Onderstepoort J. Vet. Res. (1966), 379–472
Printed in the Republic of S. Afr. by the Government Printer, Pretoria

A STUDY OF HAIR MORPHOLOGY IN THE FAMILY BOVIDAE*.

JAN HENDRIK DREYER, Veterinary Research Institute, Onderstepoort

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* Submitted in partial fulfilment of the the requirements for the degree of Master of Science in the Department of Zoology, Faculty of Science, University of Pretoria, Pretoria, December, 1964
Received for publication on 19 January 1966.—Editor

I. Introduction

(*a*) *The hair—A survey of present knowledge*

The outer hairy covering is a characteristic feature of mammals. As a rule the hair coat consists of an outer coat of thick hairs and an inner or under coat of shorter, softer and thinner hairs. Development of these two coats varies with the climate of the habitat in which the animal is found and has also been greatly modified under conditions of domestication (Hardy, 1927). The outer coat serves as protection for the animal, while the function of the inner coat is heat retention and maintenance of body temperature (Leblond, 1951; Herrington, 1951).

In animals of the temperate and frigid zones the two coats have a more precise function as noted by Dearborn (1939). The inner coat, called underfur, is composed of fine hair packed closely together. This shields the animal from cold and dampness, while the longer fibres, or guard hairs, which extend beyond the undercoat, form an outer coat which protects the underfur from wear. Quality and quantity of the coat are influenced by climatic factors: thus the most valuable furs are obtained from cold, damp areas (Stoves, 1944). In the tropics and subtropics at low level, animals are poorly furred and guard hairs are short.

According to Stoves & Leblond (1951) hair growth is usually cyclic, proceeding for some time until the hair is shed and new hair starts to grow again. Growth of the hairs in orderly patterns was noted by Dawson (1930) in the guinea pig, by Hale (1945) in the rabbit, where a growth pattern similar to that reported for the rat was found, and by Wolbach (1951) in the mouse. Hale (1945) also found that when a hair has ceased growing actively the proximal half of the shaft is white, while the pigmentation is confined to the distal part of the fibre. In the rat Durward & Rudall (1949) found active growth restricted to a narrow ventral zone of the body, from where it spreads dorsally, so that at any given time a major portion of the skin is inactive.

Shedding is common in most mammals and only in a few cases is hair growth continuous: wool and on the human scalp (Storey & Leblond, 1951). To this select few the long hairs of mane and tail may be added, as they also arise from persistent hair germs (Duerden & Whitnall, 1930). In apparent contradiction to the statement of continuous hair growth from the human scalp is an observation by Butcher (1951), who maintains that hair from the scalp persists for from two to four years before falling out and being renewed. Perhaps the solution to these conflicting statements lies in the conclusions of Duerden & Spencer (1927), who found in the domestic sheep and Angora goat that, although fibres tend to grow continuously from persistent hair germs, a certain percentage is usually shed. The number of fibres shed varies with the individual and the conditions to which it is subjected.

The change from summer to winter covering in the hair coat of animals is attributed to the seasonal variation in light intensity and duration per day. Shedding of hair due to this seasonal difference has been studied to a greater extent in domestic than in wild animals. Sheep have received much attention, because in this species every stage from a complete loss of the fleece to complete continuity of growth is found (Duerden & Whitnall, 1930). A complete seasonal shedding of both coats is undergone by the blackhead Persian towards the end of the winter (Boyd 1927; Duerden & Whitnall, 1930). In well-bred Angora goats the hair grows from persistent hair germs, as in the Merino, although a certain proportion is shed, while a complete shedding of the coat occurs in Angora goats which are not

well-bred (Duerden & Spencer, 1927). The occurrence of shedding was also studied by Duerden & Whitnall (1930) in the horse, donkey and cow. Yeates (1954) concluded that the incidence of shedding in cattle could be attributed to the variation in the daily photo-period during the year while Hayman & Nay (1961) observed that cattle have coats from which hair is continually shed.

Many animals undergoing a seasonal shedding of their coat in cold climates, display a colour change in the new coat. In contrast to this seasonal variation in colour of some animals, the head hair of humans from European stock gradually darkens with increasing age before greying sets in (Trotter, 1930). Attempts to measure colour on human head hair were carried out by Bellamy (1930), utilizing the colour wheel of psychological laboratories. This method could be successful in unicoloured hair, as found in humans, but bi-coloured animal hair with different ectal en ental pigmentation would pose a difficult problem.

In addition to seasonal shedding the loss of the hair coat in domestic animals, notably the Angora goat, can be attributed to adverse conditions of climate and nutrition (Duerden & Spencer, 1927). Animal hair is not only adapted to its environment, it is also conditioned by the skin, which in turn is controlled by the physical state of the body (Stoves, 1944). Van Koetsveld (1954) stressed the fact that the condition of the hair coat is a reflection of the plane of nutrition and the health of the animal. Malnutrition retards hair growth, whilst a high level of nutrition results in a luxuriant hair coat.

The length of hair, its direction and abundance or scantiness are to a great extent constant for a given species, but vary widely from species to species. The relatively uniform pattern of the common rodent, with even length of hair, is thought by some authors to be the primitive type of hair coat. Sloping of hair is backwards from head to tail and on the extremities from proximal to distal (Parnell, 1951). These hair directions or hair streams are termed *flumina pilorum* by Sisson (1917). According to Garn (1951), man differs from other primates in the amount of hair and the number of morphological types, while a big difference is noted between races in form, distribution and development of body hairs. Human taxonomy is thus unique in the importance assigned to hair.

In his treatise on the grouping of hair on the skin, de Meijere (1893) refers to the intimate relationship of hair to a scale covering (in mammals) where behind each scale one or more hairs are grouped according to a certain pattern. On the subject of the phylogeny of hair de Meijere is hesitant to commit himself and Montagna (1962) admits that even today little is known about the phylogenetic origin of hair. Wildman & Manby (1938) in their study on fibres of monotremes maintain that *Ornithorynchus* is unique in possessing a phylogenetically transitional coat. The shield hairs of *Ornithorynchus* consists of a shield portion and a shaft. The shield of the shield hair is phylogenetically more primitive than the shaft portion and is similar in all respects to the spines and hair fibres of the Echidnidae. The shaft portion of the shield hair, being phylogenetically more advanced, corresponds to the typical fur hair of most mammals.

A classification of hair types as distinguished in the hair coat of animals' according to Danforth, is given by Noback (1951). The main division in this classification is based on hair with specialized follicles containing erectile tissue and those without. The first group consists of all the types of tactile hairs, while the

second group has a passive sensory function and its subdivisions are based on size and rigidity. The second group starts with spines, while bristles, guard hairs, awns and underhair follow in a descending order.

In addition to kemp and wool a third type of fibre is found in certain sheep. These fibres are termed *heterotypes* and have a coarse and medullated distal part similar to kemp, while the proximal part is fine and non-medullated similar to wool (Duerden & Seale, 1927).

Winkelman (1959) states that the purpose of all hair is the increase of perception on the surace for tactile stimuli. A special type of guard hair with an active sensory function, which he named a *tylotrich*, was observed by Straile (1960) in the animal coat.

Hairs are dead structures consisting of keratinized epidermal cells cemented together in a compact way (Montagna, 1962). Hair structure as seen under the light microscope has been described in great detail and the ultra-structure of hair has also received close attention. The hair usually consists of a cuticle, cortex and medulla. In the case of wool and other underhair, only a cuticle and cortex are found.

The outer cuticle, one layer in thickness, consists of thin, unpigmented, transparent and overlapping scales, orientated with their free margins towards the tip of the fibre (Noback, 1951, Wildman, 1954). The function of the cuticle is to form a protective covering to prevent the cortex from splintering and wearing away (Hausman, 1930). In contradiction to the general acceptance of a non-pigmented cuticle, Benedict (1957) observed pigment in the cuticle of bats; he cites two authors who also observed this occurrence. Appleyard & Greville (1950) maintain that the scale structure of mammalian hair is more accurately revealed by ultra-violet light than by electron-microscopy. The cuticle thickness, according to these authors, is entirely dependent on the arrangement of the component scales and also on the amount of overlap between scales. In human hair the overlap is five-sixths: thus one-sixth forms the outer surface. In wool, scale length equals that of the human scale, but the amount of overlap is the other way round. Similarly, human hair has a thick cuticle and wool a thin cuticle. Stoves (1943) states that the thickness of the cuticle may vary between three and ten microns. Rogers (1959) found that the ultra-structure of the cuticle is made up of two inter-cellular layers: an inner endocuticle and an outer exocuticle, covered by a membrane on the outer surface, the epicuticle.

The cuticular scales are divided by Hausman (1930) into two types: coronal and imbricate. In the former the scales completely encircle the hair shaft. According to the contour of the free margins they are subdivided as simple, serrate or dentate. Imbricate scales do not completely surround the hair shaft and are classified as ovate, acuminate, elongate, crenate or flattened. This classification did not meet with the complete approval of Wildman (1954), who claimed that these sub-divisions were based on the observation of " casts " showing less than half of the fibre at one time. He suggested a new comprehensive classification of cuticular scales based on " rolled impressions ", which bring into relief the scale pattern over the whole fibre.

The cortex is considered by many authors to be the main portion of the hair (despite the fact that some hairs have a more voluminous medulla). This part of the fibre is built up of elongated and faceted cortical cells arranged along the long axis of the fibre (Wildman, 1954). In the cortex air spaces occur, which Hausman (1932) named cortical fusi. These fusi are abundant near the base of the hair, seldom persist to the tip and are easily detected because they appear darker by transmitted light. Fusi are frequently mistaken for pigment granules because, when small, they simulate solid dark bodies.

Wildman (1954) states that the cortical cells are made up of fibrils which are further subdivided into fibrillae and these are divided into finer fibrous structures. The units of the cortical cells are defined by Giroud & Leblond (1951) as tonofibrils, subdivided into protofibrils which are considered to be the ultimate fibrous units. The protofibrils consist of a series of particles of uniform size in lateral conjunction along the axis. These particles are thought to be true keratin molecules. Rogers (1959) regards the structure of the cortical cell as consisting of macrofibrils subdivided nto microfibrils, which are macro-molecular particles and the fibrous unit of the tructure of alpha-keratin.

The central part of the hair fibre consists of a medulla which may be absent in some cases, notably in wool and the underfur of certain animals. Usually less compact than the cortex, it is built up of fewer and larger cells in loose conjunction and contains intra- or intercellular pockets of air. Lochte (*cit.* Noback, 1951) classified these intercellular air spaces according to coarseness and distribution.

Smith & Glaister (1931) maintain tbat as a general rule the breadth of the medulla in the hair of lower grade animals is greater than in hairs of higher grade animals. According to Hausman (1930) the finest hair have no medulla while the coarsest hair have a fragmental medulla. A classification of medullae as seen in whole mounts is given by Hausman (1950). To the terms " continuous " and " discontinuous " in this classification Wildman objects and suggests that they be replaced by " broken " and " unbroken ". In two Herdwick rams, that did not shed their wool, Auber (1950–1) found that the relative width of the medulla increased with the fibre diameter. In a comparative study of the incidence of medulla and the size of the fibre shaft, Duggins & Trotter (1950) observed in children, that immediately preceding or accompanying the appearance of a medulla, a sharp increase in the fibre diameter took place. Auber (1950–1) thinks that the function of the medulla is to combine a minimum of material and weight with the greatest mechanical strength. This may not be a primitive feature, but rather a specialization, which may serve as a protection against loss of heat in the rough climates where wild sheep are found (Auber, 1950–1).

In transverse sections, and whole mounts generally, some loss in medullary detail is encountered and for this reason some research workers prefer to separate the medulla cells from the adjacent cortex by means of appropriate chemicals. Lochte (1938) parted the medullary discs with caustic potash while Vasquez (1961) employed various chemicals and enzymes to separate the medullary cells for study of their shape and pigmentation.

In contrast to the wide range of colour hues observed macroscopically, under the microscope only black, brown, yellow and red pigment granules can be differentiated (Fitzpatrick, Brunet & Kukita, 1958). The black-brown pigments are designated as " tyrosine-melanin ", the yellow-red as " pheomelanin ": both occur as granules.

A diffuse, non-granular pigment " melanoprotein ", is also observed in some hair fibres (Wildman, 1954). Pigment is located in the cortical cells and to a lesser extent in the medullary column (Hausman, 1930). Vasquez (1961) studied the type, shape and position of the pigment granules in the medullary cells.

