant fine and intermediate hairs show distinctive shapes that are useful in generic identification. Those of *Feroculus Suncus* and *Crocidura* show variations of the "H"-shaped type seen in American and European Soricids (Williams 1938; Day 1966; Keller 1980), while in *Solisorex*, they are rounded or elliptical, and more akin to the cross-sections of Talpid hairs (Keller 1980).

Family Soricidae

(1) *Feroculus feroculus* (Kelaart 1850)
Scalation: Lanceolate. Medulla: uniseriate ladder, cells ovate in shaft and flattended in shield regions. Cross-section: All hairs show sections with 2 emarginations (Fig. 40).

Pigmentation: Brown, cortical pigment granules only in shield tip of guard and intermediate hairs, apparently absent in fine hairs. Medullary cells of dorsal hairs heavily pigmented.

Dimensions: DGH 8-10 mm, 28-36 μm; VGH 5-6 mm.

(2) *Solisorex pearsoni* Thomas, 1924.
Scalation: Lanceolate. Medulla: Uniseriate ladder, cells ovate in shaft and flattened in shield regions. Cross-section: Guard hairs circular or oval,

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circular or oval, fine and intermediate hairs with a flattened area, as in Fig. 41. Pigmentation: Colour grey-brown. Cortical pigment dense in shield region of guard and intermediate hairs and sparse in fine hairs. Medullary cells heavily pigmented. Dimensions: DGH 11-13 mm, 36-48 µm; VGH 8-9 mm.

(3) *Suncus etruscus fellowes-gordoni* Phillips, 1932.
Suncus murinus (Linnaeus 1766).
Scalation: Lanceolate. Medulla: Uniseriate ladder, cells ovate in shaft and flattened in shield regions. Cross-section: Guard hairs circular. Fine and intermediate hairs show a sequence of shapes as in Fig. 42. Pigmentation: Colour dark grey-brown in *S. etruscus*, *S. murinus murinus*, *S.m. montanus*, *S.m. kandianus* and *S.m. zeylanicus*; light brown in *S.m. caerulescens*. Cortical pigment dense in shield region of guard and intermediate hairs, sparse in fine hairs. Medullary cells heavily pigmented in all except *S.m. caerulescens*. Dimensions: *S. etruscus*: DGH 4-5 mm, 24-32 µm, VGH 2-3 mm, *S. murinus*: DGH 7-9 mm, 32-52 µm, VGH 4-6 mm.

(4) *Crocidura miya* Phillips, 1929.
Crocidura horsfieldi (Tomes 1856).
Scalation: Lanceolate. Medulla: Uniseriate ladder, cells flattened in both shaft and shield regions. Cross-section: Guard hairs circular. Fine and intermediate hairs of *C. miya* with 4 emarginations (Fig. 43) and *C. horsfieldi* with 3 emarginations (Fig. 44). Pigmentation: Hair colour grey-brown in both species. Cortical pigment dense in shield region of guard and intermediate hairs, sparse in fine hairs. Medullary cells heavily pigmented. Dimensions: *C. miya*: DGH 7-8 mm, 35-44 µm, VGH 5-6 mm; *C. horsfieldi*: DGH 7-8 mm, 28-32 µm, VGH 2-3 mm.

B. Order Chiroptera

Fifteen genera and 29 species of bats have been identified on Sri Lanka. Museum samples of all species were examined, together with additional field samples of the following: *Pteropus giganteus*, *Rousettus leschenaulti*, *Cynopterus sphinx*, *C. brachyotis*, *Hesperoptenus tickelli*, *Scotophilus heathi*, *Rhinolophus rouxi*, *Hipposideros ater*, *Megaderma spasma*, *Kerivoula picta*, *Pipistrellus mimus*, *Taphozous saccolaimus*.

In the majority of bats, there seems to be no clear distinction between guard and fine hairs. Often, the only difference is that guard hairs are straighter and slightly thicker than fine hairs. Nason (1948) has found a similar situation among eastern North-American bats.

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Most species of Sri Lankan bats lack a medulla, the exceptions being *Cynopterus* sp. (Fam: Pteropodidae) and *Megaderma* sp. (Fam: Megadermatidae). In another Pteropodid *(Pteropus giganteus)*, the guard hairs alone possess a highly fragmental medulla. Other workers such as Benedict (1957), Day (1966) and Keller (1980) have not observed this structural element in chiropteran hairs, but Cole (1924) records the presence of the medulla in certain species. Interestingly, these species belong to the same families as mentioned above. It is possible, therefore, that the occurrence of a medulla among bats is restricted to the Pteropodidae and Megadermatidae. However, all species belonging to these families do not show a medulla - the hairs of *Rousettus leschenaulti* (Pteropodidae) lack this feature.

Hausmann (1920) and Mathiak (1938b) state that chiropteran hairs are characterized by the coronal type of cuticular scale, but Nason (1948) holds that imbricate scales are the commoner type, occurring in 8 out of 10 genera studied by him. Among the Sri Lankan Chiroptera, only 3 of the 15 genera studied show true imbricate scales at least on the thicker (guard) hairs. The species belonging to the other genera show coronal scales, but in many cases, the scales are deeply split or emarginated and often give a distinctly imbricate appearance, particularly on scale casts. It is possible that the imbricate scales of Nason (1948) are, in fact, coronal scales of this type. In the two genera *(Myotis* and *Tadarida)* common to Nason's study and the present one, the "imbricate" scales of *Myotis* described by that author most certainly correspond to the emarginated coronal scales observed by the present worker (The hairs of *Tadarida* possess typical coronal scales).

In this study, hair profiles were found to be extremely useful in generic identifications. Four main types of profile were recognized: zig-zag (Fig. 26), bilobed (Fig. 27), straight (Figs. 28 & 29), and spiky (Figs. 30 - 32). In some cases, a step-like or serrated outline may be seen in association with the zig-zag and straight profiles, particularly in the upper shaft and shield regions of the hairs.

Cross-sections are not useful in identification since the shapes are quite irregular in the shaft region and circular or oval in the shield.

Family Pteropodidae

(1) *Pteropus giganteus giganteus* (Brunnich 1782)

Distinct guard and fine hairs present. Scalation: Imbricate, with a chevron or mozaic pattern. Medulla: Fragmental in guard hairs and absent in fine hairs. Profile: straight.Pigmentation: Uniform

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dark brown throughout length of guard hairs, lighter towards the tip. Fine hairs are yellowish at base and brown in the mid and upper regions. Dimensions: DGH 14-16 mm, 48-56 μm, DFH 8-10 mm.

(2) *Rousettus leschenaulti* Desmarest

Distinct guard and fine hairs present. Scalation: Imbricate, with a chevron or mozaic pattern in guard hairs. Coronal serrate scales in fine hairs. (Fig. 23). Medulla: Absent. Profile: spiky, with short but distinct spikes along the entire length of the hairs. Pigmentation: Hair colour brown. Guard hairs light at base and tip, dark in-between. Fine hairs with brown streaks in cortex and cuticle. Dimensions: DGH 6-8 mm, 28-36 μm, DFH 6-8 mm.

(3) *Cynopterus sphinx sphinx* (Vahl 1797)
Cynopterus brachyotis ceylonensis Gray, 1870

Guard and fine hairs fairly distinct. Scalation: Coronal, those of guard hairs being more flattened than in fine hairs. Medulla: Uniseriate ladder, with flattened cells, in both hair types. Profile spiky. Pigmentation: Hair colour brown. Guard hair cuticle and cortex with uniform pigmentation, lacking in fine hairs. Medullary cells show heavy pigmentation. Dimensions: C. sphinx: DGH 8-10 mm,24-32 μm, DFH 6-8 mm; *C. brachyotis* DGH 6-8 mm,36-48 μm, DFH 4-6 mm.

Family Rhinolophidae

(4) *Rhinolophus luctus sobrinus* Anderson, 1918
Rhinolophus rouxi rouxi Temminck, 1835

Guard hairs darker and straighter than fine hairs, and lacking the constricted regions present along the latter. Scalation: Coronal, the scales often do not encircle the hair completely, and give an appearance as in Fig. 25. Medulla: Absent. Profile: Zig-zag type. Pigmentation: Hair colour brown, *R. rouxi* being the paler of the two species. Cortical pigment in the form of thin streaks in both species. Dimensions: *R. luctus:* Dorsal hairs 10-12 mm, 11-16 μm; *R. rouxi* Dorsal hairs 6-8 mm, 12-16 μm.

Family Hipposideridae

(5) *Hipposideros lankadiva lankadiva* Kelaart,1850
Hipposideros speoris speoris (Schneider 1800)
Hipposideros galeritus brachyotus (Dobson 1874)
Hipposideros ater Templeton, 1848

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No clear distinction between guard and fine hairs, the former usually darker and straighter than the latter. Regions of construction often present along the thinner hairs. Scalation: Coronal, simple or serrate type. Medulla: absent. Profile: Straight. Pigmentation: Hair colour brown. Pigment present as thin streaks and dots. Hairs pale at base, colourless at middle and dark towards tip in *H. lankadiva* and *H. speoris*; lower part of hairs pale and upper region dark in *H. galeritus* and *H.ater*. Dimensions: *H. lankadiva* and *H. galeritus*: Dorsal hairs 8-11 mm, 10-16 μm, *H. speoris* and *H. ater*: Dorsal hairs 6-8 mm, 10-14 μm.

Family Megadermatidae

(6) *Megaderma spasma ceylonense* Anderson, 1918
Megaderma lyra lyra Geoffroy, 1810

Guard hairs darker, straighter, and very slightly thicker than fine hairs. Scalation: Coronal at base, but distinctly imbricate along the rest of the hair. Medulla: Uniseriate ladder, cells ovate in shaft and flattened in shield regions. Profile: Straight. Pigmentation: Hair colour grey-brown, lighter in *M. spasma*, and darker and more greyish in *M. lyra*. Cortical pigment present only at the tips of hairs. Medullary cells heavily pigmented. Dimensions: Dorsal hairs 10-14 mm, 12-16 μm, in both species.

Family Vespertilionidae

(7) *Pipistrellus mordax* (Peters 1866)
Pipistrellus ceylonicus ceylonicus (Kelaart 1852)
Pipistrellus coromandra coromandra (Gray 1838)
Pipistrellus mimus mimus Wroughton, 1899

Guard hairs darker, straighter, and very slightly thicker than fine hairs, which have a single constricted region between the shaft and shield region. Scalation: Coronal (Fig. 21). Scales deeply cleft, giving the appearence of two rows of scales along the hair. Medulla: Absent. Profile: Bilobed type. Pigmentation: Hair colour grey-brown. Cortical pigment as streaks. Fine hairs of *P. mordax* colourless at tip, brown in the other species. Dimensions: Dorsal hair length 4-6 mm in all species; diameter 12-16 μm in *P. mordax* and *P. ceylonicus*, 8-12 μm in *P. coromandra* and *P. mimus*.

(8) *Hesperoptenus tickelli* (Blyth 1851)

Guard hairs darker, straighter, and very slightly thicker than fine hairs, which show several constrictions along their length. Scalation: Deeply split coronal scales, giving the impression of two rows of

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scales along the hair. Medulla: Absent. Profile: Spiky, as in Fig. 32. Pigmentation: Hair colour light brown. Distinct cortical pigment granules present. Guard hairs uniformly pigmented; fine hairs brown at base, pale or colourless in middle, and dark towards tip. Dimensions: Dorsal hairs 5–6 mm, 8–12 μm.

(9) *Scotophilus heathi* (Horsfield 1831)
Scotophilus kuhli Leach, 1822

Guard hairs straight, fine hairs with several constrictions along their length. Scalation: Coronal, the scales being emarginated at several points, giving the impression of elongate scales with rounded tips (Fig. 22). Medulla: Absent. Profile: Straight, sometimes with a serrated outline. Pigmentation: Hair colour brown. Cortical pigment streaky. Most hairs pale in the shaft region and darker towards the shield and tip. Dimensions: *S. heathi* : DGH & DFH 7–8 mm, DGH 24–32 μm, DFH 14–16 μm, *S. kuhli*: DGH & DFH 4–6 mm, DGH 16–20 μm, DFH 12–14 μm.

(10) *Myotis adversus* (Temminck 1840)

(According to Eisenberg & Mckay, 1970, and Mckay, 1972, this bat has not yet been adequately assigned to any of the known species.) Guard hairs straight, fine hairs constricted. Scalation: Coronal, cleft scales, giving the appearance of two rows of scales along the hair. Medulla: Absent. Profile: bilobed type. Pigmentation: Hair colour dark brown. Cortical pigment granular. Dimensions: DGH & DFH 4–7 mm, DGH 14–16 μm, DFH 10–12 μm.

(11) *Murina cyclotis eileenae* Philips, 1932
Guard hairs are longer, thicker, and darker than fine hairs. Scalation: Coronal, cleft scales, giving the impression of two rows of scales along the hair. Medulla: Absent. Profile: Straight, sometimes with a serrated outline. Pigmentation: Hair colour brown. Cortical pigment granular, with occasional thin streaks. Basal region of hairs pale, the rest being an uniform light brown. Guard hair shield region darker than in fine hairs. Dimensions: DGH 12–14 mm, 14–16 μm; DFH 7–9 mm, 7–9 μm.

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(12) *Kerivoula picta picta* (Pallas 1767)
Kerivoula hardwickei malpasi Phillips, 1932
Guard hairs straighter and slightly thicker than fine hairs. Scalation: Coronal. Guard hairs with flattened scales, fine hair scales cleft, appear as two rows of elongate scales in the shaft region. Medulla: Absent. Profile: Zig-zag in shaft region, straighter in shield. Pigment deposition at scale apices may give a somewhat bilobed appearence in *K. hardwickei*. Pigmentation: Distinctly reddish brown in *K. picta*, brown in *K. hardwickei*. Cortical pigment as thin streaks and dots. Guard hairs uniformly pigmented, while in fine hairs, the colour gradually increases in intensity from base to tip. Dimensions: DGH & DFH 6-8 mm in both species. DGH 10-12 µm, DFH 8-9 µm in *K. picta*; DGH 18-20 µ, DFH 10-12 µ in *K. hardwickei*.