The shape of melanin granules is round, oval, elliptical, or bean- or kidney-shaped (Hausman, 1930; Lochte, 1938). In addition to the round, oval and elliptical granules, Vasquez (1961) also encountered rod-shaped granules in his examination of hairs found to contaminate foodstuffs. The relative size of granules varies from coarse to fine.

In cattle and guinea pigs the red colour in hair is due to a diffuse, granular, highly translucent pigment. In some breeds of cattle the black aggregations of granules are arranged in such a manner that a red pigment is also visible in the hair (Bogart & Ibsen, 1937).

Colour differences in hair fibres are not so much due to the colour of the granules but to their arrangement in the fibre and the size of the aggregates in which they accumulate. The paler colours have an open distribution of granules whereas the fibres with dark colours display closely packed granules (Wildman, 1954). All stages between total lack of colour and intense pigmentation can occur in animal fibres. Boyd (1931–2) refers to a ' white melanin ', which is defined as a white granular pigment occurring in the medullary cells of sheep and in the white hair of certain rabbits.

The intrinsic properties of hair such as heat-retaining capacity, durability and resilience are all due to its high content of a sulphur-containing protein, keratin (Leblond, 1951). This keratin content of hair is also responsible for the low solubility and high resistance of the hair to many chemical agents. On a histological basis two types of keratin can be distinguished. Soft keratin is mostly found in structures of the hair follicles and probably in the medulla of the hair, while the hair cortex consists of hard keratin.

The hair fibre and to a greater extent wool have been subjected to exhaustive chemical analysis. The effect of various chemical products on the histological structure of the hair fibre is discussed by Dreyer (1960) and Vasquez (1961), while the histochemistry of hair was investigated by Stoves (1943, 1945).

Taking into account the vast amount of literature on the subject of animal hair, that on microscopic studies on the hair coat of South African game is practically non-existent. De Boom & Dreyer first drew attention to this lack in 1953. They mentioned the impala and blue wildebeest, two of the subjects of the present study. In a further publication de Boom (1953) covers a wider range by describing the fibre outline only of various South African game animals, all members of the Bovidae. Glaister (1931) makes but scanty reference to the impala and to the wildebeest, which probably was the blue wildebeest and not the gnu.

(b) Object of this study

This study on hair morphology of certain species of the Bovidae was undertaken to determine whether the structure and form of hair prepared in different ways for histological examination could be described in such a way that definable differences between species could be established to serve as a basis for identification. The material used was subjected to a qualitative and quantitative analysis in an effort to

arrive at such a basis. Besides determining the various basic hair types, the variations due to locality on the body of the same individual, as well as individual differences, particularly those relating to age and sex, had to be evaluated critically against inter-species differences. Since study of the hair of all members of the Bovidae would extend beyond the scope of a thesis of this nature, it was decided to select only one species representative of each of the four sub-families of the Bovidae.

No overall classification of the various histological structures of the hair has hitherto been attempted and the existing classifications of hair structure are based on only certain characteristics of the fibre. Hausman (1930) classified the cuticular scales and medulla as seen in the whole mount. Wildman (1954) revised, improved and extended these classifications. For the rest, only textual descriptions of the various characteristics of the fibre exist. By referring to these, as well as to an extensive collection of hair preparations prepared by the author from practically all the game species in South Africa, tentative classifications of the shape of fibre and medulla outline in cross-section were drawn up. A classification of the position of the pigment granules, the structure of the medulla as well as of the shape of the tip and root was attempted. If the proposed classifications seem over-elaborate, they are to be regarded as an attempt to establish as many differences as possible which are so necessary in any identification of animal fibres. Most of the terms were collected from the literature and new ones are suggested only where none exist.

II. Materials and Methods

(1) *Materials*

The materials used in this study were obtained from dried skins of representatives of the following species of Bovidae, utilizing the skin from an adult male, an adult female and a sexually immature animal (either male or female) in each case:—

Sub-family: Bovinae: *Tragelaphus strepsiceros* Pallas, 1766. The kudu.

Sub-family: Antilopinae: *Aepyceros melampus* Lichtenstein, 1812. The impala.

Sub-family: Hippotraginae: *Gorgon taurinus* Burchell, 1823. The blue wildebeest.

Sub-family: Cephalophinae: *Sylvicapra grimmia* Linnaeus, 1758. The grey duiker.

The hides of the male and female kudu were obtained from animals shot in the winter season of 1961 in the Douglas area, near the banks of the Greater Orange river, forming part of the Cape Province. The male was fully matured, the female was probably also mature. From the Tweerivier area near the Bechuanaland Protectorate came the hide of the kudu calf, probably a male, which had died at the beginning of the winter of 1962.

Skins of a fully matured impala male and female were procured from the Thabazimbi area in the Waterberg district of the Transvaal Province; both were shot in the winter of 1960. The skin of the fawn came from the Western Transvaal. It had died during the early winter of 1960 and was probably only a few weeks old.

Hides of the male, female (both fully matured) and calf of the blue wildebeest were acquired from the Merensky Game Reserve in the North-Eastern Transvaal area. The history of these hides is not known.

From exactly the same area as the male and female kudu the skins of the grey duiker male and female were obtained, both fully matured, and also shot in the winter of 1960. A skin was obtained from a grey duiker fawn approximately two weeks old which had died in the Ermelo district of the Transvaal Province towards the end of the winter of 1962.

As the majority of the hides and skins were obtained from private sources, no records of these animals or methods of preservation of the hides has been kept. Usually hides and skins are cured with salt and left to dry with the fleshy side exposed, either in the sun or shade, before being stored away.

(2) *Methods*

(*a*) *Preparation of material*

Sampling: On the following ten sites of each particular skin sampling was done: mane, the back (on the rump), the tailswitch, neck, the shoulder blade, thigh, throat, brisket, belly and the legs (Fig. 1). These sites were considered to be sufficiently representative of the variations to be met with in any sample. The sampling area was approximately three inches in diameter at the body sites; from the legs the area was approximately one inch in diameter taken above the knee.

Fibres were plucked from these sites by hand in the smaller species but this was impractical in the larger species. In the blue wildebeest, especially, the hair, being rather short, offered great resistance to hand-harvesting. Ordinary pliers were used of which the jaws were covered with rubber tubing to soften the grasp. Even so a great percentage of breakages occurred, although care was exercised in the pressure and pull applied. A quick jerk was found to be more effective than a slow deliberate pull. Experience proved that sampling from fresh skins would have been more effective but unfortunately these could not be obtained.

Cleansing: All samples were washed in a mixture of absolute alcohol and sulphuric ether in equal proportion as used by Trotter (1930). This solvent was found to be a more effective cleansing agent than benzine, which rendered the fibres too hard and brittle.

For the hair of the blue wildebeest, which offered a great resistance to cleansing agents, a more harsh cleaning method was resorted to as recommended by Glaister (1931). Even with this method it was still a problem to obtain totally clean hairs from this species. Coating of the hair by skin secretions could be the cause of this condition. The method of Glaister consisted of immersing the hairs for five minutes in a solution of two parts of two per cent alcohol added to one part of a solution liquor ammoniae fortis. Subsequently the hairs were immersed in a potassium hydrate solution (0·5 per cent should be effective) at a temperature of 50° C and then rinsed in a mixture of equal parts of one per cent sulphuric acid and absolute alcohol. It was considered good practice to rinse the fibres in distilled water after every stage. Finally the hairs were dried completely.

Cuticular imprints: Various methods exist for showing up the outer surface of the fibre. An excellent summary of the methods that have been used by different authors for making scale imprints, is presented by Hardy & Plitt (1940). Plastics as embedding media are preferred by Williamson (1951) and Hardy & Plitt (1940). Stoves (1942, 1950) favours direct photography for non-medullated fibres. The semi-embedding technique for unpigmented and non-medullated fibres is advocated by Wildman (1940). A method whereby imprints were made in the gelatine on old photographic plates was employed by Lochte (1938).

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A gelatine medium was also used for this study. Although it did not allow for such excellent photomicrographs as the method of Lochte (1938) it was possible in some cases to obtain one hundred or more imprints on a single slide. Finely granulated gelatine as used for bacteriological purposes was found to give the best results. The gelatine was gradually added to cold distilled water until the solution was saturated. A blue dye (Nile blue) was added—the equivalent of one ml of a one per cent solution per 10 ml of the gelatine solution. The container was then placed in a water bath and heated to boiling point for a brief period. The solution was allowed to cool for a few minutes and the scum forming on top was laddled off. This process was repeated two or three times to remove impurities. Filtration into a clean container was done through a short-stemmed funnel in an oven at 60 to 62° C. The filtered gelatine was poured into one or more tinctorial cylinders of about 50 ml capacity. These were placed in a water bath or on a gauze stand in a beaker half-filled with water. The water in the beaker (and thus the gelatine solution) was heated to 60 to 65° C and allowed to cool down to about 50 to 55° C—the ideal temperature range for coating the slides.

Chemically clean slides handled by forceps were heated slightly in a flame and allowed to cool. The gelatine solution was slowly and carefully stirred prior to the dipping of the slides. This ensured an even spread through the solution of the dye which tended to settle after a period. The slide was dipped into the molten gelatine to about a quarter of an inch from the top—thus leaving a space for handling and labelling of the slide. It was then removed, the thickness of the gelatine layer being controlled by allowing more or less of the gelatine to drip off. Then the slide was tilted with its furthest end uppermost to allow the gelatine to run back to the edge of the uncoated area. The underside of the slide was then wiped clean with a wet cotton pledget and placed in a perfectly horizontal position.

Within one or two minutes the gelatine on the slide started to set. As soon as fluidity had settled, which was tested by tilting the slide carefully to one side, the hairs were placed side by side on the gelatine by means of a fine pointed forceps. No pressure was exercised. When hairs tend to lift from the surface they were gently eased back into position.

Slides were put away to dry in a dust-free place or dried under a fan. When the gelatine had completely dried, the hairs were removed one by one with a fine forceps. If examination under the microscope proved the imprints unsatisfactory, the hairs were washed and dried again and the process repeated. The depth to which hair was allowed to sink in the prepared gelatine layer was about half its diameter.

Cross sections: A few methods for making transverse sections of fibres have been described. Barker & Burgess (1928) employed a special frame for holding the fibres prior to double embedding (collodion in wax). These preparations were sectioned on a standard microtome, which ensured a controlled thickness of the sections. Stoves (1950) made use of a clamping device resembling the frame used by Barker & Burgess in a somewhat similar technique. Where a wide variation of fibres in a sample may be expected, the Hardy microtome is ideal. With this hand microtome results are excellent but the thickness of the sections cannot be controlled. Hardy (1935) claims that sections as thin as three microns can be cut on his device. Fiala's (1930) method, where fibres are mounted in a soft wooden block for sectioning, is very ineffective compared to the other methods.

The technique for preparing cross-sections was that described by Barker & Burgess (1928). Modifications were introduced and the process was essentially as follows:—Clean and thoroughly dry hairs were stretched over a Barker & Burgess frame. The frames with hairs in a relaxed condition were dipped into a tube of sulphuric ether for a few minutes to remove all vestiges of greasiness. Still in a relaxed condition the bundle of hair was left to dry thoroughly and then painted over with a thin solution of collodion. The slackness of the fibres was taken up and the bundle then coated a number of times with a thicker solution. (This thicker solution was obtained by allowing a sample to evaporate down to a third of its original volume by exposing it to air). By rotating the frame between the fingers after each coating an even thickness of collodion over the fibre bundle was ensured.

Hardening of the collodion was effected by submerging the frame with its fibre bundle into chloroform. Usually the collodion showed milkiness immediately after contact with the chloroform. The bundle was allowed to stand until this cleared away, which happened in about one to two hours depending on the thickness of the collodion coat. The process can be speeded up by intermittent mild heating.

The frame with the hair bundle was now placed into molten paraffin wax (M.P. $\pm 60°$ C) and kept there until no smell of chloroform was detectable (± 10 min).

It was then removed and the fibre bundle cut loose from the frame. The collodion coated bundle was finally embedded in the paraffin wax in the usual way, taking care to keep the column absolutely at right angles to the proposed cutting face. Trimming, mounting and sectioning on a Reichert sliding microtome at 10 to 15 microns were carried out as for any histological preparation.

Slides were coated with Mayer's albumin and in addition a thin layer of natural collodion was brushed on and allowed to dry. The collodion discs containing the sections of the hairs were loosened and arranged in a row in the middle of the slide. They were exposed to ether alcohol (3:1) vapour by placing the slides on a gauze stage in a covered Petri-dish. Moderate heating was applied with the dish tilted at 15° to avoid condensation moisture dropping from the lid onto the preparations.