(13) *Miniopterus schreibersi fuliginosus* (Hodgson 1835)
Guard hairs straight, fine hairs constricted. Scalation: Coronal, with a serrate or irregular margin. Medulla: Absent. Profile: Straight or slightly serrated in guard hairs and the thick regions of fine hairs, distinctly zig-zag in constricted regions of fine hairs. Pigmentation: Hair colour grey-brown. Cortical pigment streaky. Both hair types uniformly pigmented along their length. Dimensions: DGH & DFH 7-9 mm, DGH 16-20 µm, DFH 10-12 µm

Family Emballonuridae

(14) *Taphozous longimanus longimanus* Hardwicke, 1825
Taphozous melanopogon melanopogon Temminck, 1841
Taphozous saccolaimus crassus Blyth, 1844
Only one type of hair appears to be present. A few are much heavier pigmented than the others, and may correspond to the guard hairs. Scalation: Coronal, with dentate margins. Medulla: Absent. Profile: Spiky, as in Fig. 31. Pigmentation: Hair colour brown. Cortical pigment granular. *T. longimanus* hairs are very pale in the shaft region, dark brown in the shield, and pale yellow at the tip. In the other two species, the hair tip is dark brown. *T. longimanus* and *T. saccolaimus* hairs show an uniform deposition of granules, while in *T. melanopogon*, it is uneven, a "segmented" appearence being seen in the shield region of all hairs. Dimensions: Dorsal hairs 5-9 mm, 12-16 µm in all species.

Family Molossidae

(15) *Tadarida aegyptica* (Geoffroy 1818)
Tadarida plicata insularis (Phillips 1932)
Only one type of hair appears to be present. A few hairs are more heavily pigmented than the others, and may correspond to the guard

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hairs. Scalation: Coronal, with dentate margins (Fig. 20). Medulla: Absent. Profile: Spiky, as in Fig. 30. Pigmentation: Hair colour brown. Cortical pigment granular. The lower shaft region of all hairs is colourless, the rest being pigmented. A "segmented" appearence is seen due to uneven pigmnt deposition. Dimensions: Dorsal hairs 5-6 mm, 14-16 μm in *T. aegyptica*; 3-5 mm, 16-18 μm in *T.plicata*.

C. Order Primates

Four species of primates, with 12 sub-species, are present on Sri Lanka. Museum samples of all except one sub-species of the Slender Loris (ie. *Loris tardigradus nycticeboides)* were obtained. Additional field samples from all species were examined.

Distinct guard and fine hairs are present, the former being coarser, straighter, and longer than the latter, which are of the curly type. The fine hairs of *Loris* can be easily distinguished from those of other mammals, being long, very curly, and interwoven, the matted mass of hairs being difficult to separate even when removed from the skin. Also, the guard hairs are very sparse, and have the distinction of being shorter than the fine hairs.

The fine hairs of *Loris* show coronal scales in the shaft region and imbricate scales with a mozaic pattern in the shield, while both hair types of the other species show imbricate, mozaic scales (Fig. 16). The medulla, when present, is uniseriate and fragmental in both hair types. This is an important identifying character for primate hairs, since only the insectivores and a few chiropterans exhibit uniseriate medullas in both guard and fine hairs. The cross-sections of both hair types in the four species studied, show the circular-oval sequence of shapes, as in Fig. 37.

No distinctions can be made between the hairs of the Toque Macaque *(Macaca sinica)* and the Grey Langur *(Presbytis entellus)*. The scalation, medulla, cross-section and dimensions are similar, and the differences in pigmentation are too slight to be of any value. The hairs of the Purple-faced Langur *(Presbytis senex)* can be differentiated from those of the above two species on the basis of medullary structure, *P. senex* hairs always possessing a uniseriate ladder medulla which is occasionally fragmented, whereas in *P. ente - llus* and *M. sinica*, some hairs show a highly fragmented uniseriate medulla for a short distance along their length, while other lack the medulla entirely. Koppiker & Sabnis (1976) too, have not observed a medulla in the hairs of *P. entellus* and the Rhesus Macaque *(Macaca mulatta)* in India.

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Family Lorisidae

(1) *Loris tardigradus* (Linnaeus 1758)
Four sub-species are recognized.
Guard hairs straight, fine hairs extremely curly, interwoven, and longer than guard hairs. Scalation: Guard hairs imbricate, mozaic. Fine hairs coronal at base, and imbricate, mozaic along the rest. Medulla: Uniseriate ladder. Cross-section: Circular-oval type. The medullary width is less than 0.5 that of the hair in fine hairs, and 0.5 or greater in guard hairs. Pigmentation: Dorsal hairs grey-brown and ventral hairs yellow-brown in *L.t. tardigradus*. Dorsal hairs as above and ventral hairs silvery in *L.t. nordicus* and *L.t. grandis*.Dimensions: DGH 10–15 mm in the three sub-species examined; 32–36 µm in *L.t. tardigradus* and *L.t. grandis*, and 40–44 µm in *L.t. nordicus*.

Family Cercopithecidae

(2) *Macaca sinica* (Linnaeus 1771)
Three sub-species are recognized.
Guard hairs straight, fine hairs curly. Scalation: Imbricate, mozaic. Medulla: Highly fragmental uniseriate type, absent in many hairs. Cross-section: Circular-oval. In the guard hair shield region, medullary width is less than 0.5 that of the hair. Pigmentation: Dorsal hairs brown, ventral hairs pale silvery yellow in all sub-species. Cortical pigment as granules and streaks. Dimensions: DGH 30–60 mm, 68–80 µm, VGH 25–40 mm in all sub-species.

(3) *Presbytis entellus thersites* Blyth, 1847
Presbytis senex (Erxleben 1777)
Five sub-species of *P. senex* are recognized.
Guard hairs straight, fine hairs curly. Scalation: Imbricate, mozaic. Medulla: Uniseriate, occasionally fragmented in *P. senex*. Highly fragmented uniseriate, or absent, in *P. entellus*. Cross-section: Circular-oval in both species. In the guard hair shield region, the medullary width is less than 0.5 that of the hair. Pigmentation: Dorsal hairs grey-brown and ventral hairs silvery yellow in *P.entellus*. Both dorsal and ventral hairs brown to blackish brown in *P. senex*, colour light in *P.s. senex* and *P. s. nestor*, intermediate in *P.s. harti* and *P.s. monticola*, and dark in *P.s. vetulus*. Cortical pigment as granules and streaks. Dimensions: DGH 35–40 mm, 68–80 µm, VGH 25–30 mm in *P. entellus*. DGH 30–50 mm, VGH 30–55 mm in *P. senex senex*, *P.s. vetulus* and *P.s. nestor* DGH 45–70 mm, VGH 30–60 mm in *P. s. harti* and *P.s. monticola*. DGH 72–84 µm in all sub-species.

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D. Order Lagomorpha

Only one species, the Black-naped Hare *(Lepus nigricollis)*, is native to Sri Lanka. Both museum and field samples were examined in the present study.

The hairs of this order of mammals are among the easiest to identify. The cuticular scale pattern is of the streaky-chevron type (Fig. 13), which is rare in other groups of mammals (Day 1966). The guard hair medullary structure is unique, consisting of branching rows of cells (Fig. 49), and is known as the "lagomorph medulla"; while the dumb-bell shaped cross-sections also appear to be peculiar to the order (Day 1966). Details of the cross-sectional structure of the guard hairs have been used by Keller (1980) to distinguish between hairs of *Oryctolagus* and *Lepus* and also between *L.europaeus* and *L.timidus*; previously, no reliable method of distinguishing between the hairs of genera and species in this group was known (Day 1966).

Koppiker& Sabnis (1976) report their inability to observe the scales on hairs of the Indian hare *Lepus ruficaudatus*. This may have been due to their method of observing the scales on the hairs themselves, rather than from casts. The curvature of the hairs and the dark medullary column usually obscure the cuticular structures. Remarkably, these workers have also not observed the characteristic medullary structure of the guard hairs. However, the illustrations provided in that work, and the value for hair diameter given (12 µm), suggest that they have not, in fact, examined the guard hairs of that species.

Family Leporidae

(1) *Lepus nigricollis singhala* Wroughton, 1915
Guard hairs straight, fine hairs curly. Scalation: Streaky-chevron in both hair types. Medulla: Uniseriate ladder in fine hairs, Lagomorph medulla (Fig. 49) in guard hairs. Cross-section: Circular-oval in fine hairs, dumb-bell shaped in guard hairs (Fig. 39). Pigmentation: Dorsal guard hairs dark brown or black, with yellow bands. Ventral guard hairs pale brown or silvery. Fine hairs grey. Cortical pigment granular. Dimensions: DGH & VGH 25-30 mm, 80-108 µm.

E. Order Rodentia

Twelve genera and 22 species are present on Sri Lanka. Twenty sub-species are recognized, but some of these are of doubtful validity (Eisenberg & Mckay 1970). Museum samples of all except 3 of the sub-species of *Rattus rattus* were obtained. Additional material was examined in the following species: *Petaurista petaurista*, *Ratufa macroura*, *Funambulus palmarum*, *Bandicota indica*, *B. bengalensis*, *Rattus rattus*, *Mus musculus*, *M. cervicolor*, *M. mayori*, *Vandeleuria oleracea* and *Hystrix indica*.

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The guard and fine hairs are distinct, the former being much more numerous than on insectivore and chiropteran pelages. Local species of the Cricetidae and Muridae possess constricted fine hairs, while in the Sciuridae, the curly type is seen.

The guard and fine hair scalation is imbricate, all the chief types of scale pattern, together with several intermediate types, being seen in the various species studied. Among Indian rodents, Koppiker & Sabnis (1977) report the presence of coronal scales on the hairs of the Flying Squirrel *(Petaurista petaurista)* and the Giant Squirrel *(Ratufa indica)*. However, the validity of these findings is rather doubtful, in view of the limitations of the method of direct observation of the scales used by these workers. In the Sri Lankan specimens of *P. petaurista*, the scalation is definitely imbricate, with a mozaic pattern (Fig. 11). In the local Giant Squirrel *(Ratufa macroura)*, the scales are imbricate, with a diamond-petal or diamond-petal-chevron pattern (Figs. 14 & 15), and it seems unlikely that such a fundamental difference in scalation, as between the coronal and imbricata types, would occur within the same genus.

All fine hair medullas are of the uniseriate type. In the majority of species, the guard hair medullas are of the lattice type, and show variations in structure that are useful in identification. In some species, however, the guard hairs display the multiseriate ladder type of medulla-observed only among the rodents in the present study. Previous workers such as Mathiak (1938b), Stains (1958) and Day (1966), also have found this medulla only in rodent hairs, and it seems likely that it is confined to this Order of mammals.

A unique feature of rodent guard hairs is the presence of the "Rodent-base Medulla" (Mathiak 1938b) in the shaft region (Fig. 46). This is one of the chief features by which rodent hairs are identified (Mathiak 1938b; Day 1966). Among Sri Lankan rodents, this medulla is well seen in all except 7 species: The Spiny Rat *(Mus mayori)*, the Spiny Mouse *(Mus fernandoni)*, the Bush Rat *(Golunda ellioti)*, the Porcupine *(Hystrix indica)*the Giant Squirrel *(Ratufa macroura)*, and the Bandicoot Rats *(Bandicota bengalensis* and *B. indica)*. In *Bandicota* and *Ratufa*, the guard hair shaft region is well developed but the rodent-base medulla is indistinct or absent, while in the other species, the guard hair shaft region is reduced (spinous hairs), and consequently, this medula is obscured.

The guard hair cross-sections of the local Sciuridae show the circular-oval sequence of shapes (Fig. 37), but this is not characteristic of the Family, since the hairs of *Sciurus* show kindly-shaped sections (Day 1966). Among the Muridae and the single repreentative of the Cricetidae in Sri Lanka, the sections are of the kidney-shaped type, except in *Bandicota*, where the indentation is much less marked, and often results in almost oval sections being seen.

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Family Sciuridae

(1) *Petaurista petaurista lanka* Wroughton, 1911
Guard hairs straight, fine hairs curly. Scalation: Imbricate, with a characteristic mozaic pattern (Fig. 11). Medulla: uniseriate ladder in fine hairs. Lattice, with a honeycomb appearance in guard hairs. Rodent-base present. Cross-section: Circular-oval type. In the guard hair shield region, the medulla is greater than 0.5 but less than 0.75 the width of the hair. Pigmentation: Dorsal and ventral guard hairs dark grey or black, with a single white band in the shield region. Cortical pigment sparse, granular. Dimensions: DGH 18-32 mm, 96-104 µm, VGH 21-30 mm.

(2) *Petinomys fuscocapillus layardi* (Kelaart 1850)

Guard hairs straight, fine hairs curly. Scalation: Imbricate, with a characteristic mozaic pattern, as in Fig. 11. Medulla: Uniseriate ladder in fine hairs. Lattice, with rodent-base extending half way or more along the hair, in guard hairs. Cross-section: Circular-oval type. In the guard hair shield region, the medullary width is greater than 0.5 but less than 0.75 that of the hair. Pigmentation: Dorsal and ventral hairs either unicolour black, or with a single brown band in the shield region. Cortical pigment abundant, granular. Dimensions DGH 30-40 mm, 60-80 µm, VGH 12-19 mm.

(3) *Ratufa macroura* (Pennant 1769)

Three sub-species are recognized.
Guard hairs straight, fine hairs curly. Scalation: Imbricate. Characteristic type of diamond-petal pattern on fine hairs (Fig. 14) and diamond-petal-chevron on guard hairs (Fig. 15). Medulla: Uniseriate ladder in fine hairs. Lattice, with a honeycomb appearance in the shaft region becoming more random towards the shield. No rodent base. Cross-section: Circular-oval type. In the guard hair shield region, the medullary width is greater than 0.5 but less than 0.75 that of the hair. Pigmentation: Dorsal hairs dark brown or black, sometimes with a white or yellow tip, ventral hairs brown or yellow, in *R.m. macroura*, *R.m. melanochra* and *R.m. dandolena* (dark form); colour much lighter in *R. m. dandolena* (light form). Dimensions: DGH 30-50 mm, 100-128 µm; VGH 30-40 mm.

(4) *Funambulus layardi layardi* (Blyth 1849)
Funambulus sublineatus obscurus (Pelzeln & Kohl 1867)
Funambulus palmarum (Linnaeus 1766)

Five sub-species of *F. palmarum* are recognized, but their validity is doubtful (Eisenberg & Mckay 1970). Mckay (1972) lists only three: *F.P. brodiei*, *F.p. kelaarti*, and *F. p. matugamensis*.

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Guard hairs straight, fine hairs curly. Scalation: Imbricate, with a chevron pattern, as in Fig. 12. Medulla: Uniseriate ladder in fine hairs. Lattice, with a honeycomb pattern (Fig. 52) in *F. palmarum* guard hairs; multiseriate ladder with 4-5 rows of cells in guard hairs of *F. layardi* and *F. sublineatus*. Rodent-base present in all species. Cross-section: Circular-oval type. The guard hair medullary width in the shield region is greater than 0.5 but less than 0.75 that of the hair. Pigmentation: Dorsal hairs black or reddish brown a few with a single pale band, and ventral hairs reddish brown in *F. layardi*. Dorsal hairs black, with 1-2 pale brown bands, and ventral hairs yellow or white in the five subspecies of *F. palmarum*. Cortical pigment granular in all species. Dimensions: DGH 10-15 mm, 48-56 µm, VGH 6-10 mm in *F. layardi*. DGH 12-14 mm, 60-80 µm, VGH 8-14 mm in *F. sublineatus*. DGH 9-15 mm, 60-92 µm, VGH 7-17 mm in *F. palmarum*.

Family Cricetidae

(5) *Tatera indica ceylonica* Wroughton, 1906

Guard hairs straight, fine hairs constricted. Scalation: Imbricate, with a chevron or streaky-chevron pattern. Medulla: Uniseriate ladder in fine hairs. Multiseriate ladder, with 6-7 rows of cells at the broadest region, in guard hairs. Cross-section: Circular or oval in fine hairs. Kidney-shaped type (as in Fig. 33) in guard hairs. In the guard hair shield region, the medullary width is greater than 0.75 that of the hair. Pigmentation: Dorsal hairs pale brown, ventral hairs white. Cortical pigment apparently absent. Medullary cells lightly pigmented. Dimensions: DGH 12-14 mm, 80-108 µm; VGH 6-10 mm.

Family Muridae

(6) *Bandicota indica indica* (Bechstein 1800)
Bandicota bengalensis gracilis (Nehring 1902)

Guard hairs straight, fine hairs constricted. Scalation: Imbricate, with a characteristic lanceolate-chevron pattern (Fig. 18). Medulla: Uniseriate ladder in fine hairs. Guard hair medulla lattice, random (as in Fig. 51) or transverse (as in Fig. 53). Rodent-base indistinct or absent in most hairs. Cross-section: Circular-oval type in *B. indica*, with occasional kidney-shaped sections in the mid shield region of some hairs. In *B. bengalensis*, the guard hairs are slightly, but constantly, indented, giving a more kidney-shaped sequence than in *B. indica*. In the shield region of the guard hairs, the medullary width is greater than 0.75 that of the hair. Pigmentation: Dorsal guard hairs dark brown or black, with a whitish shaft region, and ventral guard hairs pale brown in *B. indica*. The hair colour is similar in *B. bengalensis*, but the guard hairs are pale towards the upper shield and tip. Cortical pigment present as very

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fine granules, sometimes aggregated to form streaks. Dimensions: DGH 20-60mm, 172-204μm, VGH 10-12 mm in *B. indica*.DGH 12-19 mm, 100-120 μm, VGH 7-10 mm in *B. bengalensis*.

(7) *Mus musculus castaneus* Waterhouse, 1843
Mus cervicolor fulvidiventris Blyth, 1852
Mus fernandoni (Phillips 1932)
Mus mayori (Thomas 1915)

Two sub-species of *M. mayori* are recognized.
Guard hairs spinous in *M. fernandoni* and *M. mayori*, more slender in *M. musculus* and *M. cervicolor*. Fine hairs of all species are constricted. Scalation: Diamond-petal in all species, with occasional lanceolate patches in guard hairs. Medulla: Uniseriate ladder in all fine hairs. Multiseriate ladder, with 4-5 rows of cells at the broadest region, in guard hairs of *M. musculus*. In *M. cervicolor*, the guard hair medulla is often multiseriate in the shaft region, but becomes a transverse or random lattice type towards the shield. In *M. fernandoni* and *M. mayori*, the guard hair medulla is a typical transverse lattice (Fig. 53). Rodent-base present in *M. musculus* and *M. cervicolor*, absent in most guard hairs of *M. fernandoni* and *M. mayori*. Cross-section: Fine hairs are all of the circular-oval type. Guard hairs are of the kidney-shaped types: *M. musculus* as in Fig. 33, *M. cervicolor* as in Fig. 34, and *M. fernandoni* and *M. mayori* as in Fig. 35. In the shield region of guard hairs, the medullary width is greater than 0.75 that of the hair in all species. Pigmentation: Dorsal hairs brown or grey in all species. Ventral hairs grey in *M. musculus*, brownish grey in *M. mayori mayori*, and white or creamy in *M. cervicolor*, *M. fernandoni* and *M. mayori pococki*. In all species, cortical pigment is sparse, and granular. Dimensions: DGH 4-5 mm, 44-52 μ, VGH 3-4 mm, in *M. musculus*. DGH 4-5 mm, 52-64 μm, VGH 2-4 mm in *M. cervicolor*. DGH 5-9 mm, 240-280 μm, VGH 3-4 mm, in *M. fernandoni*. DGH 11-15mm, VGH 5-8 mm in *M. mayori*, DGH 192-212 μm, in *M. m. mayori* and 340-372 μm, in *M. m. pococki*.

(8) *Rattus rattus* (Linnaeus, 1758)
Rattus norvegicus norvegicus Waterhouse, 1843
Rattus montanus Phillips, 1932
Rattus ohiensis Phillips, 1929
Rattus blanfordi (Thomas 1881)

The validity of the records of 3 of the 6 sub-species of *Rattus rattus* (ie. *R. r. alexandrinus*, *R. r. rufescens* and *R. r. ceylonus* is doubtful (Eisenberg & McKay 1970). Guard hairs straight, fine hairs constricted. Scalation: Imbricate. Chevron pattern in *R. blanfordi*, diamond-petal in the other species. Medulla: Uniseriate ladder in all fine hairs. Multiseriate ladder, with 4-5 rows of cells at the broadest region, in guard hairs of

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R. blanfordi. Multiseriate ladder in shaft region becoming a random or transverse lattice in the shield, in *R. norvegicus* and *R. montanus* (see Figs. 47 & 48). Lattice medulla of the random type (as i in Fig. 51) or with transverse bands (as in Fig. 53) in *R. ohiensis* and *R. rattus*. Rodent-base present in all species. Cross-section: Circular-oval in all fine hairs. Guard hairs show a kidney-shaped sequence as in Fig. 33. In all species, the medullary width is greater than 0.75 that of the hair, in the shield region of guard hairs. Pigmentation: Dorsal hairs of all species brown. Ventral hairs pale brown in *R. rattus* and *R. montanus*, and yellowish in the other species. Cortical pigment present as granules and streaks. Dimensions: DGH 10-25 mm, 100-170 u, VGH 5-10 mm in *R. rattus rattus*, *R.r. kandiyanus* and *R.r. kelaarti*. DGH 12-16 mm, 88-128 um, VGH 8-9 mm in *R. norvegicus*. DGH 11-17 mm, 64-76 µm, VGH 8-10mm in *R. blanfordi*. DGH 9-12 mm, 110-156 µm, VGH 6-7 mm in *R. ohiensis*. DGH 21-42 mm, 108-160 µm, VGH 10-17mm in *R. montanus*.

(9) *Golunda ellioti* Gray, 1837

Two sub-species are recognized.

The guard hairs of *G.e. ellioti* are spinous, while those of *G.e. nuwara* are longer and more slender. The fine hairs are constricted in both. Scalation: Imbricate, with a diamond-petal pattern. Medulla: Uniseriate ladder in fine hairs. Guard hairs of *G.e. ellioti* lack the rodent-base, and show a transverse type of lattice (as in Fig. 53). Most guard hairs of *G.E.. nuwara* show the rodent-base for a short distance along the shaft region, followed by a multiseriate ladder medulla changing to lattice in the shield. Cross-section: Circular-oval in fine hairs. Guard hairs show a kidney-shaped sequence as in Fig. 34. In the shield region of guard hairs, the medullary width is greater than 0.75 that of the hair. Pigmentaton: Dorsal hairs dark brown, with a pale shaft region, and ventral hairs yellowish brown, in both sub-species. Dimensions: DGH 11-13 mm, 160-200 µm, VGH 8-10 mm in *G.e. ellioti* DGH 17-23 mm, 120-168 µm, VGH 7-11 mm in *G. e. nuwara*.

(10) *Millardia meltada meltada* (Gray 1837)

Guard hairs straight, fine hairs constricted. Scalation: Imbricate, with a diamond-petal pattern. Occasional lanceolate patches on some guard hairs. Medulla: uniseriate ladder in fine hairs. Multiseriate ladder, with 5-6 rows of cells at the broadest region, in guard hairs. Rodent-base present. Cross-section: Circular-oval in fine hairs. Kidney-shaped sequence, as in Fig. 33, in guard hairs. The medullary width is greater than 0.75 that of the hair in the guard hair shield region. Pigmentation: Dorsal hairs brown, ventral hairs yellowish brown. Medullary cells heavily pigmented. Cortical pigment present as granules and streaks. Dimensions: DGH 9-11 mm, 60-80 µm, VGH 7-9 mm.

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(11) *Vandeleuria oleracea* (Bennet 1832)

Two sub-species are recognized.

Guard hairs straight, fine hairs constricted. Scalation: Imbricate, with a dimond-petal pattern. Some guard hairs show lanceolate patches. Medulla: Uniseriate ladder in fine hairs. Multiseriate ladder, with 3 rows of cells at broadest region, in guard hairs. Rodent-base present. Cross-section: Circular-oval in fine hairs, kidney-shaped (as in Fig. 33) in guard hairs. In the shield region of guard hairs, the medullary width is greater than 0.75 that of the hair. Pigmentation: Dorsal hairs light brown, ventral hairs white. Medullary cells lightly pigmented. Cortical pigment absent in fine hairs. In guard hairs, pigment granules and streaks are present only in the tip region. Dimensions: DGH 6-8 mm, 36-48 µm, VGH 4-6 mm in the two subspecies *V. o. nilagirica* and *V. o. nolthenii*.

Family Hystricidae

(12) *Hystrix indica indica* Kerr, 1792

The black-and-yellow banded quills are characteristic. Only the structures of the finest bristles were studied. No fine hairs were obtained. Scalation: Imbricate, with a diamond-petal or lanceolate pattern. Medulla: Fragmental. Cross-section: Circular-oval. Pigmentation: Dorsal and ventral bristles (and quills) are black or dark brown, with white or yellow bands. Some bristles are unicolour black or brown.

F. Order Carnivora

In Sri Lanka, the Carnivora are represented by 8 genera and 14 species. Four sub-species of the Brown Mongoose *(Herpestes fuscus)* are recognized. Museum samples from all except two of the sub-species of the Brown Mongoose (ie. *H. f. rubidior* and *H. f. siccatus)*, were obtained. Additional material from all except the Otter *(Lutra lutra)*, the Ruddy Mongoose *(Herpestes smithi)* and the Stripe-necked Mongoose *(Herpestes vitticollis)* was examined.

Distinct guard and fine hairs are present, the latter being of the curly type. The cuticular scales are imbricate, with lanceolate, diamond-petal or mozaic patterns. Koppiker & Sabnis (1976, 1977) report the presence of coronal scales on the hairs of the Sloth Bear *(Melursus ursinus)* the Palm Civet *(Paradoxurus hermaphroditus)* and the Rusty Spotted Cat *(Felis rubiginosa)* However, the hairs from specimens of these species examined in the present study all showed imbricate scales, with a mozaic pattern in *Melursus* and a lanceolate pattern in *Paradoxurus* and *Felis*.

All fine hair medullas are of the uniseriate ladder type, those of guard hairs being lattice types. The guard hairs of *Lutra*,

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Herpestes, *Felis* and *Panthera* usually show a lattice medulla with transverse bands as in Fig. 58, while in *Canis* and *Paradoxurus*, the medulla appears more random. A honeycomb type of lattice is sometimes seen in the guard hair shaft region in *Viverricula* (Fig.57), but this degenerates in the shield region. These medulla types are quite distinct from those seen in the Artiodactyla, and help to differentiate between the hairs of the two groups, which are often similar in other respects.

The cross-sections of both guard and fine hairs are usually circular or oval in shape, and are thus not very useful in generic or species-level identifications. However, the hair colour and banding pattern are extremely useful in this regard.

Family Mustelidae

(1) *Lutra lutra nair* F. Cuvier, 1823

Guard hairs with a weak, thin shaft region and an expanded shield. Fine hairs curly. Scalation: Imbricate, with a characteristic type of lanceolate pattern (Figs. 8 & 9). Medulla: Fragmental in shaft region and uniseriate ladder in shield region of fine hairs. Guard hair medulla fragmental in lower shaft, transverse lattice in upper shaft, and random in shield region. Cross-section: Oval-flattened type (Fig. 36). In the shield region of guard hairs, the medullary width is greater than 0.5 but less than 0.75 that of the hair. Pigmentation: Dorsal hairs brown, ventral hairs paler. Cortical pigment present as minute granules, sparse in the shaft region and very dense in the shield. Dimensions: DGH 15-20 mm, 132-140 μm, VGH 15-22 mm.

Family Canidae

(2) *Canis aureus lanka* Wroughton, 1916

Guard hairs straight or curly, fine hairs curly. Scalation: Imbricate. Diamond-petal in fine hairs, mozaic in guard hairs. Most guard hairs show a distinct diamond-petal pattern for a short distance along the mid shaft region. Medulla: Uniseriate ladder in fine hairs. Guard hair medulla a transverse lattice as in Fig. 58, usually becoming more random or solid (Figs. 54 & 60) in the shield region. Cross-section: Circular type (Fig. 38). In the shield region of guard hairs, the medullary width is 0.5 to 0.75 that of the hair. Pigmentation: Dorsal hairs black, most with yellow bands at the base and middle region. Ventral hairs pale yellow. Cortical pigment granular. Dimensions: DGH 65-80 mm, 124-140 μm, VGH 35-45 mm.

Family Ursidae

(3) *Melursus ursinus inornatus* Pucheran, 1855

Only guard hairs were present in the samples examined. Scalation:

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Imbricate, with a mozaic pattern. Scale edges distinctly wavy and crenate towards the shield region. Medulla: Uniseriate fragmental. Cross-section: Oval-rectangular sequence. In the guard hair shield region, the medullary width is less than 0.4 that of the hair. Pigmentation: Dorsal and ventral hairs black or blackish brown. Cortical pigment streaky, very dense, and uniformly distributed. Dimensions: DGH & VGH 100-130 mm, 124-148 µm.