As soon as the sections flattened, the slides were rapidly transferred to a jar of chloroform for a brief rinse, then to xylol (2 to 3 min) for removal of any vestiges of paraffin wax and chloroform and thence to carbol xylol (5 min) for cleaning. The preparations were mounted in Canada balsam and left in an embedding oven from one to two hours for a final clearing of the collodion. (Longer periods were found to discolour the collodion). Rapid transfer from the ether alcohol vapour was imperative since drying of the sections in any of the stages resulted in an irreversible cloudiness of the collodion.

After a considerable number of sections from hairs of the kudu and the grey duiker had been cut on the Reichert microtome a Hardy type microtome was obtained. All the sections were again prepared by means of this instrument according to Wildman's (1954) method. (Those from the previous sectioning were kept in reserve should they be needed to complete the total when measurements and classifications were carried out).

Whole mounts: These were prepared by drawing a thin film of euparal over a slide leaving it to become tacky. The hairs, cleaned and dried, were placed in parallel arrangement by means of forceps and pressed into the medium. Complete drying was carried out in an oven at $\pm 60°$ C and the slide allowed to cool again. A drop

or two of fluid euparal was placed on the preparation and the whole covered by a cover slip. The process had to be executed rapidly before the hardened mounting medium became fluid again and the hairs disarranged. Excess mounting medium was gently eased out and lead weights slightly smaller than the cover slips were put on the slides. The latter were again placed into the oven for about 20 minutes after which the lead weights were immediately removed and the excess mounting medium, still warm and fluid, wiped off with a small square of blotting paper.

In the case of thick hairs, air was usually drawn into the preparation after a few days. To counteract this, slides were sealed off with an application of a thickened solution of isobutyl methacrylate dissolved in xylol.

(*b*) *Method of investigation*

The following observations were made—

Macroscopy of the fibres:
General description of the hair coat.
Colour of individual fibres.
Fibre length.
Fibre types.

Microscopy of the fibres:
Cuticular imprints.
Cross-sections.
Pigment in cross-sections.
Medulla in cross-section.
The tip.
The shaft.
The base and root.
Fibre measurements.

The total hair coat of the animal was described generally with respect to coat colour and colour markings.

On the macroscopy of the individual fibres an account of the colour, fibre length and fibre types was recorded. Judging the colour of individual fibres was a major problem as no colour guide, adapted for this particular purpose, was available. The true colour of the fibre is not shown by making use of different background colours. A fibre which may appear to be black against a white background, may show up reddish-brown on a black background and brown over a grey board. Fibres grouped together on the skin or in an undisturbed sample may show a totally different colour arrangement compared to the single fibre. A fibre may also change in colour along its length or may even have different colour shades on the ectal and ental aspects. By working in direct sunlight against the various backgrounds, however, a reasonable colour approximation was obtained.

Measurement of fibre length was confined to a few fibres to obtain an indication of length from each site; no organised effort at measuring fibres was attempted.

In attempting to classify the fibre types, the following classification of Danforth as given by Noback (1951) was useful:—

> " 1. *Tactile hairs.*—Hairs with follicles containing erectile tissue. (The classification of tactile hairs is omitted since they were not considered in this study).

2. *Hairs with follicles not containing erectile tissue.*—The remaining types of hair, most of which are more or less defensive or protective in function. In many cases, the follicles have a good nerve supply, endowing the hair with a passive sensory function as well. These hairs are grouped here according to their size and rigidity.

(1) Coarser, more or less stiffened ' overhair ', guard hair, top hair—

(*a*) *Spines.*—Greatly enlarged and often modified defensive hair, quills.

(*b*) *Bristles.*—Firm, usually subulate, deeply pigmented and generally scattered hairs. ' Transitional hairs ' (Botezat, 1914), ' Leithaare ' (Told, 1910), ' protective hair ', ' primary hair ', ' overhair ', this group also includes mane hairs.

(*c*) *Awns.*—Hairs with a firm, generally mucronate tip but weaker and softer near the base. ' Grannenhaare ' (Told, 1910) ' overhair ', ' protective hair '.

(2) Fine, uniformly soft ' underhair ', ' ground hair ', ' underwool '.

(*a*) *Wool.*—Long, soft, usually curly hair.

(*b*) *Fur.*—Thick, fine, relatively short hair—' underhair ', ' wool hair '.

(*c*) *Vellus.*—Finest and shortest hair '—down ', ' wool ', ' fuzzy ', ' lanugo ' (Danforth, 1939)."

Many intergrade hairs between bristles and awns and awns and fur hair were recognized (Noback, 1951).

A very practical classification of the hair types is presented by de Boom (1953):—

" (1) *Ornamental hairs.*—Long, thick hairs forming mane, tail and sometimes adorning the forehead and dewlap.

(2) *Tactile hairs.*—Long stiff hairs which have well developed nerve-endings associated with their roots. By giving timely warning they serve to protect certain parts of the body and thereby the body as a whole. Whiskers and eye-brows of some animals serve as examples.

(3) *Guard hairs.*—Long, relatively thick hairs, often projecting above the other hairs forming the pelt.

(4) *Contour hairs.*—Body hairs which are slightly thinner than the foregoing and which, in their most typical form, show a thickening of the shaft present at a varying distance from the root. In typical cases the body hairs become shorter and relatively thicker on the face, paws and groin.

(5) *Downy hairs.*—Fine and relatively short hairs which tend to be curly. The medulla is poorly developed and their cuticular pattern tends to be wide.

(6) *Wool.*

Guard and contour hairs show many intermediary forms, whilst downy hairs represent an intermediate form between ordinary body hairs and wool."

This last mentioned classification is eminently suited to the hair types of the South African Bovidae and was largely followed in this study.

As no classification of tip and root form exists, a proposed classification of the shapes of these structures is suggested.

In the microscopic examination of the fibres the identification of cuticular imprints was based on the excellent classification of these patterns by Wildman (1954). It was not possible, however, to duplicate his method of making " rolled impressions "—the firm, thick and comparatively short body hairs of the species concerned did not lend themselves so readily to rolling as the thin soft and usually long textile fibres apparently did.

Although a large variation in the cross-sectional outline of fibres was found, no system has been formulated for grouping these shapes into a classification. On the same basis a classification of the medulla outline in transverse sections is also lacking, although a classification for medulla patterns in whole mounts does exist (Hausman, 1930; Wildman, 1954). A system of classification for both fibre outline and medulla outline in cross-section has been devised and put forward with some hesitancy as many difficulties were encountered.

The character of the pigment is considered one of the major points in an identification of animal fibres and in addition to type, size, distribution, amount and colour the position where it occurs is important. A classification of the appearance and pattern of distribution in cross-section is suggested.

All transverse sections were made at base level. Actual measurements on cross-sections and on whole mounts of fibres, also at base level, were made on a Reichert lanameter. From the cross-sections of fibres at each of the sampling sites a hundred measurements each were taken of the greatest and least diameters of the whole fibre and of the medulla. A hundred readings, also, were taken of the fibre and medulla in the whole mounts of each site. The greatest diameter referred to was measured along the longest axis of the fibre in cross-section and the least diameter was the maximum measurement obtainable at right angles to the greatest diameter. Fibre measurements in whole mounts were indicated as whole fibre diameters. By substituting " medulla " for fibres in these terms the medulla measurements were denoted on exactly the same basis. For the purpose of classification of fibre outline, medulla outline, pigment and all the other items appropriate to the classifications, a hundred observations were also recorded.

The fibre index for cross-section given by Trotter & Duggins (1948) is:—

$$\frac{\text{least diameter}}{\text{greatest diameter}} \times 100.$$

With the bean-shaped fibres the measurements were taken linearly across the greatest diameter and across the groove for the least diameter. In fibres with a papilla the least diameter was measured straight across the papilla.

Further indices used for the cross-sections were:—

1. A fibre-medulla index (greatest diameter): $\frac{\text{medulla greatest diameter}}{\text{fibre greatest diameter}} \times 100$
2. A fibre-medulla index (least diameter): $\frac{\text{medulla least diameter}}{\text{fibre least diameter}} \times 100.$
3. An index for whole mounts: $\frac{\text{medulla diameter}}{\text{fibre diameter}} \times 100.$

The data from the measurements were subjected to an analysis of variance done according to a two-way classification with n elements per cell. When it was found, however, that the interaction mean square was significant compared to the sampling error mean square in the first number of results obtained, the interaction mean square was used as error for testing the main effects (Scheffé, 1961).

By applying the F-test, the mean differences between, firstly the males, females and young and secondly the species (kudu, impala, blue wildebeest and grey duiker) were determined interspecifically at every body site.

Within each species an F-test was done to test the mean differences between the male, female and young on the one hand and the body sites on the other.

III.—Classifications

The gathering of certain characteristics of the fibre into a few plain systems of classification was deemed necessary when this study was undertaken. Classifications of cuticular scale patterns and of medullae as seen in whole mounts already existed (Wildman, 1954). Scattered through the literature were descriptions of fibre and medulla outlines, structures of the medulla and distribution of pigment in cross-sections. A standard collection of sections and whole mounts of hair of South African game containing fibres with characteristics probably never seen elsewhere was available. These features, from literature and collection, were gathered into a few classifications and new terms introduced only where no description could be found. In the classification of the medullae, as seen in whole mounts, a few minor features were added.

A proposed classification of the **cross-sectional outline** of the fibre would read as follows:—

1. Round or circular and crude circular: In the crude circular fibre the outline gives the impression of being corrugated.
2. Elliptical: According to Chamber's Dictionary, a shape, rather narrow, slightly acute at each end and broadest in the middle. Subdivided into (*a*) short, (*b*) medium, (*c*) long, (*d*) flat, (*e*) curved.
3. Oval: Defined by Chamber's Dictionary as egg-shaped, longer than broad and broadest near one end. Subdivided into (*a*) short, (*b*) flat, (*c*) long.
4. Piriform: Pear-shaped.
5. Angular (Glaister, 1931; Wildman 1954): Having corners.
6. Biconcave: Concave on both sides.

7. Concavo-convex: A few typical shapes can be recognized under this heading: (*a*) fabiform (bean-shaped, Glaister, 1931); (*b*) reniform (kidney-shaped, Glaister, 1931) (*c*) cordiform (heart-shaped); (*d*) unguliform (hoof-shaped).
8. Lineo-concave: One side flat and the other side curved inwards.
9. Lineo-convex: One side flat and other side rounded.
10. Papillo-convex: One side with a projection shaped like a papilla and the other side rounded.
11. Trilateral: Bearing a rough resemblance to a triangle.
12. Quadrilateral: Roughly resembling a square or rectangle.
13. Multilateral: Polygonal (Wildman, 1954).
14. Dumb-bell-shaped (Wildman, 1954).

It is granted that a majority of the above outlines may occur in a representative sample from a single animal but in some cases a cross-sectional outline may be typical and confined to only one species.

In shape the medulla outline usually follows the fibre outline in those fibres with regular shapes. When the cross-sectional outline of the fibre deviates from the simple shapes the medulla tends to follow an outline of its own.

A suggested classification of the **medulla outline** in cross-section will include the following shapes:—

1. Circular and crude circular.
2. Elliptical: (*a*) short; (*b*) medium; (*c*) long; (*d*) flat; (*e*) curved.
3. Oval: (*a*) short; (*b*) medium; (*c*) long.
4. Piriform: Pear-shaped.
5. Angular: As defined.
6. Biconcave: As defined.
7. Concavo-convex: (*a*) Fabiform; (*b*) reniform; (*c*) cordiform; (*d*) unguliform.
8. Lineo-concave: As defined.
9. Lineo-convex: As defined.
10. Papillo-convex: As defined.
11. Lateral: (*a*) Trilateral; (*b*) quadrilateral; (*c*) multilateral.
12. Partite (Wildman, 1954): (*a*) Bipartite; (*b*) tripartite; (*c*) quadripartite, (*d*) multipartite.
13. Lobulate: Division into small lobes. (*a*) Bilobulate; (*b*) trilobulate; (*c*) quadrilobulate; (*d*) multilobulate.
14. Loculate: Having small compartments. (*a*) Biloculate; (*b*) triloculate; (*c*) quadriloculate; (*d*) multiloculate.
15. Lacunate: Slit-like medulla.
16. Crenate: Displaying a notched appearance.
17. Canaliculate: Containing small channels.
18. Rudimentary: A slight indication of a medulla.