Family Viverridae

(4) *Viverricula indica mayori* Pocock, 1933
Guard hairs straight, fine hairs curly. Scalation: Imbricate, with a lanceolate pattern (Fig. 19). Medulla: Uniseriate ladder in fine hairs. Transverse or random lattice in guard hairs (Fig. 54&58). Often, a honeycomb type of lattice is seen in the guard hair shaft region (Fig. 57). Cross-section: Circular-oval type, as in Fig. 37. The medullary width is greater than 0.75 that of the hair, in the shield region of guard hairs. Pigmentation: Dorsal and ventral hairs dark brown, with a paler or white band in the shield region. Cortical pigment present mainly as streaks. Dimensions: DGH 20-25 mm, 152-160 µm, VGH 18-22 mm.

(5) *Paradoxurus hermaphroditus hermaphroditus* (Pallas 1777)
Paradoxurus zeylonensis (Pallas 1777)
Guard hairs straight, usually with the shaft region more than twice the length of the shield. Fine hairs curly. Scalation: Imbricate, with a lanceolate pattern. Medulla: Uniseriate ladder in fine hairs. Lattice medulla of guard hairs random (as in Fig. 54) or transverse (as in Fig. 58). Cross-section: Circular-oval type, with the sections being somewhat flat on one side, in *P. hermaphroditus*. Oval-flattened type (as in Fig. 36) in *P. zeylonensis*. In both species, the medullary width is slightly greater than 0.5 that of the hair, in the shield region of guard hairs. Pigmentation: Dorsal hairs brown or black, often with a pale or white shaft region, and ventral hairs brown or white, in *P. hermaphroditus*. Dorsal and ventral hairs brown, with a colourless shaft region, in *P. zeylonensis*. In both species, the cortical pigment is granular, very sparse in the shaft region and dense in the shield. Dimensions: DGH 35-45 mm, 104-140 µm, VGH 15-25 mm in *P. hermaphroditus*. DGH 25-35 mm, 108-116 µm, VGH 20-30 mm in *P. zeylonensis*.

(6) *Herpestes fuscus* Waterhouse, 1838
Herpestes edwardsi lanka (Wroughton 1915)
Herpestes smithi zeylanicus Thomas, 1921
Herpestes vitticollis vitticollis Bennett, 1835
Four sub-species of *H. fuscus* are recognized.

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Guard hairs straight, fine hairs curly. Scalation: Imbricate. Fine hairs diamond-petal and guard hairs mozaic in *H. fuscus*. Both fine and guard hairs mozaic in the other three species. Medulla: Uniseriate ladder in all fine hairs. Guard hairs show a transverse lattice type (Fig. 58) in the shaft region, which becomes random (Fig. 54) in the shield. Cross-section: Circular-Oval, as in Fig.37, in *H. fuscus* and *H. vitticollis*. Oval-flattened, as in Fig. 36, in *H. edwardsi* and *H. smithi*. In all species, very coarse guard hairs are circular in section. The medullary width is 0.5 to 0.75 that of the hair, in the guard hair shield region, in all species. Pigmentation: Dorsal and ventral hairs brown or reddish brown, with 3-4 white bands in *H. edwardsi*, *H. smithi* and *H. vitticollis*. Dorsal and ventral hairs dark brown, with 3-4 light brown bands in *H. fuscus flavidens* and *H. f. maccarthiae*. Cortical pigment occurs as granules and streaks in all species. Dimensions:DGH 30-45 mm, 120-144 µm, VGH 20-25 mm in *H. fuscus flavidens* and *H. f. maccarthiae*. DGH 30-40 mm, 108-156 µm, VGH 24-35mm in *H. smithi*. DGH 50-70 mm, 140-156 µm, VGH 30-41 mm in *H. vitticollis*.

Family Felidae

(7) *Felis chaus kelaarti* Pocock, 1939
Felis rubiginosa phillipsi (Pocock 1939)
Felis viverrina Bennet, 1833

Guard hairs straight, fine hairs curly. Scalation: Imbricate. Lanceolate or lanceolate-chevron in guard and fine hairs of *F. chaus* and *F. rubiginosa*; diamond-petal in fine hairs and chevron-mozaic in guard hairs of *F. viverrina*. Medulla: Uniseriate ladder in all fine hairs. In guard hairs, the medulla is transverse (Fig. 58) in the shaft region and more random (as in Fig. 54) in the shield. Cross-section: Circular-oval type (as in Fig. 37) in all species. In the shield region of guard hairs, the medullary width is 0.5 to 0.75 that of the hair in *F. viverrina*, 0.75 or greater in *F. chaus* and *F. rubiginosa*. Pigmentation: Dorsal guard hairs unicolour dark reddish brown or with white bands at base and middle, and ventral hairs pale brown or white in *F. rubiginosa*. Dorsal guard hairs dark grey or black, usually with white or yellow bands at base and middle, and ventral hairs pale grey or white, in *F. chaus* and *F. viverrina*. Fine hairs pale brown or white in *F. chaus* and *F. rubiginosa*,dark grey in *F. viverrina*. Cortical pigment present as granules and streaks in all species. Dimensions: DGH 17-25 mm, 124-132 µm, VGH 28-35 mm in *F. chaus*. DGH 15-20 mm, 76-84 µm, VGH 10-20 mm in *F. rubiginosa*. DGH 20-25 mm, 90-110 µm, VGH mm in *F. viverrina*.

(8) *Panthera pardus fusca* (Meyer 1794)

Guard hairs straight, fine hairs curly. Scalation: Imbricate. Diamond-petal pattern in fine hairs, chevron-mozaic in guard hairs. Medulla:

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Uniseriate ladder in fine hairs. Guard hair medulla transverse lattice (Fig. 58) in the shaft region and more random (as in Fig. 54) in the shield region. Cross-section: Circular-oval type, as in Fig. 37. In the shield region of guard hairs,the medullary width is 0.5 to 0.75 that of the hair. Pigmentation: Dorsal guard hairs unicolour black, unicolour brown, or brown with a black tip. Ventral guard hairs black or white. Fine hairs pale brown or white. Cortical pigment present as granules and streaks. Dimensions: DGH 15-21 mm, 108-121 µm, VGH 20-40 mm.
Note: The hairs of the Domestic Dog *(Canis familiaris)* are similar to those of the Jackal *(Canis aureus)* with regard to scalation, medulla and cross-section. In the case of the Domestic Cat *(Felis catus)*, the hair structure is similar to that seen in *F. chaus* and *F. rubiginosa*. Obviously, the pigmentation and dimensions of the hairs vary widely, in the different breeds of domestic dogs and cats.

(G) Order Artiodactyla

Reference samples of hair from specimens of all 7 species of wild Artiodactyla occuring on Sri Lanka were obtained. Additional field samples from all except the Hog Deer *(Axis porcinus)* were examined. The hairs of several specimens of the Domestic Goat *(Capra hircus)* and Domestic Cattle (*Bos* sp.) were also studied, because of the possibility of these animals falling prey to the Leopard.

Both guard and fine hairs are present on the coat of these mammals, but the former type predominates, often to such an extent that the fine hairs are difficult to find. Many of the original samples did not contain any fine hairs, and fresh samples had to be obtained in order to study these hairs. In the case of the adult Wild Pig *(Sus scrofa)* and the Water Buffalo *(Bubalus bubalis)*, distinct fine hairs could not be found. Very young juveniles of *Bubalus* usually possess thin,long, silvery grey hairs, which may correspond to the fine hair type.

The scalation of the hairs is imbricate, with a mozaic pattern, as in Fig. 17. The hairs of the Mouse Deer *(Tragulus meminna)* are peculiar in that, despite an overall imbricate type of scalation, many apparently coronal scales are seen. Indeed, Koppiker & Sabnis (1977) have seen only coronal scales on the hairs of Indian specimens of this species.

Fine hair medullas are generally uniseriate, while guard hair medullas are lattice. The lattice medullas of the Cervidae and Tragulidae are distinct from those of other artiodactyles, containing large air chambers which may appear separate and rounded (Fig. 55)

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or flattened, serrated and inter-connected (Fig. 56). When air is displaced, a fine, regular polygonal network is seen in the former case, and a thicker, more disrupted network seen in the latter. However, these details may be difficult to discern in heavily pigmented hairs. Koppiker & Sabnis (1976, 1977) for instance, do not appear to have observed these medullary structures in hairs of *Tragulus meminna* and *Axis axis*. They have, however, recognized a reticular polygonal appearance in hairs of *Cervus unicolor*, which obviously refers to the medulla type described above.

Among the Bovidae, the hairs of the Water Buffalo *(Bubalus bubalis)* and the Domestic Goat *(Capra hircus)* generally possess a reticular medulla (Fig. 59), while in Domestic Cattle (*Bos* sp.) the medulla appears solid (Fig. 60). The hairs of the single member of the Suidae, the Wild Pig *(Sus scrofa)*, present on Sri Lanka, also possess a solid medulla. However, the long, coarse bristles on the mid-dorsal line of the body possess a much reduced, fragmental lattice medulla.

The cross-sectional shape seems to be generally of the circular-oval type, but many hairs are entirely circular. In the Cervidae and Tragulidae studied, some hairs are oval-flattened in section. Such flattened shapes, however, were not observed among the Suidae and Bovidae studied.

Family Tragulidae

(1) *Tragulus meminna* Erxleben, 1777

Guard hairs straight, fine hairs curly. Scalation: Imbricate, with a mozaic pattern. Some apparently coronal scales are also seen. Medulla: Uniseriate ladder in fine hairs. Guard hair medulla usually with flattened, serrated, inter-connected air chambers (Fig. 56). When air is displaced, a thick, disrupted network is seen. Cross-sections: Circular, or oval, or flattened shapes. In the guard hair shield region, the medullary width is greater than 0.75 that of the hair. Pigmentation: Dorsal guard hairs dark brown, usually with a pale or creamy band towards the shield or tip; some hairs entirly pale. Ventral guard hairs white or creamy. Cortical pigment present as granules and streaks. Dimensions: DGH 20–30 mm, 100–126 μm, VGH 15–25 mm.

Family Cervidae

(2) *Muntiacus muntjak malabaricus* Lydekker, 1915

Guard hairs straight, fine hairs curly. Scalation: Imbricate, with a mozaic pattern. Medulla: Uniseriate ladder in fine hairs. Guard hair medulla lattice, as in Fig. 55, with rounded, separate, air chambers.

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When air is displaced, a fine, polygonal framework can be seen. Cross-section: Circular, oval or flattened sections seen. In the guard hair shield region, the medullary width is greater than 0.75 that of the hair. Pigmentation: Dorsal guard hairs almost colourless in the shaft region, blackish brown for a short distance in the middle, and reddish brown towards the shield. Tip blackish. Ventral guard hairs pale brown, a few white. Cortical pigment present as granules an streaks. Dimensions: DGH 20–25 mm, 140–162 µm, VGH 18–22 mm.

(3) *Axis axis ceylonesis* Fischer, 1829
Axis porcinus porcinus (Zimmermann 1780)

Guard hairs straight. Fine hairs curly in *A. axis*. No fine hairs were present in the samples of *A. porcinus*. Scalation: Imbricate, with a mozaic pattern. Medulla: Uniseriate ladder in fine hairs of *A. axis*. Guard hairs of both species with a chambered lattice, as in Fig. 55, with separate, rounded air cells (polygonal framework when air is displaced). Some hairs of *A. axis*. show connections between the chambers, as in Fig. 56. Cross-section: Circular, oval, or flattened shapes. In the guard hair shield region, the medullary width is equal to, or slightly greater than, 0.75 that of the hair. Pigmentation: Dorsal guard hairs range from dark reddish brown to pale brown, some white, and ventral guard hairs white, in *A. axis*. Dorsal and ventral guard hairs white in the shaft region and very pale brown in the shield, in *A. porcinus*. Cortical pigment present as granules and streaks in both species. Dimensions: DGH & VGH 28–35 mm, 100–120 µm in *A. axis*. DGH & VGH 35–55 mm, 184–236 µm in in *A.porcinus*.

(4) *Cervus unicolor unicolor* Kerr, 1792

Guard hairs straight, fine hairs curly. Most of the dorsal guard hairs are broadest at the base of the shaft region. Scalation: Imbricate, with a mozaic pattern. Medulla: Uniseriate ladder in fine hairs. Chambered lattice with separate, rounded air cells, as in Fig. 55. When air is displaced, a fine polygonal framework is seen. Cross-section: Oval or flattened sections seen. At the broadest region of guard hairs, the medullary width is greater than 0.75 that of the hair. Pigmentation: Dorsal guard hairs brown, with a whitish shaft region. Ventral hairs pale. The shield region of many guard hairs have a speckled appearence due to the presence of dark brown patches within the medulla. Dimensions: DGH 50–75 mm, 362–400 µm, VGH 48–55 mm.

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Family Suidae

(5) *Sus scrofa cristatus* Wagner, 1839

Only guard hairs were present in the samples examined. Scalation: Imbricate, with a mozaic pattern. Medulla: Solid type (Fig. 60). Dorsal bristles show a fragmental medulla. Cross-section: Circular or oval. In section, the medullary column appears to be composed of fine, densely packed granules. In most hairs, the medullary width is greater than 0.5 but less than 0.75 that of the hair. Pigmentation: Hair colour dark brown or black, a few hairs with a white band. Dorsal bristles black, and with characteristically split tips. Cortical pigment present as very fine granules. Dimensions: DGH & VGH 60-75 mm, 200-240 μm, Dorsal bristles 75-90 mm, 360-400 μm.

Family Bovidae

(6) *Bubalus bubalis bubalis* (Linnaeus 1758)

Only guard hairs were present in samples collected from adults. Scalation: Imbricate, with a mozaic pattern. Medulla: Usually reticulate (Fig. 59), sometimes solid (Fig . 60), fragmental or absent in the shield region. Cross-section: Circular or oval. In the shield region, the medullary width is slightly greater than 0.5 that of the hair. Pigmentation: Hair colour grey-brown. Cortical pigment present as granules and streaks. Dimensions: Guard hairs 70-120 mm, 120-150 μm.

Note: Juveniles often possess an abundance of long, slender silvery grey hairs, with a mozaic scale pattern and oval cross-sections. The medulla is fragmental or absent. Cortical pigment is present as large granules.