Position of the medulla: The medulla may be placed centrally or eccentric. Usually it occupies a central position.
Degree of medullation: A medulla may assume such proportions that the cortex is only a thin layer under the cuticle or it may be so insignificant that it shows up as tiny dots in the fibre.

The medulla may be single, in which case the fibre is monomedullary, or occur in multiples: bimedullary or trimedullary (Wildman, 1954).

Features of **medullary structure** may be grouped as follows:—

1. Medullary wall: (*a*) Regular outline.
   (*b*) Irregular outline.
   (*c*) Striations present or absent.
2. Cellular: (*a*) Regular.
   (*b*) Irregular.
3. Granular: (*a*) Finely granular.
   (*b*) Coarsely granular.
4. Reticular: (*a*) Regular.
   (*b*) Irregular.
5. Fibrous: Appearance of fibres pressed together.
6. Smooth: No indication of structure.
7. Luminal (Glaister, 1931): No structure present.
8. Pigment: (*a*) Present.
   (*b*) Absent.

The appearance of the pigment can be diffuse, discrete, or in aggregates. Intensity of pigmentation can be indicated as light, medium or heavy.

For the **distribution of the pigment** the following classifications are suggested:—

1. The distribution of pigment in the regular shapes (circular, etc.).

   (*a*) Absent.

   (*b*) Present.

   (i) Cortical: The total width of the cortex contains pigment granules. A fibre can have a *total* or *partial* cortical distribution the emphasis being on the width of the distribution and not the area.

   (ii) Peripheral: The outer part of the cortex contains the pigment. This distribution can also be total or partial in quantity.

   (iii) Intermedial: Here the pigmentation is encountered in the middle part of the cortex. A total or partial distribution can also occur.

   (iv) Axial: Pigment granules concentrate in the inner part of the cortex bordering on the medulla. Distribution of the granules can also be total or partial.

   (v) Radial: The granules appear to be arranged in lines or rays diverging from a central core.

(vi) Stellate (Wildman, 1954): The pigment forms a star-shaped pattern in the middle of the fibre. Usually it is found in fibres where the medulla is rudimentary.

(vii) Sectorial (De Boom, 1963): In fibres where a medulla is absent or rudimentary the pigment is concentrated in sectors projecting into a central zone free of pigment.

(viii) Medullary: Where pigment granules occur in the medulla.

2. The distribution of pigment in irregular shapes (concavo-convex, etc.).

(*a*) Absent.

(*b*) Present.

In fibres from the blue wildebeest and related forms the groove is placed in an ectal position. This provides an opportunity of dividing the fibre tri-positionally, viz. ectal, lateral and ental. In combination with the four positions of pigment distribution in the cortex (cortical, peripheral intermedial and axial) it is possible to indicate a definite location of the pigment, e.g. latero-axial, etc. This again can be indicated as unilatero-axial or bilatero-axial depending on the occurrence in one or both sides.

In whole mounts the **medulla** shows quite a variation in form and type in fibres from different animals. The classification of Wildman (1954), as augmented, is as follows:—

Unbroken medullae: (*a*) Unbroken lattice—
(i) Sides erose (Vasquez, 1961).
(ii) Sides entire (Vasquez, 1961).
(*b*) Simple unbroken—
(i) Wide.
(ii) Medium.
(iii) Narrow.

Interrupted medullae: (*a*) Simple interrupted.
(*b*) Fragmental.

Particulate medulla: Ladder type of medullae: (*a*) Uniserial.
(*b*) Multiserial.

In the lattice type of medulla Vasquez (1963) discriminates between an outer side appearing irregularly notched as if bitten (erose) and a smooth outer wall (entire). The subdivisions under the simple unbroken medulla is added simply because they do occur in different widths. The interrupted medulla of Wildman is classed as a type with two subtypes since a fragmental medulla is also a degree of interruption in the medullary column. The particulate medulla, where small particles are found in the place of a continuous central canal, is inserted in the classification.

The medulla can occupy a central or eccentric position in the fibre.

The tip and root of the fibre have received but scanty attention in a literature dealing mostly with textile fibres. This is the result of the shearing of wools and mohair, so that naturally neither tip nor root occur.

Variation in the form of the tip is much less striking than for instance the variation in cross-sectional outlines. The tendency is for short, coarse fibres to have tips adjusted to that structure and the same holds true for long fine fibres. Exceptions are found where some contour fibres have a broad apical region and a long thin segment at the base.

A proposed classification of the **shape of the tip** is as follows:—

(*a*) Flagelliform: Where the tip has a whip-like appearance. It can be subdivided into long, medium and short types.

(*b*) Filiform: The tip has a thread-like appearance, seen mostly in long thin fibres.

(*c*) Acicular: A short, needle-shaped tip.

(*d*) Penicillate: The tip is split into smaller segments giving it a brush-like appearance.

In the case of the **root**, variation in form is the least of all the fibre components. Only two types could be recognized for which the following terms are suggested:—

(*a*) Clavulate: Somewhat club-shaped with a pronounced bulb, subdivided into long, medium and short.

(*b*) Virgate: The root bulb is not as pronounced as in the former, being more stick or rod-shaped. A long, medium and short subtype is also recognized.

Observations on the **hair** characteristics of the four animal species were conducted within the frame-work of these classifications.

IV.—Observations

(1) The Kudu (*Tragelaphus strepsiceros* Pallas, 1766) (Fig. 7)

The kudu is one of the larger South African game species which still has a wide distribution throughout the country and is found in all four provinces of the Republic of South Africa. According to Roberts (1951) the males are much larger than the females and have a long mane from the nape to the shoulders, long hairs along the ridge of the back to the tail and a long mane on the throat. The general colouring of the male is fawny-grey with a variable number of white stripes from behind the shoulders to the rump. Females have shorter manes and are more fawn coloured than the males.

(*a*) *General Description of the Hair Coat*

The coat of the male was fawny-grey with a bluish tinge and nine white stripes were present across the body. The mane was of a dark brown colour while the long hairs on the throat were black and brown alternating with white giving a motley appearance. Thick long hairs on the back formed alternating patches of white and brown to the brush of the tail. Brown-black was the predominant colour on the forelegs and gaskins. White and black occurred on the hinder part of the belly. On the inside of the buttocks white patches were found. No underhair or fur was apparent in the coat of this male.

Overall colouring of the female coat was much lighter than that of the male and five white stripes were noted. The mane was a light buff-brown and of a definite paler colour than that of the male, while no long hairs occured in the throat region The posterior parts of forelegs and belly were light brown in colour. A ridge of thick long hairs on the back showed alternating patches of brown and white hair.

No tail was present. White patches occurred behind the forelegs and on the flank. These white patches were also obvious inside the buttocks. Underhair was absent in this specimen.

In the calf the general coat colour was a light cinnamon. Eight white stripes were evident over the body but no long hairs were present on the throat. The mane was dark brown while the ridge of long hair on the back showed an intermingling of brown and white hair. A major portion of the tail was missing. White hairs were present behind the forelegs and on the flanks. An undercoat was not noticeable in the calf.

(b) Macroscopy of the Fibres

(i) *Colour of the Individual Fibres:* Individual fibres from male, female and young varied from white, yellowish white, yellow brown to brown. Usually the fibres were lightly coloured at the base ending in a brown or dark brown tip.

(ii) *Fibre Lengths*: Measurements of the fibres showed that the longest fibre, measuring 254 millimetres, came from the throat region of the male and the shortest, measuring five millimetres, from the leg of the calf. On the belly and the brisket region of the bull, fibres measuring over 100 millimetres were quite a common occurrence, whereas on a region such as the thigh of all three specimens, lengths varied between 12 and 50 millimetres.

(iii) *Fibre Types*: Fibre types over the body, as defined in the systems of Danforth (cit. Noback, 1951) and De Boom (1953) were difficult to identify. Among the fibres a homogeneity occurred which defied classification. A measurement of length and diameter might show a variation in the fibre population, but no clear demarcation of types according to the classical definitions could be ascertained. The only fibre types were the ornamental hairs of mane, tail and throat and the body hairs as a whole.

(c) Microscopy of the Fibres

(i) *Cuticular imprints*: Only two patterns could be distinguished according to the classification of Wildman (1954): an irregular mosaic (Fig. 19) and an irregular wave pattern (Fig. 20). The units of the mosaic were flattened and the major axis of the unit lay in the direction of the minor axis of the fibre. The mosaic pattern occurred mostly in the basal part of the fibre whereas the wave pattern was found most frequently in the apical region. At the extreme tip the scales appeared coronal. Scale-margins were ripple-crenate in the case of the wave pattern and tended to be smooth where mosaic patterns were found.

Distances between the external margins of the scales were *near* in the mosaic and from *close* to *near* where the wave was apparent. The wave amplitudes in both patterns varied from *shallow* to *medium*.

(ii) *Cuticle, Fibre Outline and Measurements in Cross-sections*: The cuticle was reasonably thick in the ornamental hairs of the adults. This was especially noticeable in the mane (Fig. 8) snd throat hairs (Fig. 12) of the male. In the mane of the calf (Fig. 13) it tended to be of intermediate thickness. In the body hairs it varied from intermediate to thin.

Characteristic shapes of the fibre outline in body hairs were elliptical and oval. Particularly the medium ellipse and short and medium oval (Fig. 14) were very prominent. In some areas, such as the thigh of the kudu female, the long and flat elliptical shapes were very common (Fig. 11). These shapes also occurred among the leg fibres (Fig. 16). A great regularity of shape was obvious in fibres from the calf (Fig. 10 and 13).

Among the long throat fibres of the male the greatest variation in fibre outline was observed: no less than sixteen shapes were identifiable, including isolated lineo-concave, lineo-convex, tri-lateral and quadrilateral forms. Fibres from the legs of the three individuals showed much less variation in fibre outline. Their shapes were practically confined to the three subdivisions (short, medium and long) of the elliptical outline with an occasional oval shape.

These throat fibres from the male had the largest value for the mean greatest fibre diameter of all body sites: 207 microns compared to 157 microns of the mane and 132 microns of the tail. The same sequence in diameter of the ornamental fibres of the calf was noted, supplying additional evidence to the conjecture that this was probably a male animal. In the female, however, the mean greatest diameter of the throat fibres was the lowest for the ornamental hairs.

A regional variation in fibre size was very marked in these measurements: the ornamental hairs of mane, tail and throat had higher means for the greatest diameters than hair from the belly of the same animal. An analysis of variance for cross-sectional readings of the greatest diameter of the fibre [Table 1 (*b*)] showed a highly significant difference ($P = 0{\cdot}01$) for site means of the group (male, female and young) within the species. This highly significant difference was repeated for mean values of the least fibre diameter [Table 3 (*b*)], the greatest medulla diameter [Table 2 (*b*)] and the least medulla diameter [Table 4 (*b*)].

In the young animal all the mean, greatest and least diameters of fibre and medulla were smaller than those of the male. An analysis of variance of the overall means of male, female and young revealed highly significant differences for all mean transverse diameters excepting the least diameter of the medulla. This could be attributed to the tendency of the fibres from the young animal to be more broadly elliptical than those from the adults.

A characteristic of the species was that the female was appreciably smaller in size than the male. Whether a correlation between animal size and relative hair diameter existed within a species is not known but here the greatest and least diameters of fibre and medulla indicated that the female occupied a position nearer to the calf than to the adult male.

In respect of the three indices [Fibre (Table 7), Fibre medulla/greatest diameter (Table 8) and Fibre/medulla least diameter (Table 9)] no significant differences existed between the group and the sites. This pointed to a great homogeneity in fibre outline within this species.

(iii) *Pigment in Cross-sections*: Pigment occurred in the majority of the fibres, whether densely or sparsely distributed. Notable absences of pigment occurred in the tail and throat of the male and the tail and legs of the young animal (Fig. 12).

Distribution of the pigment according to the suggested classification (Fig. 4) was *cortical* with a tendency for the pigment to concentrate in the *peripheral* and *intermedial* areas, e.g. in the back fibres of the male (Fig. 9). The intensity of pigment concentration was difficult to determine as it varied from light to heavy (Fig. 14). In the majority of the body hairs pigment intensity could be classified as medium, while in 50 per cent of the mane and tail fibres of male, female and calf the intensity was heavy. Some fibres had a *partial* dispersion of pigment according to the classification (Fig. 6) but in the majority the pigment was *totally* dispersed throughout the section.

All three types of pigment, viz. tyrosine-melanin, pheomelanin and melanoprotein were present to a greater or lesser degree. Tyrosine-melanin formed the major portion of the pigment in the fibres. A few fibres with pheomelanin were interspersed but more general was an admixture of tyrosine-melanin and pheomelanin in one fibre, sometimes with a dash of melanoprotein as well.

Usually the granules clumped together in aggregates with a quota of discrete granules interspersed. The granules seemed to be mostly circular in shape.

(iv) *Medulla in Cross-section:* The shape of the medulla outlines (Fig. 3) tended to follow those of the fibre outline of body hairs, but the medulla outline was often slightly irregular. In thick and ornamental hairs, however, the medulla outline was totally different from fibre outline. In neck fibres from the kudu male the medulla outline could only be described as shapeless in 75 per cent of the cases. The throat fibres of the male were without a medulla in 33 per cent of the observations. To a minor degree the same pattern was repeated in fibres from the young animal. Medulla outlines in fibres of the female seldom deviated from the fibre outline. A variation in the medullation of fibres could be observed in the belly regions of male (Fig. 14) and female (Fig. 15).

In the majority of the fibres the medulla was situated centrally. A few fibres had an eccentrically placed medulla. Striations on the cortico-medullary border occurred in all sections of fibres. In some cases the striations might not be so conspicuous as in others.

Medullary structure appeared to be fine-grained granular in a majority of fibres. The only exception was the throat fibres of the male where a cellular structure was more evident. In some fibres the cellular structure appeared to be compressed giving the medulla a fibrous appearance while a few had no medullary structure: this condition was termed luminal by Glaister (1931).

Medullary pigmentation was usually identical to that of the cortex even to the mixture of the types. The granules were mostly circular in shape. However, angular inclusions resembling pigment granules, only much larger, were found in the medulla of throat fibres of the male.

(v) *The Tip*: The fibres from male, female and calf had tips tending to become gradually thinner like a whip and were thus designated as flagelliform. The three subtypes—long, medium and short—were fully represented.

The colour of the tips varied from a reddish-brown to a light yellowish-brown; some without pigment were also observed. The pigment granules were mostly arranged in streaky aggregates. Sometimes the extreme tip was of a lighter shade than the remainder of the apical region.

In some fibres the medulla was continued into the tip in fragmentary or particulate form.

(vi) *The Shaft*: In its course from base to tip the shaft was usually regular in width until it narrowed down to form the tip. The pigment usually occurred in streaky aggregates throughout the fibre, varying in colour from dark reddish-brown to a buff colour.

A medulla was normally present but was absent from throat hairs of the male and neck hairs of the young in about a third of the fibres. The medulla was centrally situated in the majority of fibres. It was of the simple, unbroken type usually wide and followed a regular course (Fig. 18).

The cuticular scales were not very prominent in whole mounts, giving the impression of having " rounded " edges instead of being sharply defined.

Shaft colours varied from white to buff, brown to dark reddish-brown. The paler colouring usually originated at the base and gradually darkened towards the tip. Pigment dispersal was usually in streaky aggregates (Fig. 17).

(vii) *The Base and Root*: No thickening of the base was noticed while the root portion contained no medulla. The shape of the root was mostly medium to short clavulate with discrete pigment granules present.

(viii) *Fibre and Medulla Measurements* [*Tables* 5 (*a*) *and* 5 (*b*) *to* 6 (*a*) *and* 6 (*b*)]: Mean diameters of fibres in whole mounts of the kudu male varied from 189·6 microns for the throat hairs to 74·0 microns for hairs from the brisket. The fibres with the largest mean whole fibre diameter were the ornamental hairs of throat, mane and tail: 189·6 microns, 144·5 microns and 127·1 microns respectively.

In the calf, hairs from the belly had the smallest mean whole fibre diameter: 55·2 microns. The highest mean fibre diameter was found in the throat region, as was the case in the male, contrasting sharply with the female where the mean diameter of throat hairs did not differ from that at the other body sites.

An analysis of variance of the mean whole fibre diameters showed highly significant differences between the body sites and also between the individuals. The mean whole fibre diameter in the female, as the cross-sectional mean diameter, was again nearer to that of the calf than to the mean values for the male.

The mean whole medulla diameter was slightly higher in the female than in the male and much higher than that of the calf. This could be explained by the observation that ornamental hairs of the female, especially from the throat, did not display the same degree of development as those of the male. The typical diminution of medulla area usually found in fully developed ornamental hairs did not occur in these fibres from the female.

There were also no significant differences between the fibre/medulla indices (Table 10) for members of the group, emphasising the regularity of fibre to medulla relation in this species.

(2) The Impala (*Aepyceros melampus* Lichtenstein, 1812) (Fig. 21)

The impala is an animal of the acacia savannahs from Northern Zululand northwards, Western Transvaal and Northern Transvaal (Roberts, 1951). It is the most common buck in the Kruger National Park (Ellerman *et al.*, 1953).

Roberts (1951) described the impala's coat as follows:—

> " Upper part of head, whole neck, upper half of body and partly down thighs, dark fawn colour, legs lighter fawn; a broad band of brownish-buffy below the dark fawn and white of underparts of body extends from behind the shoulders to thighs, and a similar shade of colour occurs behind the thighs on each side of a black stripe that extends from opposite the root of the tail downwards for about seven inches, narrowing downwards. A thin black line extends along the middle of the rump to the tail and then broadens and extends along the whole top of the tail to the white tip. Undersides and inside of legs, white and a glandular tuft of hairs on the lower back leg, black."

(*a*) *General Description of Hair Coat*

All three individuals, male, female and young, had a markedly uniform colour which tallied exactly with Roberts' description, except that the coat colour of the young animal was lighter than that of the adults. The regularity of hair length gave this species a smooth appearance, the only long hairs occurring in the tail region.

(*b*) *Macroscopy of the Fibres*

(i) *Colour of the Individual Fibres*: The colour of the individual fibres was very regular—a dark reddish-brown on the dorsal parts, a lighter reddish-brownish-buffy colour latero-ventrally and white undersides. The tail showed an admixture of white, light reddish-brown, dark reddish-brown and black fibres. From the brisket extending over the back to the tail most of the fibres possessed a dark brown, almost black, tip in all three animals.

(ii) *Fibre Lengths:* The fibre with the greatest length was a tail fibre from the female: 101 millimetres as against 60 millimetres measured on a tail fibre from the fawn and only 41 millimetres for the longest tail fibre of the male impala. Tail hairs of the male showed definite signs of weathering and was probably longer originally. Body hairs varied from eight millimetres on the legs of the male to 57 millimetres on the shoulder of the female: this being the longest body fibre.

(iii) *Fibre Types:* As in the case of the kudu, body fibres could not be separated into distinct types. Some longer fibres in the coat would appear to belong to the guard hair type, whilst a majority in the shorter class could be classed as contour hairs, but these hairs did not conform to the standard definitions of fibre types. Ornamental hairs were found only in the tail area. Thus a distinction of fibre types could only be drawn between ornamental and body hairs.

(*c*) *Microscopy of the Fibres*

(i) *Cuticular Imprints:* The same basic patterns occurring in the kudu were also present in the impala. An irregular mosaic pattern (Fig. 34) was found with the scale edges more or less flattened while the scale margins appeared to be smooth. The units of the mosaic were flattened in the direction of the minor axis of the fibre.

The irregular mosaic pattern persisted from base to tip in body hairs. Imprints from the side where the ridge (cf. shaft) occurred also exhibited an irregular mosaic pattern on the ridge (Fig. 35). The tail fibres differed from the body hairs in that the wave and mosaic patterns alternated between fibres. In the male 75 per cent of the fibres had an irregular mosaic pattern at the base and 50 per cent of the fibres had an irregular mosaic pattern at the tip. In the female, however, 95 per cent of the fibres had an irregular wave pattern at base and tip. The converse occurred in the fawn: in 95 per cent of the fibres an irregular mosaic pattern was present at the base and apical region.

In the wave pattern the scale margins were ripple-crenate and where a mosaic pattern dominated, scale-margins were usually smooth. In both the mosaic and wave patterns external scale margin distances were *near*. Wave depths in the patterns varied between shallow and medium.

(ii) *Cuticle, Fibre Outline and Measurements in Cross-sections:* Thickness of the cuticle varied from thin in the young impala to intermediate in the hairs of the male. The cuticle of hairs from the tail of the male (Fig. 26) did not differ in thickness to any extent from those of the throat and mane which are not ornamental hairs in the impala.

Due to a unilateral thickening resembling a papilla in the cross-sections of fibres of the impala, the typical fibre outline was papillo-convex (Fig. 2). On occasion this convex side could be flattened to be almost linear (Fig. 30 and 31). Two types of fibre outline were apparent: a more rounded shape and a more flattened one (Fig. 29). These types occurred in all body hairs of the male and female. In the tail fibres (Fig. 26) elliptical and oval outlines were encountered of which about half had a thickening to one side reminiscent of the papilla on body hairs. Among the fibres of the young two clear outline types could be distinguished (Fig. 23 and 25). The ordinary papillo-convex outline conforming to that of the adults was present together with an oval or elliptical shape with a slight unilateral thickening. Occasionally the slight thickening was absent from a fibre and only a one-sided concentration of pigment was evident.

In the adults there was a regional variation in the localization of the two outline types. The more flattened type of outline usually occurred in the belly fibres (Fig. 30) while the rounded outline type was found in the mane fibres (Fig. 22). An admixture of these types was found in fibres from the shoulder region (Fig. 29).

Measurement on the greatest fibre diameter indicated that the throat fibres of the male had the largest mean diameter, 169·1 microns, followed by the brisket with 161·3 microns and the belly (160·3 microns). The mean greatest fibre diameter of fibres from the mane (142·6 microns) did not differ to any extent from that of other body sites, while the tail fibres had the smallest mean diameter (91·7 microns). In the female the belly fibres had the largest mean for the greatest fibre diameter (168·4 microns); the throat fibres were next (162·0 microns) followed by fibres from the brisket (159·8 microns). In the fawn the mane hairs had a mean of 77·7 microns for the greatest fibre diameter while the mean of the tail fibres was 66·0 microns and fibres from the back 63·5 microns.

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A homogeneity in the measurements of greatest and least diameters of fibre and medulla was noted. In the impala the absence of typical ornamental hair on neck and throat regions, and the smaller mean diameters of tail fibres as compared to body hairs were responsible for this lack of regional variation. The analysis of variance indicated that no significant differences existed between the means of the sites for greatest fibre diameter [Table 1 (*b*)] and greatest medulla diameter [Table 2 (*b*)]. The means of the sites for the least fibre diameter [Table 3 (*b*)] and the least medulla diameter [Table 4 (*b*)] indicated highly significant differences ($P = 0{\cdot}1$); this was probably due to the occurrence of two structural types (flattened and rounded) among the fibres and their localization at certain sites.

The difference between the means of the greatest and least diameters of fibre and medulla in the male and female impala was not large. The differences in the mean greatest diameter of the fibre and medulla between adults (male and female) and young were very pronounced: the overall means of the greatest diameter of fibre and medulla in the fawn was less than half for those of male and female. The analysis of variance of the means of male, female and fawn indicated highly significant differences for the mean greatest diameter of fibre and medulla as well as for the least fibre diameter. The mean of the least medulla diameter showed no significant difference between male, female and young: this could be attributed to the flattened type of medulla in fibres from the adult animals compared to the relatively wider medulla in fibres from the fawn.

Analysis of the fibre indices (Table 7) denoted significant differences ($P = 0{\cdot}5$) for the means of the sites and for the means of male, female and young. Due to the peculiar shape of the impala fibre in cross-section the use of the fibre index had to be confined to the species. This index only illustrated the relative broadness of fibres from the fawn over those of the adults. The shape of the fibre did not influence medulla measurements as medulla outline did not follow fibre outline in this respect. Analysis of the fibre/medulla indices in respect of the greatest diameter (Table 8) indicated a significant difference for the means of the sites but no significance for the means of the individuals, whereas that for the fibre/medulla indices in terms of the least diameter (Table 9) exhibited highly significant differences for both means of the sites and means of the individuals.

(iii) *Pigment in Cross-sections:* Pigment was found in all fibres except in those from the white undersides and in some white tail fibres. Distribution of the pigment could be classified as *cortical* (Fig. 4) with a tendency to become concentrated in the papilla on the ectal side: on the ental sides the pigment was more sparsely dispersed. Even macroscopically the fibres appeared to be paler coloured on the undersides. Intensity of pigmentation differed between heavy and sparse in fibres of the same section. A few fibres from the tail region of male, female and fawn had a *partial* dispersion of pigment (Fig. 26). In all body hairs the pigment displayed a *total* dispersion in the fibre (Fig. 6).