(7) *Capra hircus* Linnaeus, 1758

No fine hairs were present in the samples collected. Scalation: Imbricate, with a mozaic pattern. Medulla: Reticulate type (Fig. 59). Cross-section: Circular or oval. In the guard hair shield region, the medullary width is greater than 0.75 that of the hair. Pigmentation: Hair colour very variable. Cortical pigment present as very fine granules.

(8) *Bos indicus* Linnaeus, 1758

Several breeds present, many of which show some inter-breeding with European Cattle *(Bos taurus)*. The hair samples collected probably belong to *B. indicus*. Only guard hairs were obtained. Scalation:

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Imbricate, with a mozaic pattern. Medulla: Solid type (Fig. 60). Cross-sections: Circular or oval. In the shield region of guard hairs, the medullary width is 0.5 to 0.75 that of the hair. Pigmentation: Hair colour variable. Cortical pigment present as granules.

H. Order Probòscidea

Samples of hair of the Ceylon Elephant *(Elephas maximus maximus)* were obtained from domesticated animals.

The hairs of this species have imbricate scales, with a chevron-mozaic pattern. The medulla is either absent or highly fragmental. These characters seem to be common to the Order, as they are also present on the hairs of the African Elephant *(Loxodonta africanâ)* and the Mammoth *(Elephas primigineus) (Hausman 1920)*

(1) *Elephas maximus maximus* Linnaeus, 1758

Only guard hairs were present in the samples obtained. Scalation: Imbricate, with a chevron-mozaic pattern. Most scales have a wavy, crenate margin. Medulla: Absent, or only minute fragments present. Cross-section: Circular-oval. Pigmentation: Hair colour black, a few hairs creamy. Cortical pigment very heavy, so dense that the nature of the particles cannot be discerned. Dimensions: DGH 40-60 mm, 400-500 µm.

KEYS FOR HAIR IDENTIFICATION

Keys for hair identification, based on the characters already described, are presented below. Only generic-level identifications have been attempted in the keys. In many instances, species identifications are possible, but since these are usually based on criteria such as pigmentation and hair dimensions, they are not incorporated into the keys.

It has not been possible to examine the hairs of juveniles of the great majority of species studied. Day (1966),in a study on British mammals, states that juveniles usually exhibit the hair characteristics described for adults, but, in some cases, to a lesser degree. However, such differences in degree are not serious enough to affect identification. Mathiak (1938b) states that at the age of several weeks, juvenile mammals develop hairs which, though small, resemble those of adults. Moreover, in the present study it was possible to examine the hairs of juveniles of the Musk Shrew *(Suncus murinus)*, the House Mouse *(Mus musculus)*, the Field Mouse *(Mus cervicolor)* the Spotted Deer *(Axis axis)*, the Mouse Deer *(Tragulus meminna)* and the Grey Mongoose *(Herpestes edwardsi)* — cases the hair characters such as scalation, medulla, cross-sectional structure, and even pigmentation, were smilar to those of adults.

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Thus it is likely that the keys could be used successfully to identify the hairs of juveniles as well as adults.

The keys are based on structures observed on hairs from the main body trunk. According to Day (1966), it is these hairs that best display the features that are typical of the species; hairs from the extremities usually show features that are reduced or simplified versions of those seen on the trunk. The examination of hairs from various body regions of specimens from several species in the present work, confirms Day's observations.

Ideally, therefore, it is the typical body hairs that should be used for making identifications. This should present no problem when an entire specimen, or part of one, is available. However, problems may arise in faeces analysis, since hairs from all regions of the body of one or more prey species may be present. In this case, a preliminary superficial examination of all or most of the hairs in the scat is necessary, so that obviously different hair types (which may belong to different prey species) can be separated. Representative samples from these different types could then be studied in detail. In analysing the faces of the Leopard, the author has not encountered serious difficulties in finding hairs which display the various structures sufficiently clearly for positive identifications to be made (Amerasinghe, unpublished data).

Both guard and fine hair structures are used in constructing the keys, but the emphasis is on the guard hairs, since it is these that show structural variations that are most useful in identification. Also, the guard hairs are much less subject to deterioration in the digestive tract of predators, than are the fine hairs (Mathiak, 1938b).

KEY - I : Orders of Mammals

1.	(a)	Medulla highly fragmental or absent in all guard and fine hairs.	2
	(b)	A continuous or occasionally fragmented medullary column present in most or all guard and fine hairs.	5
2.	(a)	Medulla totally absent. All hairs <20 mm in length, <40 µm in width.	Chiroptera (part)
	(b)	Medulla fragmental in guard hairs, absent in fine hairs. Guard hairs <25 mm in length, <60 µm, in width.	Chiroptera (Pteropus)

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	(c)	Medulla fragmental or absent in both guard and fine hairs. Guard hairs > 25 mm in length, >60 μm in width.	3
3.	(a)	Hair colour deep black or brownish black. Cortical pigment heavy and uniform. Scales imbricate, mozaic pattern.	4
	(b)	Hair colour grey-brown, yellowish or silvery. Cortical pigment heavier towards the shield. Guard hairs <100 mm in length, ≤ 100 μm in width. Scales imbricate, mozaic.	Primates (part)
	(c)	Black-and-yellow (or white) banded quills or bristles. Scales imbricate, lanceolate or diamond-petal pattern in shaft region.	Rodentia *(Hystrix)*
4.	(a)	Guard hairs generally <100 mm in length, >300 μm in width.	Proboscidea *(Elephas)* Artiodactyla (dorsal bristles of *Sus)*
	(b)	Guard hairs generally >100 mm in length, <200 μm in width.	Carnivora *(Melursus)*
5.	(a)	Medulla uniseriate ladder in both guard and fine hairs.	6
	(b)	Medulla uniseriate ladder in fine hairs, multiseriate or lattice in guard hairs.	8
6.	(a)	Guard hairs straight. Intermediate and fine hairs constricted. Scales imbricate, lanceolate pattern.	Insectivora
	(b)	All hairs unconstricted Scales various.	7
7.	(a)	No definite distinction between guard and fine hairs. Scales coronal, or imbricate with 2 rows of scales along shaft. All hairs < 25 mm in length.	Chiroptera (part)
	(b)	Guard hairs straight, with imbricate scales (mozaic pattern). Fine hairs curly, either coronal at base and imbricate (mozaic) at shield, or imbricate (mozaic) throughout. ..... Most hairs > 25 mm in length.	Primates (part)

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8.	(a)	Streaky-chevron scale pattern (Fig. 13), lagomorph medulla (Fig. 49) and dumb-bell shaped guard hair cross-sections (Fig. 39).	Lagomorpha
	(b)	Scalation, medulla and cross-section not as above.	9
9.	(a)	Guard hairs straight (sometimes spinous), fine hairs constricted.	10
	(b)	Guard hairs straight, fine hairs curly. ...	11
10.	(a)	Rodent-base medulla usually present in shaft region of guard hairs (Fig. 46). If absent, guard hairs spinous, with transverse lattice medulla (Fig. 53).	Rodentia (part)
	(b)	Rodent-base medulla indistinct or absent in shaft region of guard hairs. Guard hair medulla random (Fig. 51) or or transverse (Fig. 53) lattice type. Scales imbricate, a characteristic lanceolate-chevron type (Fig. 18), ...	Rodentia *(Bandicota)*
11.	(a)	Rodent-base medulla present in shaft region of guard hairs(Fig. 46).	Rodentia (part)
	(b)	Rodent-base medulla absent in shaft region of guard hairs.	12
12.	(a)	Guard hair scale pattern lanceolate, diamond-petal, or diamond-petal-chevron in the shaft region. (Fine hair scalation similar).	13
	(b)	Guard hair scale pattern chevron or mozaic in the shaft region. (Fine hair scalation similar or different).	15
13.	(a)	Lattice medulla with a honeycomb appearance in guard hair shaft region (Figs. 52 & 57).	14

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(b) Guard hair medulla random (Fig. 54) or Transverse (Fig. 58) lattice type. ..... Carnivora (part)

14. (a) Scalation of guard and fine hairs lanceolate (Fig. 19). ..... Carnivora (part)

(b) Scalation of guard and fine hairs diamond-petal or diamond-petal-chevron (Figs. 14 & 15). ..... Rodentia *(Ratufa)*

15. (a) Most guard hairs brown, with 3-4 pale bands. Guard hair medulla random (Fig. 54) or transverse (Fig. 58) lattice type. Fine hair scalation diamond-petal-chevron or mozaic. ... Carnivora *(Herpestes)*.

(b) Guard hair colour various, unicolour or with 1-2 pale bands at most. Guard hair medulla various, fine hair scalation various..... 16

16. (a) Fine hair scalation lanceolate or diamond-petal. Guard hair medulla random (Fig. 54) or transverse (Fig. 58) lattice type. ..... Carnivora (part)

(b) Fine hair scalation chevron or mozaic. Guard hair medulla chambered, as in Figs. 55 & 56 (network effect when air is displaced), or reticulate (Fig. 59), or solid (Fig. 60), or fragmental. ..... Artiodacyla.

KEY - II : The Insectivora

Guard and fine hairs show a lanceolate scale pattern and uniseriate ladder medulla. All fine hairs are constricted.

1. (a) Intermediate and fine hair cross-sections without deep emarginations. 2

(b) Intermediate and fine hair cross-sections with deep emarginations. 3

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2. (a) Guard hair sections circular or oval. Intermediate and fine hair sections as in Fig. 41. ..... *Solisorex pearsoni*.

   (b) Guard hair sections circular. Intermediate and fine hair sections as in Fig. 42 . ..... *Suncus*.

3. (a) Cross-sections with 2 deep emarginations as in Fig. 40. ..... *Feroculus feroculus*.

   (b) Cross-sections with 3-4 deep emarginations as in Fig. 43 & 44 . ..... *Crocidura*.

KEY - III : The Chiroptera

1. (a) Uniseriate ladder medulla in guard and fine hairs. 2

   (b) Medulla absent in guard and fine hairs. 3

   (c) Medulla absent in fine hairs, fragmental in guard hairs. Scale pattern chevron-mozaic in both hair types. ....., *Pteropus giganteus*.

2. (a) Cuticular scales coronal. Hair profile spiky. ..... *Cynopterus*.

   (b) Cuticular scales imbricate, in two rows along the hair shaft. Hair profile straight (Fig. 29). ..... *Megaderma*.

3. (a) Guard hair scales imbricate, with chevron-mozaic pattern. Fine hairs coronal, serrate. Guard and fine hair profile spiky. ..... *Rousettus leschenaulti*.

   (b) All hairs have simple, dentate, or irregular coronal scales. 4

   (c) Coronal scales deeply cleft, giving the impression of imbricate scalation. 7

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4.	(a)	Coronal scales distinctly dentate.	5
	(b)	Coronal scales simple or irregular.	6
5.	(a)	Hair profile spiky, as in Fig. 30.	*Tadarida.*
	(b)	Hair profile spiky, as in Fig. 31.	*Taphozous.*
6.	(a)	Hair profile zig-zag (Fig. 26a) at proximal region, straighter along the rest, including any constrictions.	*Rhinolophus.*
	(b)	Hair profile straight (or step-like) in guard hairs and thick regions of fine hairs. All constricted zones of fine hairs with zig-zag profile.	*Miniopterus schreibersi.*
	(c)	Hair profile straight or step-like. No distinct zig-zag profile at base.	*Hipposideros.*
7.	(a)	Fine hair coronal scales with a single cleft, appearing as 2 rows of alternately arranged scales, as in Fig. 21.	8
	(b)	Fine hair coronal scales cleft at several points, giving the appearance of elongate, spirally arranged scales, as in Fig. 22.	*Scotophilus.*
8.	(a)	Hair profile straight, as in Fig. 26.	*Kerivoula.*
	(b)	Hair profile straight (as in Fig. 28), or step-like.	*Murina cyclotis.*
	(c)	Hair profile spiky, as in Fig. 32.	*Hesperoptenus tickelli.*
	(d)	Hair profile bilobed, as in Fig. 27.	9
9.	(a)	Fine hairs with several constrictions.	*Myotis.*
	(b)	Single constriction between shaft and shield region of fine hairs.	*Pipistrellus.*

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KEY - IV : The Primates

All medullas are of the uniseriate ladder or uniseriate fragmental type. The cross-sections are circular or oval.

1. (a) Fine hairs predominate, form inter-woven mass. Guard hair scalation chevron-mozaic. Fine hairs coronal in the shaft region, imbricate (chevron-mozaic) in shield. ..... *Loris tardigradus.*

   (b) Guard and fine hairs equally well represented, fine hairs not inter woven. Both hair types with chevron-mozaic scale pattern. 2

2. (a) Guard and fine hair show a uniseriate ladder medulla, which is occasionally fragmented. ..... *Presbytis senex.*

   (b) Guard and fine hair medulla highly fragmental uniseriate type, or absent. ..... *Presbytis entellus* & *Macaca sinica.*

KEY - V The Rodentia

In cases where the keys terminate with 2 alternatives (genera or species), the detailed hair characteristics provided in the previous section can be used to attempt further identification.