Fibres containing both tyrosine-melanin and pheomelanin occurred in varying numbers throughout samples from the various body sites: notably fibres from the throat (Fig. 27) and brisket. Granules, usually circular in shape, were usually aggregated in groups, with a few discrete granules interspersed (Fig. 28).

(iv) *Medulla in Cross-section:* In the adults the medulla outline of the flattened type of fibre was that of a long, extremely flat ellipse with no reciprocating bulge opposite the papilla in the majority of fibres (Fig. 31). The more rounded type of fibre had an elliptical shaped medulla (Fig. 24). In the young animal the medulla outline in the fibres with the slight unilateral thickening was either oval or elliptical or followed fibre outline: fibres with well-developed papillae had medulla outlines following fibre outline as well as others that did not have this tendency (Fig. 25). In fibres from the male and female the medulla was so flattened in shape that it could be classed as lacunate (Fig. 31). The unilateral thickening of the cortex placed the medulla in an eccentric position relative to fibre outline. In 50 per cent of cases the tail fibres from male, female and young the medulla was situated centrally: many body hairs of the fawn also exhibited this trait. Striations were visible on the cortico-medullary border: in some cases more apparent than in others.

The medullary structure in the more rounded type of fibre had a cellular and granular appearance (Fig. 24). This type of structure occurred practically without exception in the medulla of fibres from the impala fawn. In the more flattened type of fibre the tendency for the medulla was to be more fibrous and granular in appearance (Fig. 30).

Medullary pigmentation was similar to cortical pigmentation. In addition to the pigment there were some inclusions, angular in shape and dwarfing the ordinary pigment granules, having the colour of pheomelanin. The origin of these particles was obscure.

(v) *The Tip:* In fibres from adult animals and fawn at all body sites, except the ventral line and tail, the tip was acicular. Tips of the tail fibres were mostly long or medium flagelliform. Fibres from the throat, brisket and legs had an extended tip intermediate in shape between acicular and flagelliform.

The colour of the tip varied from a dark reddish-brown to light brown and was unpigmented in the white fibres of belly and tail. Where pigment was present it occurred in streaky aggregates. In the majority of fibres the extreme apical region was of a paler colour than the remainder of the tip.

In some fibres the medulla entered the tip region in fragmentary or particulate fashion.

(vi) *The Shaft:* A gradual increase in the width of the shaft was observed from the base, progressing towards the apical region and reaching its maximum thickness just before narrowing down to form the acicular tip. Body fibres and some tail fibres of the impala exhibited an unusual characteristic: a unilateral thickening in the form of a ridge extended from the base to the tip of the fibre (cf. cross-sections). The presence of pigment was in streaky aggregates throughout the length of the fibre and varied from reddish-brown to light brown. In some cases the cortex appeared to be more deeply pigmented to one side of the fibre than to the other.

A medulla was found, practically without exception, in all fibres. It was centrally situated and was of the simple unbroken type, wide in diameter and without undulations (Fig. 33). The sides of the medulla were slightly *erose*. Where the medulla was infiltrated by mounting medium the ridge could be seen as a darkly pigmented area (Fig. 32).

Edges of the cuticular scales were not very prominent although the visible portions appeared to be acute.

(vii) *The Base and Root:* The root was of the medium clavulate type throughout and discrete pigment granules were present up to the bulb region.

(viii) *Fibre and Medulla Measurements* [*Tables* 5 (*a*) *and* 5 (*b*), 6 (*a*) *and* 6 (*b*)]: Mean fibre diameter varied from 166·7 microns on the neck of the male to 40·9 microns on the belly of the young animal: a difference of approximately 126 microns. The neck fibres of the male were much coarser than those of the mane and tail. The finest fibres of the male were found on the back (mean fibre diameter: 76·5 microns). In the female the throat fibres had the greatest mean diameter (151·6 microns) whereas those on the back, like the male, had a mean diameter of 75·2 microns. In the fawn the coarsest fibres were found on the tail (56·6 microns) while all the body hairs varied consistently between 40 and 50 microns.

The analysis of variance on mean whole fibre diameter indicated that there were no significant differences between the body sites. Mean whole fibre diameter for male, female and fawn differed highly significantly owing to the low fibre diameter of the young compared to that of the two adult animals.

The differences between the mean whole medulla diameters were significant as regards the sites and highly significant between the individuals. Fibres with large diameters on the throat, belly and brisket of the male and female and neck of the male had large mean whole medulla diameters compared to small fibres with similar medullae in the fawn. The mean whole medulla diameter of the male was nearly thrice the value of that of the young.

The fibre/medulla index (Table 10) differed in highly significant fashion in respect of both the sites and the individuals.

(3) The Blue Wildebeest (*Gorgon taurinus* Burchell, 1823) (Fig. 36)

This species is one of the larger game animals, occurring from Northern Zululand to the Transvaal Bushveld. It is also found in the Kruger National Park (Roberts, 1951).

Roberts (1951) gave the following description of the blue wildebeest's coat: " General colour silvery grey, varying in different lights, and with brownish bands more or less present on neck, shoulders and to the middle of the body: the face and mane, the beard along the throat and long hairs of tail, black: the forehead is more or less reddish mixed with dark brown, the cheeks almost white and contrasting with the black of the face, the muzzle brownish, of a lighter colour." According to Shortridge (1934) " the calves are fawn brown in colour . . . . . Both males and females tend to become darker with age ".

(*a*) *General Description of Hair Coat*

The male, female and young displayed a striking similarity in coat colour and conformed in all respects to the description given by Roberts. In the coat of the calf no bands occurred and the long beard hairs were a mixture of black and reddish-brown fibres. In the light of Shortridge's statement, the calf in question could not have been very young.

(*b*) *Macroscopy of the Fibres*

(i) *Colour of the Individual Fibres:* The fibres of the mane consisted of two different colour types: a long fibre, dull black throughout, and a much shorter type, yellow brown from base to the top of the shaft with a dark brown tip. Tail fibres also displayed two colour types: an evenly black fibre and a fibre with a light brown base becoming darker brown towards the tip. In the throat region these two colour types were also apparent: long hairs having a dark brown base and shaft and with a yellow brown tip, and a shorter fibre with a yellow brown base and shaft culminating in a brown tip.

Body fibres displayed a difference in colour between ectal and ental sides. The ectal side containing the groove was of a paler colour than the ental side. Sometimes an off-white stripe was found down the ectal side of the fibre. The lateral sides of the fibre were the darkest and were dark brown in colour. By rotating a small skin sample the light effect on the fibres could be followed. The silvery-grey colour was probably due to the light reflecting from the two dark brown sides and the off-white groove at a particular angle of illumination. As a rule the base had an off-white colour also, the hair darkening towards the brown tip.

(ii) *Fibre Lengths:* Incidental measurements of length showed that the longest fibre was in the mane of the female: 222 millimetres against 200 millimetres of the male. The longest tail fibre measured 133 millimetres while the fibre with the greatest length in the throat region was 182 millimetres—both from the female. Body hairlengths varied from five millimetres on the legs of the calf to 44 millimetres on the brisket of the male.

(iii) *Fibre Types:* Two fibre types could be distinguished: ornamental hairs in mane, tail and throat, and body hairs. In the body hairs no fibre types could be established according to the classification of these types. A variation in length and diameter was apparent but the differences between fibres were gradual and not distinct.

(*c*) *Microscopy of the Fibres*

(i) *Cuticular Imprints:* Two basic patterns were observed. An irregular mosaic pattern occurred in the groove of the fibre with units practically rectangular, the short sides orientated towards the short axis of the fibre (Fig. 46). The other pattern was an irregular wave found on the fibre from base to tip (Fig. 45). In the mane, tail and throat fibres, where the groove was absent, the irregular wave pattern occurred over the whole fibre.

The scale margins were ripple-crenate in the wave pattern and mostly smooth in the mosaic pattern. Distances between scale margins were *near* in both mosaic and wave patterns but in ornamental hairs these margins were *close*. The wave depth in all patterns was *shallow* in most cases.

(ii) *Cuticle, Fibre Outline and Measurements in Cross-sections:* The thickness of the cuticle was intermediate in all hairs—both in ornamental and body types (Fig. 37 and 38) of all three individuals.

In cross-section the typical fibre outlines were fabiform (beanshaped) and lineo-convex but not exclusively so. Fibres from the mane varied most in outline: in the female eleven shapes were distinguishable, notably circular, elliptical, oval, concavo-convex, lineo-concave, lineo-convex, trilateral, quadrilateral, etc. The belly was the area with the least variation in fibre outline in all three animals. Here all fibres were fabiform without exception. By contrast no tail fibres of male, female and calf had this typical body hair outline: they were mostly oval or elliptical in shape. The outline of the long throat fibres resembled that of the tail fibres to a great extent (Fig. 39). Two definite types of fibre outline were discerned in the young animal (Fig. 44): the usual fabiform outline and a lineo-convex shape that appeared to be quadrilateral in some cases when the rounded corners were angulated. Fibre outlines of the leg fibres from the female (Fig. 43) and young animal (Fig. 44) were quite regular compared to the diversity of outline found in leg fibres from the male (Fig. 42). The same divergence from the usual outline was encountered in fibres from the buttocks of these animals (Fig. 41).

The long fibres from the tail had the largest mean greatest fibre diameter, namely 242·5 microns, 216·0 microns and 172·7 microns for male, female and young respectively. Then those from throat and mane followed. The coarsest body fibres were found on the brisket of the male (241·4 microns), the belly of the female (206·5 microns) and neck of the calf (134·8 microns). Fibres having the smallest least fibre diameter were from the leg region of the male (151·5 microns) and female (140·2 microns), and the shoulder area of the calf (111·6 microns).

The analysis of variance for the greatest fibre and medulla diameters [Tables 1 (*b*) and 2 (*b*)] revealed highly significant differences ($P = 0·01$) between the means of the sites due to regional differences in fibre size: the thick ornamental hairs compared to the relatively much thinner leg fibres. Significant differences ($P = 0·05$) for sex and age were due to the difference in fibre thickness between adult animals and the young.

In terms of the mean least diameter of the fibre [Table 3 (*a*)] and medulla [Table 4 (*b*)] highly significant differences were noted between the body sites where the regional variation between ornamental hair and body hair thickness was the contributory factor. The absence of medulla in ornamental hairs in contrast to the body hairs (where a medulla was usually present) explained the significant differences of the mean least medulla diameter between the sites. In the case of the male, female and young the mean least fibre diameters were only significantly different due to the more regular occurrence of the lineo-convex outline of fibres from the calf, which were structurally more broad than the fabiform fibre outline of hairs of the adult animals, thus lessening the gap between measurements of male, female and young.

Analysis of the three indices [Fibre (Table 7), Fibre/medulla greatest diameter (Table 8) and Fibre/medulla least diameter (Table 9)] revealed highly significant differences for the means between the sites. Between the three individuals a highly significant, significant and no significant difference respectively were recorded for each of the three indices (*vide supra*).

(iii) *Pigment in Cross-sections:* All body and ornamental fibres of the blue wildebeest were pigmented. The distribution of the pigment in the fabiform fibres was *bilatero-cortical* (Fig. 38), the highest concentration of granules being found at the sides. Intensity of the pigment varied in the same cross-sectional group of fibres from heavy, medium, light to sparse (Fig. 41).

The mane and tail fibres of male, female and calf were heavily pigmented in most cases with a *cortical* distribution (Fig. 37 and 39) and a partial or total dispersion of pigment. Pigment was absent from the ectal side of some fibres and occasionally from the ental side of other fibres.

In the male and female the pigment is mostly tyrosine-melanin. The body hairs (excepting ornamental hairs) of the calf contained a variable mixture of pheomelanin and tyrosine-melanin giving the hair a golden-brown, instead of dark brown, appearance The granules were usually aggregated in clumps with some discrete granules interspersed. Only circular shaped granules were visible in the fibres.

(iv) *Medulla in Cross-sections:* The medulla outline in fabiform fibres, with few exceptions, never resembled the fibre outline. In these cases the medulla had an outline of its own: crenated or, more aptly, bi-crenated (Fig. 38). As most of the body hairs of male and female were of the fabiform type, this medulla outline was found in most fibres. Fibres with a lineo-convex outline had medulla outlines sometimes approximating this shape, but were mostly irregular, thus making classification nearly impossible. This was the situation in most of the body fibres of the calf (Fig. 40).

Most of the ornamental hairs had no medulla: in nearly 90 per cent of fibres from the mane of the male and over 90 per cent in throat hairs of the young animal the medulla was absent. When present, it was usualy rudimentary or atypical. Fibres from other regions, notably the legs of the male, may also be without a medulla (Fig. 42).

The medulla was eccentrically placed in all body hairs due to its bi-crenated shape and also because it was nearer to the groove on the ectal side of the fibre. Whenever a medulla was present in ornamental hairs, it was usually in a central position.

The cortico-medullary border had an irregular contour and the appearance of the medulla varied from smooth to granular. In the bean-shaped fibres the medulla had a fibrous structure.

Pigmentation of the medulla was similar to that of the cortex.

(v) *The Tip:* All fibres had a blunted acicular tip with the exception of fibres from the mane of male, female and young, where the tips were short flagelliform.

The colour of the tip varied from dark brown in the mane, reddish-brown in some tail fibres, to light brown elsewhere.

(vi) *The Shaft:* A gradual increase in width of the shaft was noticeable from the base towards the tip. The greatest width was reached at the distal end of the shaft. Pigment was present in streaky aggregates throughout the fibre, varying from light brown to dark reddish-brown in colour.

As already stated under the description of fibre cross-sections, a medulla was present in all body hairs, most of the leg hairs of the male and in some ornamental hairs. In the latter case a medulla may be absent in as many as 91 per cent of mane fibres of the male; this was in close agreement with the figure obtained by studying cross sections. By contrast, in whole mounts of throat fibres of the young animal the medulla was absent in 26 per cent of cases. Comparison of this figure with that obtained from cross sections (over 90 per cent) indicated the extent of sampling

error that might occur. In whole mounts the medulla appeared to be situated centrally in all cases (Fig. 47): the true eccentric position was only observable in cross-sections of fibres. The medulla was medium at the base with a gradual increase in diameter distally; it continued unaltered into the tip almost to the extremity of the fibre. In body hairs the medulla was of the simple unbroken type with slightly *erose* sides. In ornamental hairs the medulla, when present, was of the interrupted type, rather narrow, of regular width with *entire* sides.

Edges of the scales were " blunt " in appearance giving the impression of being compressed against the shaft of the fibre.

(vii) *The Base and Root:* The shape of the root was usually medium clavulate. Discrete pigment granules were present in the root area of the fibres.

(viii) *Fibre and Medulla Measurements* [*Tables* 5 (*a*) *and* 5 (*b*) *to* 6 (*a*) *and* 6 (*b*)]*:* Mean whole fibre diameters measured in the whole mounts were very similar for male and female animals: 191·5 microns and 180·0 microns respectively, whereas that for the calf was considerably lower, 127·2 microns. In the male the largest mean whole fibre diameter was found at the brisket (236·3 microns) and the smallest mean diameter at the legs (117·4 microns)—less than half of the first mentioned value. All-round lowest values were obtained from fibres on the back of the calf, with a mean of 99·9 microns.

In the blue wildebeest an analysis of variance showed highly significant differences ($P = 0{\cdot}01$) between the means of whole fibre diameters at the body sites and between the means of male, female and calf. This significance was due to regional variations in fibre diameter where the ornamental hairs had the largest mean whole fibre diameters and the leg fibres the smallest. Significant differences ($P = 0{\cdot}05$) in the means of male, female and young were due more to the variations in diameter between adult animals and young rather than between male and female, where values corresponded closely.

The virtual absence of a medulla in ornamental hairs—when an occasional medulla was encountered it was of a rudimentary nature—explained the highly significant differences for the means of whole medulla diameter between the body sites. The highly significant differences between the means of male, female and calf were due to the small mean diameters of the young compared to those of male and female.

Analysis of the fibre/medulla indices (Table 10) showed a highly significant difference between the means of the sites but no significant difference between the means of male, female and calf.

(4) The Grey Duiker (*Sylvicapra grimmia* Linnaeus, 1758) (Fig. 48)

Members of this species are inhabitants of scrub country or savannahs where patches of bush or scrub are found—according to Roberts (1951). They have a wide distribution: occurring in the Transvaal, Natal, Zululand and the Cape Province. Roberts' description (abbreviated) is as follows:—

> " The general colour dull, ochraceous-tawny on the upper parts of the body with numerous hairs with black tips intermingled, becoming less on the sides and absent below. On the underside of the body the colour is more uniform than above with a white patch on the throat and white at, and inside, the upper part of fore and hind legs; the legs are bright tawny, the tail black above, white on side and below."

(*a*) *General Description of the Hair Coat*

The coat colour of both male and female tallied with the description of Roberts except for a black streak that showed on the back in line with the shoulders. The general coat colour of the fawn was more a greyish-buff, becoming paler down the sides and terminating in a greyish-white on the undersides. On the shoulders and over the back numerous hairs with black or dark brown tips were intermingled with the other hair making this the darkest area of the coat. The outer aspect of the legs was dark brown.

(*b*) *Macroscopy of the Fibres*

(i) *Colour of the Individual Fibres:* The fibres at all sites except for part of the tail were dull white or light brown at the base and part of the shaft with a yellow band near the brown tip. Some fibres, notably from the legs, were dark grey near the base instead of white but had the same yellow band and brown tip. The so-called black fibres from the tail, when examined individually, were found to be dark brown from base to tip.

(ii) *Fibre Lengths:* From random samples the longest and shortest fibres were measured. The longest fibre (76 millimeter) was from the belly of the female and the shorest, measuring eight millimetres, came from the thigh of the same female. Tail fibres from the male measured from 22 to 80 millimetres and those from the fawn from nine to 60 millimetres. A tail was missing from the skin of the female.

(iii) *Fibre types:* Two hair types were found: ornamental hairs confined to the tail region and body hairs. Body fibres could be sorted out into three types according to length and appearance. The first type corresponded to guard hairs, the second type, more numerous than the first, might be regarded as the equivalent of contour fibres and the third type, thin and slightly crimped, conformed to underhair or downy hair of the classification system used.

(*c*) *Microscopy of the Fibres*

(i) *Cuticular Imprints:* An irregular mosaic pattern was present with the units higher and wider than those from the same pattern occurring in the other three species (Fig. 61). The units were flattened in the direction of the short axis of the fibre. The irregular mosaic pattern tended to make way for an irregular wave pattern at the tip. In the thicker fibres an irregular wave pattern occurred from base to tip (Fig. 60). In some fibres, notably from the fawn, an irregular mosaic pattern was dominant from base to tip.

Scale margins were ripple-crenate in the wave pattern and crenations, alternating with smooth margins, occurred to a certain extent in the irregular mosaic pattern. In both patterns the distances between external scale margins were *near*. Wave depth in both patterns varied from shallow to medium.

(ii) *Cuticle, Fibre Outline and Measurements in Cross-sections:* In all hairs—body and ornamental—of male, female and fawn the cuticle was thin without exception.

The prevalent cross-sectional outline was elliptical; the oval shape occurred more infrequently (Fig. 49 and 56). Fibres from the back and neck of male, female and young showed a greater divergence in outline than those from other sites. Outlines varied from circular to elliptical but a few odd oval, bi-concave, concavo-convex, lineo-concave and lineo-convex shapes were recognized (Fig. 52). The leg fibres of the male, female and fawn varied least in cross-sectional outline, being almost exclusively elliptical, with an occasional round and oval shape (Fig. 57).

A large variation in size was observable in cross-sections of fibres from the shoulder of the male (Fig. 54). In some of the coarser fibres the cortex had a lateral thickening on the border of the medulla (Fig. 54 and 57).

Measurements indicated that the largest mean value for greatest fibre diameter was recorded at the brisket of the male (126·4 microns) while the smallest value was registered at the shoulder (72·1 microns). In the female the neck fibres had the largest value for the greatest fibre diameter (107·7 microns) whereas the smallest reading was from the shoulder fibres (54·9 microns). In the young grey duiker these extremes were found between the tail (92·8 microns) and the belly region (43·1 microns) respectively. The latter figure was the smallest all round mean recorded.

In the grey duiker some similarity between fibre and medulla measurements was noted due to the absence of ornamental hairs on the anterior aspects of the specimens. Tail fibres showed an agreement to body hairs in their mean diameter values for fibre and medulla. An analysis of variance similarly showed no significant differences to exist between the means of the body sites and between the greatest and least diameters of fibre and medulla [Table 1 (*b*) to 4 (*b*)].

In the fawn mean greatest and least diameters for fibres and medullae were smaller than those of the adult animals and highly significant differences ($P = 0{\cdot}01$) were noted between the means of all diameters except between female and young in the values for the mean greatest fibre diameter.

This lack of variation in the means of cross-sectional diameters was reflected in the three indices [Fibre (Table 7): Fibre/medulla greatest diameter (Table 8) and Fibre/medulla least diameter (Table 9)] where no significant differences were established for means of the sites. The means of male, female and fawn indicated a significant difference for both the fibre and fibre/medulla least diameter indices but no significant difference was found between the fibre/medulla greatest diameter indices.

(iii) *Pigment in Cross-sections:* Pigment was present in most of the fibres, even in the belly fibres of male and female grey duiker. In the fawn 33 per cent of the belly fibres were devoid of pigment. Tail fibres of the male and throat fibres of the female also had some unpigmented fibres among them.

Distribution of the pigment was *cortical*, tending to concentrate peripherally and intermedially with discrete granules scattered axially (Fig. 51). The tendency for elliptical fibres was to be more deeply pigmented than those having a more circular outline (Fig. 50). In a few fibres the pigment was partially dispersed but the majority of fibres had a total dispersion of pigment.

The three pigment types were all present in variable amounts. Tyrosine-melanin formed the major portion of the pigment while some fibres contained pheomelanin. A number of fibres had a mixture of tyrosine and pheomelanin, whereas others had pheomelanin and melanoprotein in the same fibre.

Granules, mostly circular, occurred in aggregates with a number of discrete ones interspersed.

(iv) *Medulla in Cross-section:* The cross-sectional outline of the medulla followed that of the fibre in most cases: some of the elliptical fibres with large diameters had a lateral thickening of the cortex encroaching on the medulla (Fig. 57). The elliptical outline, as in fibre shape, dominated over the other outlines present; an oval outline was found occasionally. Medulla outline was not always as regular as fibre outline: irregularly elliptical or oval is perhaps a truer description.

In almost all fibres the medulla occupied a central position. A medulla was absent from a few leg fibres of the female and fawn. The degree of medullation varied from wide, medium to narrow (Fig. 53 and 55).

The medulla had a cellular structure with a fine, granulated appearance (Fig. 49). Pigment in the medulla was similar to that of the cortex, even the same mixing of types was observed. The granules were round and no other inclusions were noticeable.

(v) *The Tip:* Fibre tips of male, female and young were long to medium flagelliform. Some short flagelliform tips occurred among fibres from the neck, thigh and legs of the fawn.

Tip colour varied from light to dark brown. The extreme apical region was of a paler colour than the remainder of that region in most fibres.

(vi) *The Shaft:* The shaft of the grey duiker fibre had a regular width from the base to the upper part until it narrowed to form the tip. Pigment occurred in streaky aggregates throught the shaft varying from light brown to darker brown with a yellowish-brown band just below the tip. In belly fibres the shaft was either light brown from base to tip or totally unpigmented.

A centrally situated medulla of the unbroken type with *erose* sides was found in most fibres (Fig. 59). The width of the medulla varied from narrow to wide and was more or less regular in its course from base to tip.

Cuticular scales were not prominent and appeared to be pressed close to the shaft with the visible edges having a rounded appearance.

(vii) *The Base and Root:* No enlargement of the base was observed and a medulla was absent from the root portion. When pigment was present the granules were discretely dispersed down to the root bulb. The root was mostly clavulate: a few were long clavulate.

(viii) *Fibre and Medulla Measurements* [*Tables* 5 (*a*) *and* 5 (*b*) to 6 (*a*) *and* 6 (*b*)]*:* Maximal and minimal values for fibre diameter measured in whole mounts were found at the throat and belly of the male (123·3 and 57·3 microns respectively), neck and belly of the female (98·3 and 53·7 microns respectively) and from the tail and shoulder of the fawn (91·0 and 37·7 microns respectively).

An analysis of variance revealed no significant difference between the mean whole fibre diameter from the various body sites: however, a significant difference ($P = 0{\cdot}05$) between whole medulla diameters from the different sites was found.