1. (a) Multiseriate ladder medulla in guard hairs (Figs. 47 & 50). 2

   (b) Various types of lattice medulla in guard hairs. 8

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2.	(a)	Scale pattern chevron.	3
	(b)	Scale pattern lanceolate or Diamond-petal.	5
3.	(a)	Guard hair cross-sections circular-oval, as in Fig. 37. Fine hairs unconstricted.	*Funambulus.* (*F. layardi, F. sublineatus*)
	(b)	Guard hair cross-sections kidney shaped, as in Fig. 33. Fine hairs constricted.	4
4.	(a)	Guard hair medulla with 4-5 rows of cells, medullary cells heavily pigmented.	*Rattus blanfordi.*
	(b)	Guard hair medulla with 6-7 rows of cells. Medullary cells with very light pigment.	*Tatera indica.*
5.	(a)	Multiseriate ladder medulla in shaft and shield region of guard hairs.	6
	(b)	Multiseriate ladder medulla in shaft, becoming distinctly lattice in the shield region of guard hairs (Figs. 47 & 48).	7
6.	(a)	Guard hair medulla with 3-4 rows of cells.	*Vandeleuria oleracea, Mus musculus.*
	(b)	Guard hair medulla with 6-7 rows of cells.	*Millardia meltada, Mus cervicolor.*

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7.	(a)	Guard hair cross-sections kidney shaped, as in Fig. 33.	*Rattus (R. norvegicus, R. montanus)*
	(b)	Guard hair cross-sections kidney shaped, as in Fig. 34.	*Golunda ellioti, Mus cervicolor.*
8.	(a)	Scale pattern mozaic (Fig.11) or chevron (Fig. 12). Rodent-base medulla present (Fig. 46). Cross-sections circular-oval (Fig. 37). Fine hairs constricted.	9
	(b)	Scale pattern otherwise. Rodent-base medulla present or absent. Cross-sections and fine hairs various.	10
9.	(a)	Scale pattern chevron (Fig. 12). Honeycomb medulla present (Fig.52).	*Funambulus palmarum.*
	(b)	Scale pattern a characteristic mozaic type (Fig. 11). Honeycomb appearance of medulla occasional.	*Petaurista petaurista.*
10.	(a)	Cross-section of the circular-oval type.	11
	(b)	Cross-sections of the kidney shaped type.	12
11.	(a)	Scale pattern diamond-petal or diamond-petal-chevron (Figs.14 & 15). Medulla honeycomb lattice, as in Fig. 52, in the shaft and lower shield regions of guard hairs. Fine hairs unconstricted.	*Ratufa macroura.*

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(b) Scale pattern a characteristic lanceolate-chevron type (Fig. 18). Medulla random (Fig. 51) or transverse (Fig. 53). Fine hairs constricted. ..... *Bandicota.*

12. (a) Scale pattern diamond-petal (as in Fig. 10), may be modified in spinous hairs. 13

(b) Scale pattern a characteristic lanceolate-chevron type (Fig. 18)..... *Bandicota.*

13. (a) Guard hair not spinous, medulla transverse (Fig. 53) or random (Fig. 51), cross-sections as in Fig. 33. Rodent-base present (Fig.46). ..... *Rattus.* *(R. rattus, R. ohiensis)*

(b) Guard hairs spinous, medulla transverse, rodent-base absent. *14*

14. (a) Guard hair cross-sections as in Fig. 34. ..... *Golunda ellioti.*

(b) Guard hair cross-sections as in Fig. 35. ..... *Mus.* *(M. mayori, M. fernandoni)*

KEY - VI : The Carnivora

In cases where the keys terminate with 2 or more alternatives, the detailed hair characteristics provided in the previous section can be used to attempt further identification.

1. (a) Most guard hairs > 100 mm in length, Medulla fragmental or absent. Hairs black or brownish black in colour. ..... *Melursus ursinus.*

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	(b)	Guard hairs < 100 mm in length. Lattice medulla present. Hairs brown, grey or black, often banded.	2
2.	(a)	Scale pattern lanceolate in guard and fine hairs.	3
	(b)	Scale pattern diamond-petal, diamond-petal-chevron or mozaic in guard and fine hairs.	6
3.	(a)	Medulla with a honeycomb appearance (Fig. 57) in shaft region of many guard hairs. Cross-sections circular-oval (Fig. 37).	*Viverricula indica.*
	(b)	Random (Fig. 54) or transverse (Fig. 58) medulla in guard hairs.	4
4.	(a)	Characteristic lanceolate scales with rounded tips in guard and fine hairs (Figs. 8 & 9). Guard and fine hair medulla fragmental in shaft and continuous in shield. Cross-sections oval-flattened (Fig. 36).	*Lutra lutra.*
	(b)	Lanceolate scales as in Fig. 19. Guard and fine hair medulla not fragmental in shaft region.	5
5.	(a)	Medulla transverse in shaft and random in shield region of guard hairs. Cross-sections circular-oval (Fig. 37). Medullary width ≥ 0,75 that of hair in shield region.	*Viverricula*, (some hairs) *Felis.* *(F. chaus, F. rubiginosa)*
	(b)	Medulla usually random throughout guard hairs. Cross-section oval-flattened (Fig. 36). Medullary width ≤ 0,5 that of hair in shield region	*Paradoxurus.*

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6. (a) Guard hairs with 3-4 pale bands. ..... *Herpestes.*

   (b) Guard hairs unicolour or with 1-2 pale bands. 7

7. (a) Guard hair cross-sections circular (Fig. 38). Distinct patch of diamond-petal scales usually present in mid region of guard hairs. .... *Canis aureus.*

   (b) Guard hair cross-sectons oval (Fig. 37). No distinct diamond-petal scalation in mid region of guard hairs. 8

8. (a) Guard hairs without pale bands. Dorsal guard hairs unicolour black or brown, or with blackish tips. Ventral guard hairs black or white. Fine hairs pale brown or white. ..... *Panthera pardus.*

   (b) Dorsal and ventral guard hairs grey or black, most with a single pale band in the shield region. Fine hairs grey. ..... *Felis viverrina.*

KEY - VII : The Artiodactyla

In cases where the keys terminate with 2 alternatives, the detailed hair characters provided in the previous section can be used to attempt further identification.

1. (a) Guard hair medulla with prominent air spaces, or distinct network effect. ..... 2 *(Cervidae, Tragulidae).*

   (b) Guard hair medulla without prominent air spaces or distinct network effect. .....5 *(Suidae, Bovidae).*

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2.	(a)	Medullary chambers flattened, serrated, and inter-connected (Fig.56). When air is displaced, a thick, disrupted network effect is seen.	3
	(b)	Medullary chambers generally rounded and separate (Fig. 55). When air is displaced, a fine polygonal network is seen.	4
3.	(a)	Most brown guard hairs with a prominent pale or creamy band in the shield region.	*Tragulus meminna.*
	(b)	Brown guard hairs without a pale band in the shield region.	*Axis*
4.	(a)	Most guard hairs > 250 μm in width at the broadest region.	*Cervus*
	(b)	Guard hairs < 200 μm in width at the broadest region.	*Axis, Muntiacus.*
5.	(a)	Guard hairs stiff, bristles. Usually > 50 mm in length, > 200 μm in width. Medulla always solid (Fig. 60). Dorsal bristles > 350 μm in width, with a fragmental medulla. Hair colour usually black	*Sus.*
	(b)	Guard hairs very flexible, usually > 50 mm in length, < 200 μm in width. Medulla reticulate (Fig. 59) or solid (Fig. 60) in parts. Hair colour dark grey or grey-brown.	*Bubalus.*
	(c)	Hair colour very variable; dimensions variable, but usually < 50 mm in length, < 200 μm in width. Medulla solid or reticulate.	*Bos, Capra.*

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SUMMARY

This paper presents the results of a microscopical study of the hairs of 108 species and sub-species of wild mammals occurring on Sri Lanka. The characters investigated are the cuticular scales, medulla, cross-sectional appearance, pigmentation and hair dimensions. Descriptions of the hair structures of the genera and species studied, together with generic level keys for hair identification are provided.

ACKNOWLEDGEMENTS

My thanks are due to Professor H. Crusz for his encouragement of this work and for making available the facilities of the Department of Zoology, University of Peradeniya, where this study was carried out; to Dr.G.Mckay who initiated this project, supervised the collection of museum samples and offered helpful advice and criticism; to Dr. P.H.D.H. de silva, former Director, Sri Lanka National Museums, and Mr. Lyn de Alwis, Director, National Zoological Gardens, for their co-operation in obtaining hair samples; to Mr. B.W.B.Van Cuylenberg, Mr. V.Nugegoda, Dr. C.V.M. Santiapillai, Mrs. P.H. Amerasinghe and Mr. L.Baranage for help in obtaining additional hair samples; to Mr. G.W.Abeysekera and Mr. U.B.Ekanayake for help with the photography and to Mrs.P.Pereira for typing the manuscript.

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EXPLANATION OF PLATES AND FIGURES

PLATE 1

Figure 1. Longitudinal section through a generalized mammalian hair. a = cuticle, b = cortex, c = medullary column.

d = medullary cell, e = pigment granules.

Figure 2. Constricted fine hair, showing regions of constriction at points of bending of the hair.

Figure 3. Curly fine hair, showing an even taper throughout.

Figure 4. Intermediate hair, with a weak, slender shaft region and a coarse, expanded shield region.

Figure 5. Typical guard hair, with a well developed shaft and shield region.

Figure 6. Spinous hair, with a reduced shaft region and a highly expanded shield region.

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PLATES 2 & 3

Cuticular Scales and Scale Patterns

(Camera lucida drawings of shaft regions of hairs)

Figure 7. Lanceolate scale pattern. Note pointed scale apices. (Guard hair of *Crocidura miya)*

Figure 8. Lanceolate scale pattern. Note rounded scale apices. (Fine hair of *Lutra lutra)*

Figure 9. Lanceolate scale pattern. Note rounded scale apices. (Guard hair of *Lutra lutra)*

Figure 10. Diamond-petal scale pattern (Guard hair of *Mus mayori)*.

Figure 11. Mozaic scale pattern (Guard hair of *Petaurista petaurista)*.

Figure 12. Chevron scale pattern (Guard hair of *Funambulus palmarum)*.

Figure 13. Streaky-chevron scale pattern (Guard hair of *Lepus nigricollis)*.

Figure 14. Diamond-petal scale pattern (Fine hair of *Ratufa macroura)*.

Figure 15. Diamond-petal-chevron scale pattern (Guard hair of *Ratufa macroura)*.

Figure 16. Mozaic scale pattern (Guard hair of *Presbytis senex)*.

Figure 17. Mozaic scale pattern (Guard hair of *Axis axis)*.

Figure 18. Lanceolate-chevron scale pattern (Guard hair of *Bandicota indica)*.

Figure 19. Lanceolate scale pattern (Guard hair of *Viverricula indica)*.

Figure 20. Coronal dentate scales (Fine hair of *Tadarida aegyptica)*.

Figure 21. Coronal cleft scales, giving the appearance of 2 rows of imbricate scales (Fine hair of *Pipistrellus mordax)*.

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Figure 22. Coronal scales split at several points along margin. These give the impression of imbricate scales arranged spirally around the hair. (Fine hair of *Scotophilus kuhli*).

Figure 23. Coronal serrate scales (Fine hair of *Rousettus leschenaulti*).

Figure 24. Coronal simple scales (Fine hair of *Hipposideros lankadiva*).

Figure 25. Coronal scales that do not completely encircle the hair (Fine hair of *Rhinolophus rouxi*).

PLATES 4 & 5

Hair Profiles of the Chiroptera

(Camera Lucida drawings. a = proximal region of hair, b = middle region of hair, c = distal region of hair)

Figure 26. Zig-zag profile (Fine hair of *Rhinolophus luctus*).

Figure 27. Bilobed profile (Fine hair of *Pipistrellus mordax*).

Figure 28. Straight profile, no medulla (Fine hair of *Hipposideros lankadiva*).

Figure 29. Straight profile, medulla present (Fine hair of *Megaderma spasma*).

Figure 30. Spiky profile, with the distal region bell-like (Fine hair of *Tadarida aegyptica*).

Figure 31. Spiky profile, with the distal region broad and flattened (Fine hair of *Taphozous longimanus*).

Figure 32. Spiky profile with short spikes, almost absent in the distal region (Fine hair of *Hesperoptenus tickelli*).

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PLATES 6,7 & 8

Cross-sectional Shapes of Hair

(Camera Lucida drawings)

Figure 33. Oval-kidney shaped sequence (Guard hair of *Rattus rattus).*

Figure 34. Kidney shaped-flattened sequence (Guard hair of *Golunda ellioti).* Note square shape of tip.

Figure 35. Kidney shaped-flattened sequence (Guard hair of *Mus mayori).* Note indented tip.

Figure 36. Oval-flattened sequence (Guard hair of *Lutra lutra).* The flat section is twice as long as it is broad.

Figure 37. Circular-oval sequence (Guard hair of *Viverricula indica).* The oval section is less than twice as long as it is broad.

Figure 38. Circular sequence (Guard hair of *Canis aureus).*

Figure 39. Dumb-bell shaped guard hair sections of *Lepus nigricollis.*

Figure 40. Sections of intermediate hair of *Feroculus feroculus.* Note that the sections have two clear emarginations.

Figure 41. Sections of intermediate hair of *Solisorex pearsoni.* Note the flat surface on one side.

Figure 42. Sections of intermediate hair of *Suncus murinus.*

Figure 43. Sections of intermediate hair of *Crocidura miya.* Note that the sections have four emarginations.

Figure 44. Sections of intermediate hair of *Crocidura horsfieldi.* Note that the sections have only three clear emarginations.

PLATES 9 & 10

The Medullas

Figure 45. Uniseriate ladder medulla (Fine hair of *Rattus blanfordi).*

Figure 46. Rodent-base medulla (Shaft region of guard hair of *Funambulus palmarum).* Note the double row of alternately arranged medullary cells.

Figure 47. Multiseriate ladder medulla (Shaft region of guard hair of *Rattus norvegicus).* Note the medullary structure in the shield region, in Fig. 48.

Figure 48. Lattice medulla, seen in the shield region of the same hair as in Fig. 47 *(Rattus norvegicus)*.

Figure 49. Lagomorph medulla (Shield region of guard hair of *Lepus nigricollis)*.

Figure 50. Multiseriate ladder medulla, showing the appearance when air is present in the medullary column. (Shield region of guard hair of *Rattus blanfordi)*.

Figure 51. Random lattice medulla, as seen in the Rodentia. (Shield region of guard hair of *Bandicota indica)*.

Figure 52. Honeycomb lattice medulla. The upper region shows the appearance when air is present in the medulla, and the lower region, the appearance when air is displaced. (Shield region of guard hair of *Funambulus palmarum)*.

Figure 53. Transverse lattice medulla, as seen in the Rodentia. The upper region shows the appearance when air is present in the medulla, and the lower region, the appearance when air is displaced. (Shield region of guard hair of *Mus mayori)*.

Figure 54. Random medulla, as seen in the Carnivora.The upper and lower regions show the appearance when air is present and absent, respectively, from the medulla. (Shield region of guard hair of *Herpestes fuscus)*.

Figure 55. Lattice medulla with prominent air chambers rounded and separate. When air is displaced, a polygonal network is visible. (Shield region of guard hair of *Muntiacus muntjak)*.

Figure 56. Lattice medulla with prominent air chambers flattened, serrated, and often inter-connected. When air is displaced, disrupted network is visible. (Shield region of guard hair of *Tragulus meminna)*.

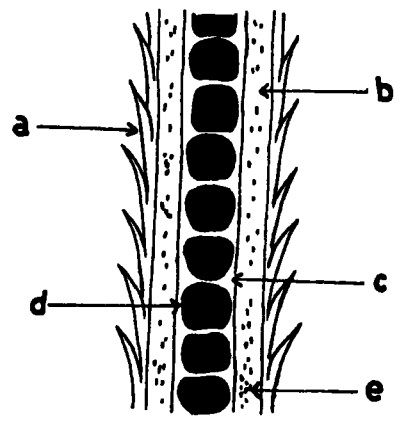
Figure 57. Honeycomb lattice medulla, sometimes seen in the shaft region of guard hairs of *Viverricula indica*. The upper and lower parts of the photograph show the appearance when air is present and absent, respectively, from the medullary column.

Figure 58. Transverse lattice medulla, as seen in the Carnivora. (Shaft region of guard hair of *Panthera pardus)*.

Figure 59. Reticulate type of lattice medulla (Shaft region of guard hair of *Bubalus bubalis)*.

Figure 60. Solid medulla (Shaft region of guard hair of *Bos* sp.).

PLATE - 1



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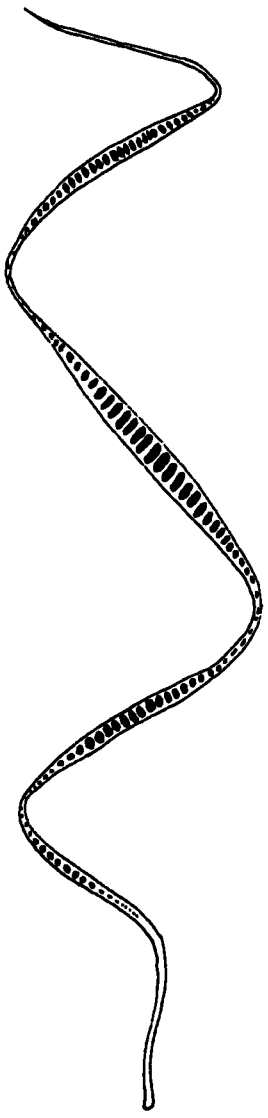

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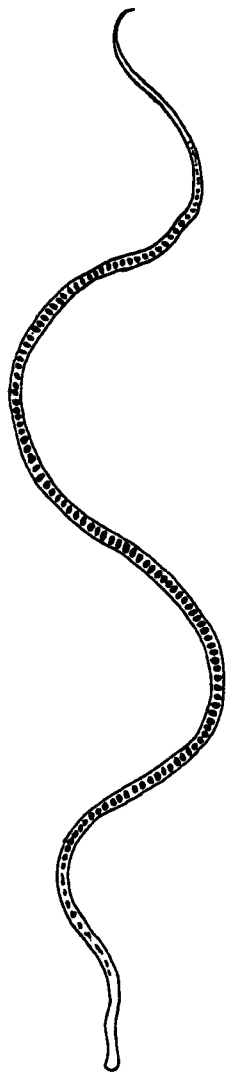

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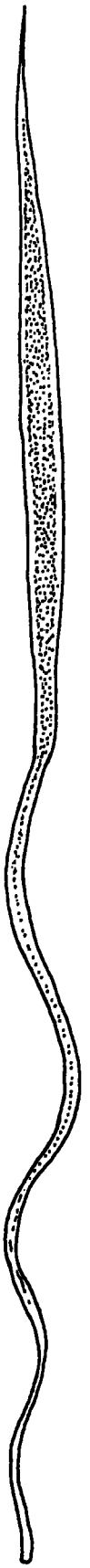

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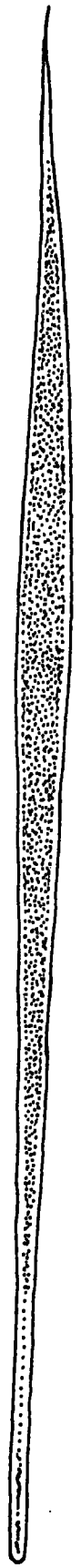

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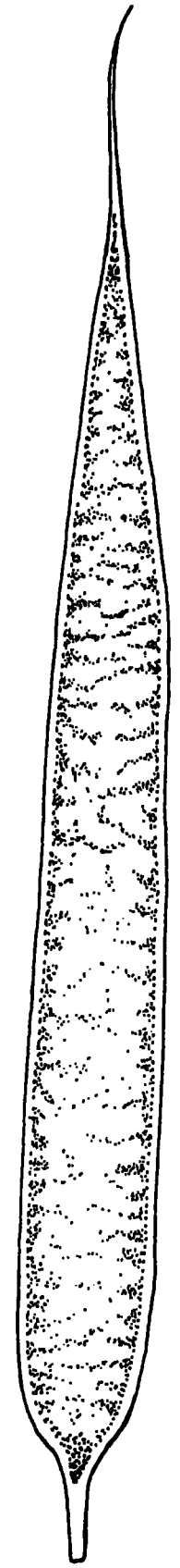
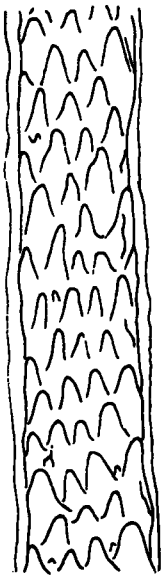


fig. 6

PLATE - 2

fig. 7

fig. 8



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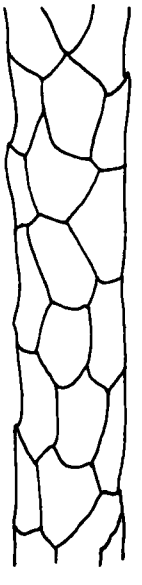

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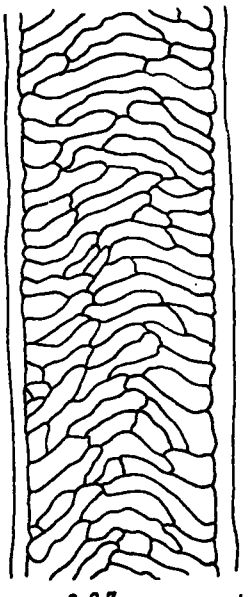

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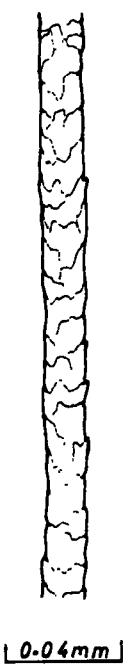

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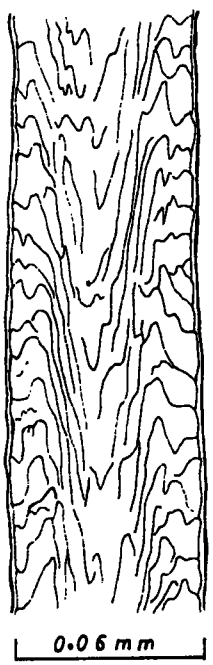
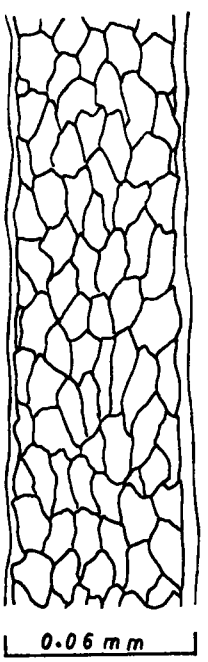


fig. 13

fig.14



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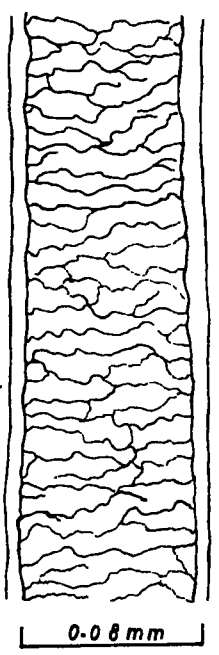

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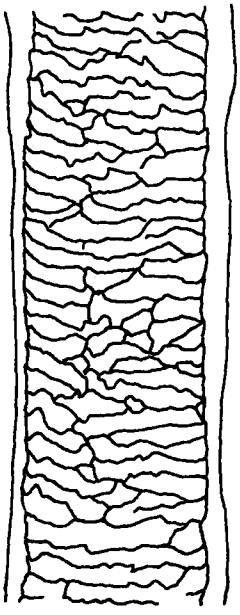
PLATE - 3



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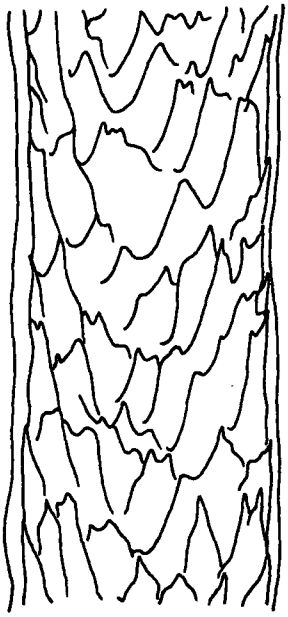

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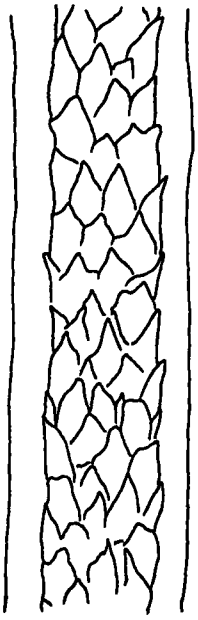
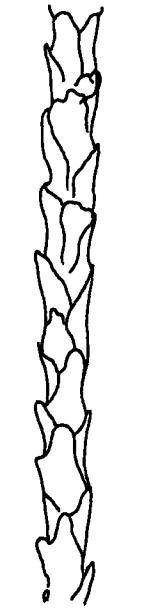


fig. 19

fig. 20

fig. 21



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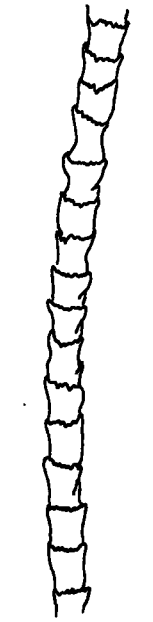

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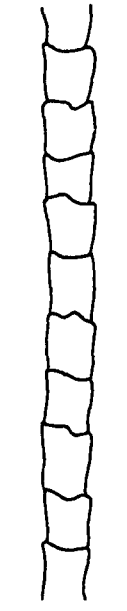

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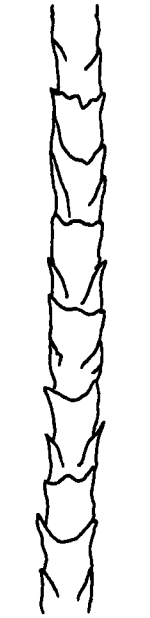

fig. 25

PLATE - 4

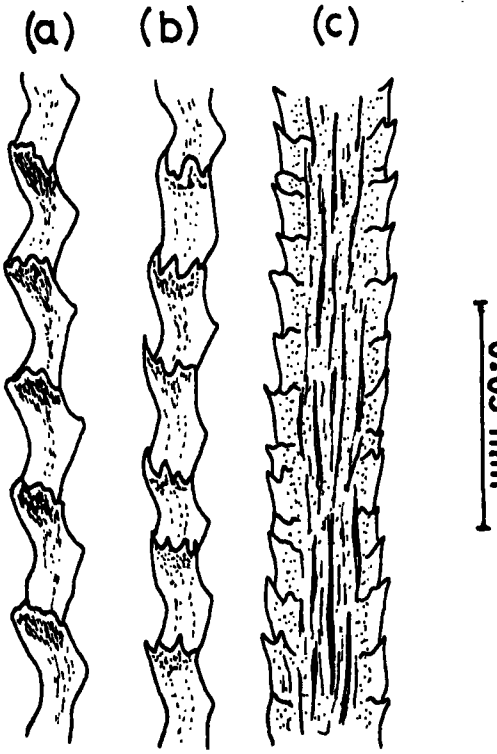

fig. 26

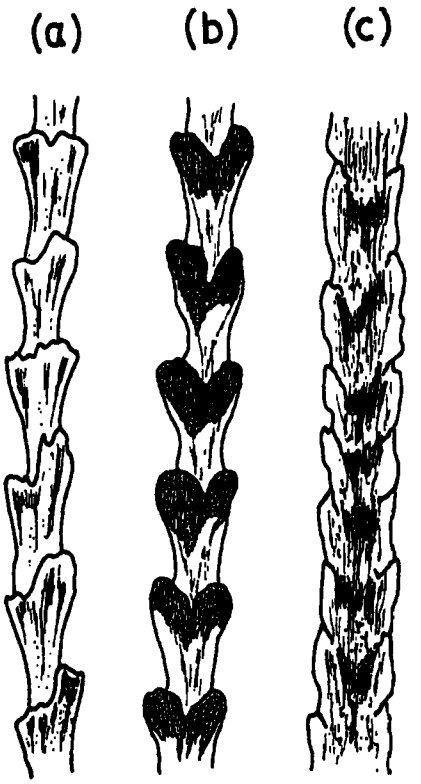

fig. 27

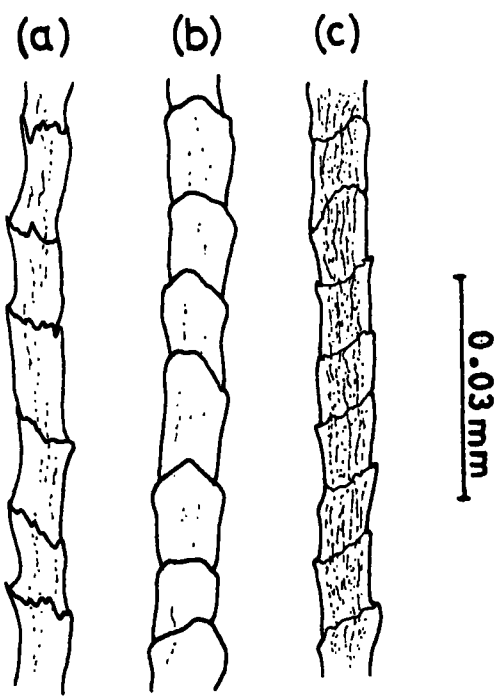

fig. 28

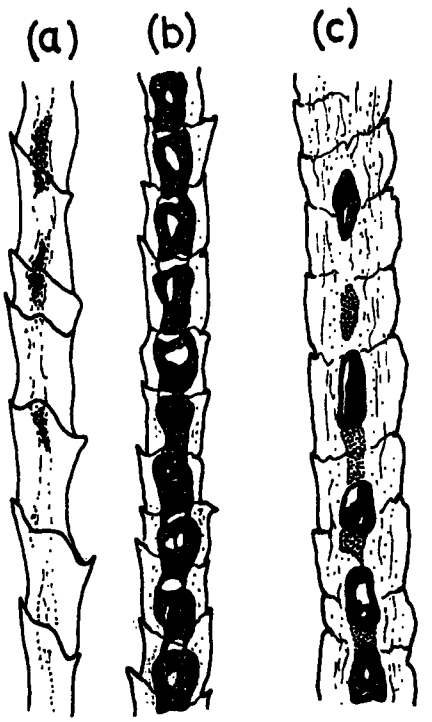

fig. 29

PLATE -5

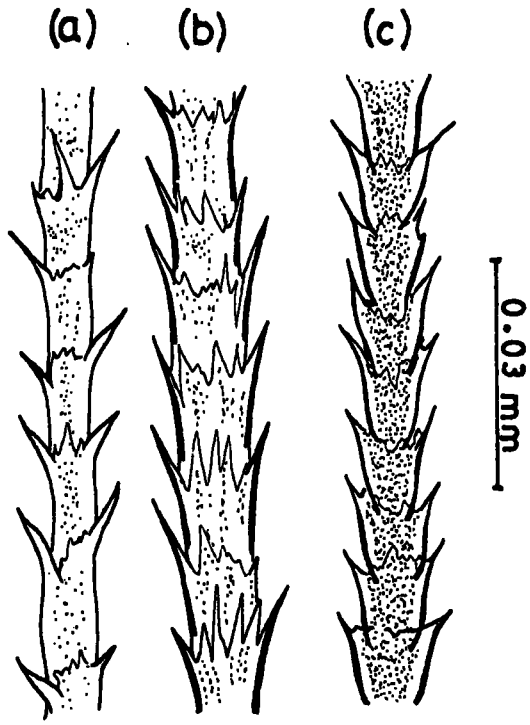

fig. 30

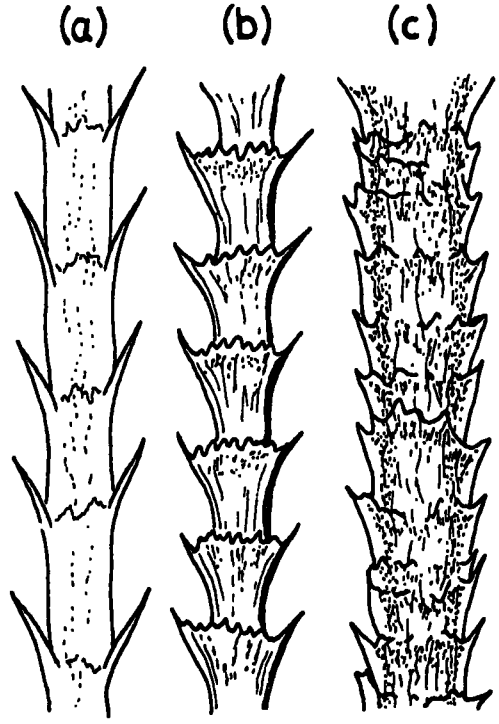

fig. 31

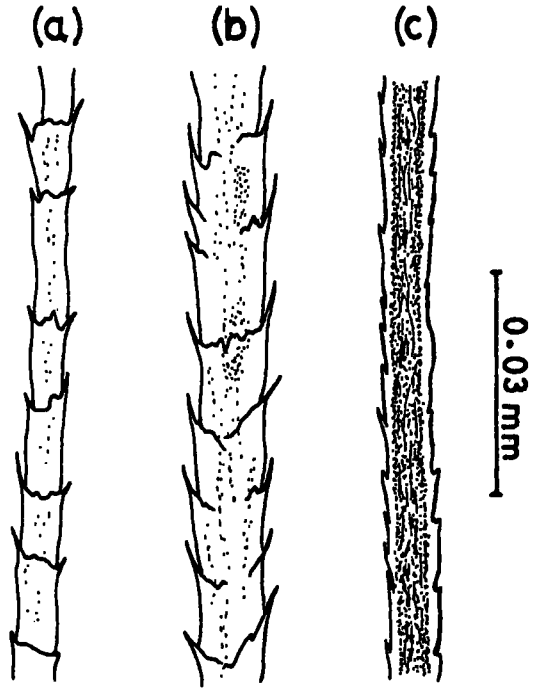

fig. 32

PLATE - 6

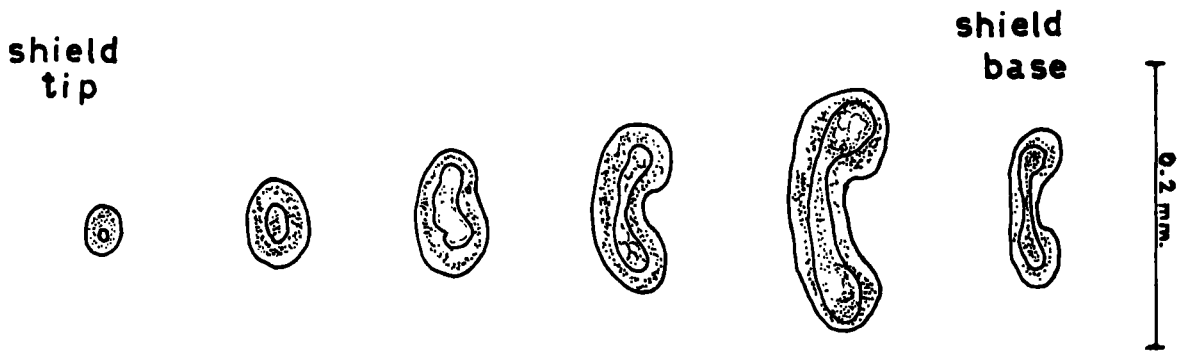

fig. 33

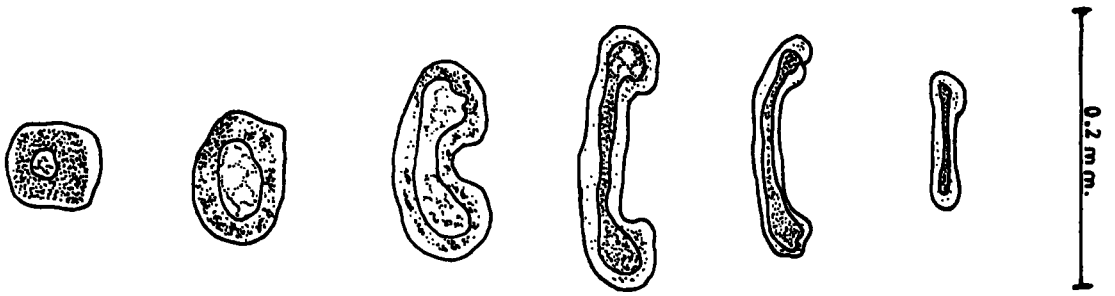

fig. 34

fig. 35

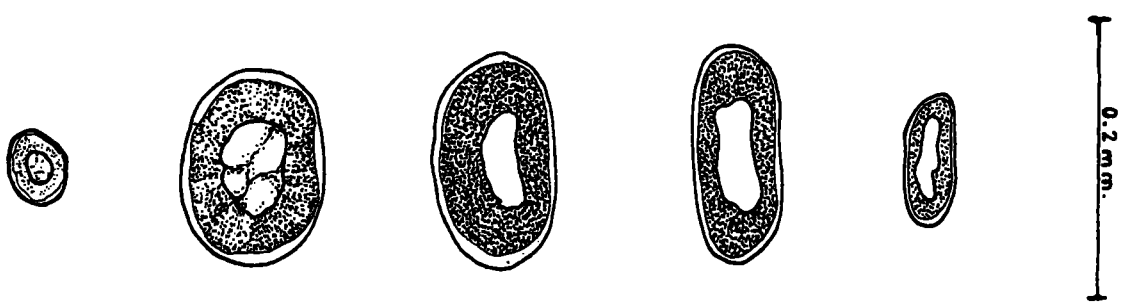

fig. 36

PLATE - 7

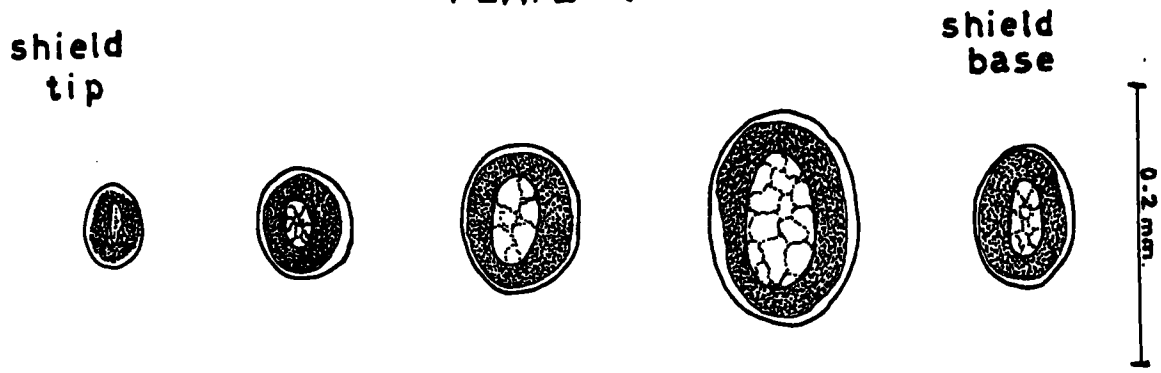

fig. 37

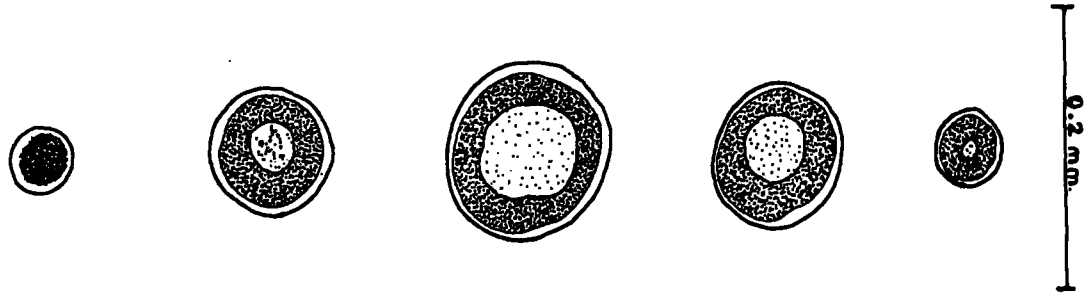

fig. 38

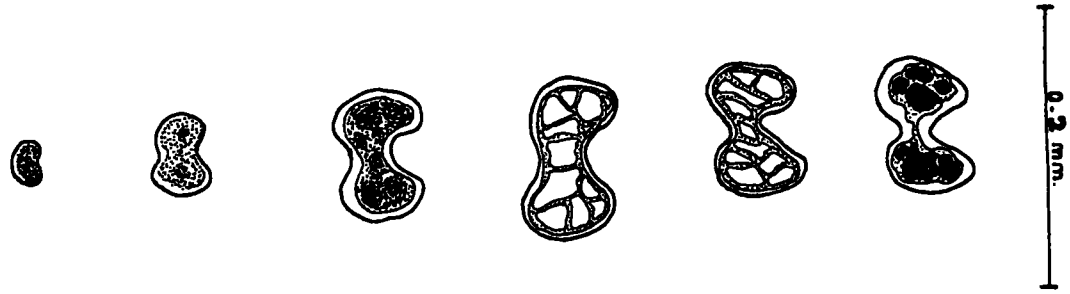

fig. 39

fig. 40

PLATE - 8

fig. 41

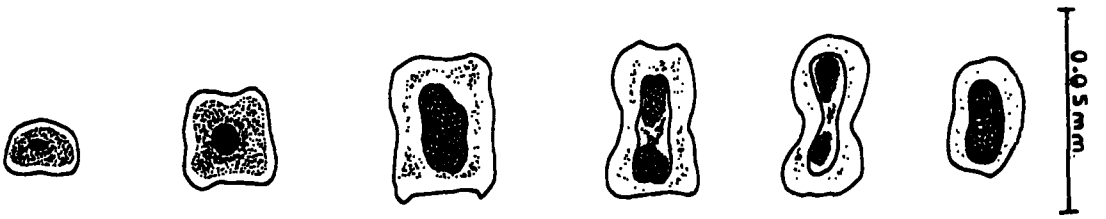

fig. 42

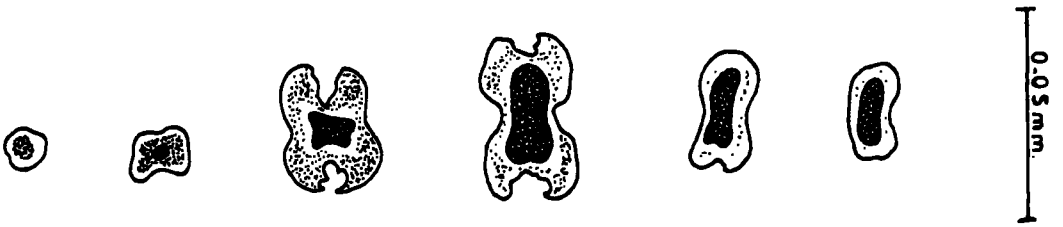

fig. 43

fig. 44

PLATE - 9

fig. 45

fig. 46

fig. 47

fig. 48

fig. 49

fig. 50

fig. 51

fig. 52

PLATE - 10

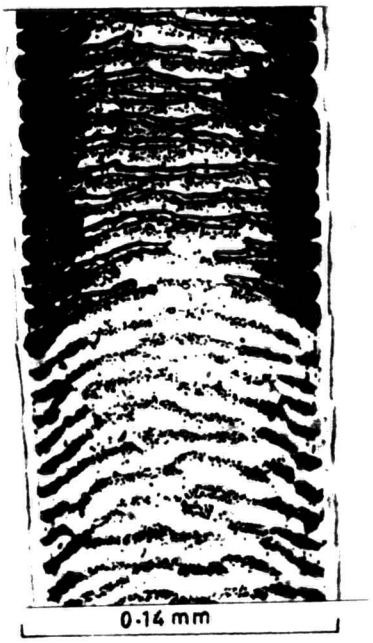

fig. 53

fig. 54

fig. 55

fig. 56

fig. 57

fig. 58

fig. 59

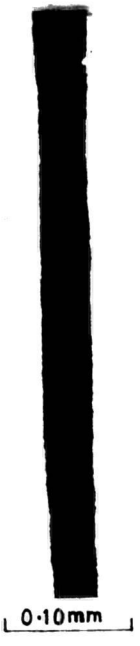

fig. 60