Fibres from the fawn were markedly smaller than those from the adult animals: this was reflected by the significant difference obtained between the means of whole fibre diameter of the male, female and young. A highly significant difference ($P = 0{\cdot}01$) was found between the mean whole medulla diameters of the three specimens: the male for instance had a mean whole medulla diameter value twice that of the fawn.

The fibre/medulla index (Table 10) showed no significant difference between the means of the body sites and a significant difference between the means of male, female and fawn.

IV.—Discussion

The hair coat of mammals, taken as a whole, varies appreciably in appearance and colour from species to species. In the four different species of the Bovidae studied, the gross differences in colour tones of the coat are so well defined that they are utilized in taxonomical classification. These differences found in the coat as a whole, however slight in some respects, are extended to the individual fibre. A single hair in a certain locality may differ in colour from hairs from other body sites of one and the same animal. Fibres on the undersides of the body are, when not totally unpigmented, usually paler in colour than those from the upper parts. It is also found that some hairs exhibit a paler colour at the base, gradually darkening towards the tip, which usually appears to be the darkest coloured part of the fibre. Sometimes the ectal and ental sides of a fibre may also display a difference in colour intensity, visible to the unaided eye. Fibres from the grey duiker, for example, have a yellow band near the tip in most cases, differentiating them from hairs of the kudu, impala and blue wildebeest, where no colour-banding of the hair occurs. Impala hairs and those from the blue wildebeest also have a different intensity of colour on the ectal and ental sides. Nevertheless, macroscopic examination of the individual fibre for establishment of its colour, although useful, is unreliable for purposes of identification except in certain specific instances. The structure, size and shape of the fibre are such that differences in nature and angle of incidence of light employed and in background against which the fibre is viewed, profoundly modify the colour effect (see also page 390).

Some mammals, notably the fur-bearing species, have distinctly different fibre types in their pelage with a concomitant variation in colour. Only two fibre types are distinguishable with certainty in the hair coat of the kudu, impala, blue wildebeest and grey duiker. The first type is the ornamental hair, restricted to the mane, throat and tail as a rule. The second type is the body hair which covers the largest area on any animal. Of the four species the kudu and blue wildebeest have the full complement of ornamental hair sites, namely mane, throat and tail. The kudu female, however, does not possess the long thick throat hairs of the kudu male. In the impala and grey duiker the tail region is the only site where ornamental hairs are found: the mane and throat area are covered by hair that cannot be differentiated from body hairs. A difference in body fibre types can not be indicated in the kudu, impala and blue wildebeest. Macroscopically there is some indication of an existence of three types of body hairs in the grey duiker: guard hairs, contour hairs and downy

hair. With this exception, no signs of an inner coat are found in the specimens studied and it appears as if only an outer coat is present. The possibility of an inner coat under certain climatic conditions does exist; this question needs further investigation. Diameter and length of body hairs vary from fine to coarse and from short to long. Determination of fibre length on a limited number of fibres from the various body sites indicates that these measurements would be of no value for species identification. There is a considerable overlap of these lengths even in the ornamental hairs of kudu and blue wildebeest.

Microscopical examination of hair structure in various types of preparations reveals numerous major and minor species and site differences. The pattern formed by the external margins of the scales can be observed in some specially prepared whole mounts of fibres, but is visible to a greater degree in imprints made in a suitable impression medium. Wildman (1954) emphasizes that scale pattern is not a diagnostic feature under all conditions, since fibres from the same genus of animals may have certain characteristics in common and even certain fibres from animals of different groups may produce a similar scale pattern. This observation has been found true to a great extent, as on all hair of the four species concerned only two patterns could be distinguished: an irregular mosaic and an irregular wave pattern.

In fibres of the adult kudu and grey duiker of both sexes the base tends to have an irregular mosaic pattern whereas an irregular wave pattern occurs towards the tip. In the young of these two species the irregular mosaic pattern is the dominant one and persists from base to tip of the fibres. This distribution of scale patterns is somewhat different in the impala and blue wildebeest. In almost all impala fibres an irregular mosaic pattern is found on the ectal and ental sides of the fibre, whilst an irregular wave pattern is common on the ridge of the fibre. Fibres from the blue wildebeest, however, have an irregular wove pattern on the ectal and ental sides of the fibre with an irregular mosaic pattern occurring in the groove. When the ridge of the impala hair and the groove of the blue wildebeest hair show in the imprint, i.e. when the ectal sides faced the medium during preparation, the total scale pattern distribution of the fibre constitutes a major diagnostic feature, which serves not only as a means of distinction between these two species but also sets them apart from the kudu and grey duiker.

The scale patterns of the four species appear to be so similar that differences in the arrangement of the units of the pattern have to be considered. These differences may be very slight but they merit consideration. The units in the mosaic pattern of kudu fibres appear to be more flattened and longer than those of the impala, resembling the units in the groove of the blue wildebeest fibre. In the mosaic pattern of the grey duiker fibres, the units appear to be shorter and wider than in the other three species. The irregular wave pattern of the fibres of the blue wildebeest is subject to variation: the scale margins follow a more erratic course than in the other species.

Scale margins of the mosaic pattern of impala and blue wildebeest fibres have less crenations than those of the kudu and grey duiker, while scale margins in the wave pattern are ripple-crenate in all cases. The external margins are " near " in kudu, impala and grey duiker and " close " in the blue wildebeest.

The characteristics of the cuticular scales seen in the whole mounts are not so conspicuous as in the imprints of the fibres. Practically the only part of the scale that can be viewed unobstructedly, is its profile on the edges of the fibre. These were referred to as " serrations " by earlier investigators, but this designation has fallen into disuse. The appearance of the scales in profile is " rounded " in the kudu and grey duiker fibres and " acute " in impala fibres. In blue wildebeest fibres these scale profiles appear to be " blunt " and close to the shaft. However, these scale profiles can only constitute a minor feature for consideration in any process of identification.

In cross-sections the cuticle has the least diagnostic value. Only the thickness of the cuticle can really come in for consideration. Glaister (1931) states that the cuticle of the impala hair is irregular and ill-defined in cross-section. With the improved sectioning methods used in this study the reverse was found to be the case. Yet differences among the four species are so slight that they constitute a negligible factor.

No regional variation in scale pattern can be demonstrated in any of the body hairs. However, in the hairs of mane, throat and tail of the kudu and blue wildebeest no transition of patterns is found: only one scale pattern (irregular wave) is encountered throughout the whole fibre Adult sex differences in scale pattern of the fibres appear to be non-existent. In the young kudu and grey duiker an irregular mosaic pattern is dominant in the body hairs, even at the tips, whereas an irregular wave pattern occurs mostly in the adults.

In support of Wildman (1954), it is concluded that the appearance of the scale edges in profile in whole mounts, the thickness of the cuticle in cross-section together with the features of the scale patterns may provide evidence of a fibre's identity but it must be considered as supporting evidence only and must be taken in conjunction with other characteristics of the fibre.

Transverse sections of the fibres prove to be the most illuminating for illustrating major species differences. Fibre outline (papillo-convex) of hairs of the impala is absolutely typical. On this feature alone the body and leg hairs of the impala are distinguishable from those of any other species. Fibres from the site of the mane resemble the body hairs in shape: those from the tail either resemble the body hairs, have a simple elliptical outline, or are of an intermediate type with a slight unilateral thickening of the cortex and an aggregation of pigment.

The fabiform shape of the body and leg hairs of the blue wildebeest in cross-section is more characteristic than the oval and elliptical outlines of the fibres from kudu and grey duiker. This bean-shaped outline is not typical for the species or even genus. In addition to the gnu (*Connochaetus gnou* Zimmerman) the hartebeest (*Alcelaphus* spp.), the blesbok (*Damaliscus dorcas phillipsi* Pallas) the bontbok (*Damaliscus dorcas dorcas* Pallas) also exhibit this fibre outline. Fibres from the two wildebeest species (*G. taurinus* and *C. gnou*) are similar in other respects as well. Among the long hairs of mane, throat and tail of the blue wildebeest a negligible number of bean-shaped outlines is found; the outlines of most vary between elliptical and oval with a few odd trilateral and quadrilateral shapes interspersed. In the young blue wildebeest cross-sections of the body and leg hairs show a larger number of lineo-convex and trilateral fibre outlines than the more common bean-shaped ones of the adults. The two outlines are actually closely related: angulation of the convex side would result in a trilateral outline.

Comparison of fibre outlines in body and leg hairs from the four species shows that the papillo-convex outline of the impala and the fabiform outline of the blue wildebeest are readily recognisable, differing from each other and from fibres of the kudu and grey duiker which display a greater degree of similarity in their elliptical and oval cross-sectional shapes. Regional differences in the outline of the fibres are quite conspicuous between sites of ornamental hairs and body hairs. Among hairs from different body sites, however, variation in outline is not so marked except for differences in fibre size. Fibres from the legs of the young blue wildebeest tend to have a greater amount of trilateral shapes among them than fibres from other body sites.

In the adults no differences in body fibre outlines between male and female can be determined. Between adults and young some difference in fibre outline is noticeable apart from fibre size. These distinctions are not so marked in fibres from kudu and grey duiker as in the other two species. In the impala fawn two types of fibre outline can be discerned: one conforming to that of the adults in most respects, and the other, much smaller type, without the pronounced papilla, although slightly thickened to one side. Similarly in the blue wildebeest calf two fibre types are noted: the one type corresponding in outline to that of the adult fibre, while the second type has a lineo-convex outline without the groove.

In certain cases it would be possible on the basis of cross-sectional area and outline variation to distinguish between fibres from adults and young of the same species, particularly in the impala. In the other three species the difference between fibre outlines of adults and young is not so pronounced; also, cross-sectional area seems to be more indicative, with these reservations: the sample must be representative and sectioning must be done at the same level for all fibres.

Pigment distribution in the cortex can be a major diagnostic feature. The three pigment types are all present to a greater or lesser degree in fibres of the four species. Tyrosine-melanin predominates in fibres from the kudu, blue wildebeest and grey duiker, whilst the reverse holds true for the impala. Of the four species only the impala has no pigment whatsoever in fibres from the belly area in both adults and young. In the grey duiker fawn only a third of the belly fibres is totally devoid of pigment. All the other fibres, although appearing white, have a sparse dispersion of pigment granules throughout the fibre.

In body hairs, although the distribution may be totally cortical, there is a tendency for the pigment to be more concentrated in certain areas. This localization can sometimes prove to be a strong diagnostic feature. Such a concentration of pigment is found peripherally and intermedially in both kudu and grey duiker: in the blue wildebeest it is situated bilaterally and in the impala on the ectal side in the thickening of the cortex. In this variation in topical pigment concentration, the impala and blue wildebeest differ from each other and from the kudu and grey duiker.

The intensity of the concentration differs not only between fibres from the same site but also regionally. It appears that in the dorsal parts of the body (mane, shoulders and back) fibres have a higher concentration of pigment which gradually diminishes in density in those towards the ventral aspect (belly) of the animal. The ornamental hairs of the three blue wildebeest have a dense aggregation of black pigment granules throughout the fibre, differing from the bilateral concentration in body hairs of the same animal. In the impala the fibres from the dorsal regions

definitely show a higher density in pigmentation than those from the sides and a total absence of pigment occurs along the ventral side. The same pattern of pigment density is noticeable in the kudu and grey duiker although not so well-defined as in the impala, while in the blue wildebeest this differential pattern is not conspicuous at all.

Between adult male and female no definable differences in intensity of pigmentation can be established. Even in the kudu, where the female has a hair coat of a lighter shade than the male, differences in intensity could not be demonstrated microscopically in the fibres from the various body sites. Pigment differences between adults and young are more marked. Lineo-convex shaped fibres from the blue wildebeest calf show a lesser degree of pigmentation at all body sites. An admixture of pheomelanin and tyrosine-melanin gives all the calf fibres a more golden-brown appearance. In this respect the calf differs from the adult, where pheomelanin is absent from the hair. In the impala fawn the papillated fibre types are intensely pigmented while the smaller ones, with only an indication of a papilla present, are slightly pigmented. This probably accounts for the lighter shade of the impala fawn's hair coat compared to that of the adult.

The shape of the pigment granules is almost always circular. They are usually packed together in aggregates. In the impala, angular particles, greatly exceeding pigment granules in size, occur in cortex and medulla. Their origin and significance were not determined. These angular inclusions appear to be characteristic of fibres where pheomelanin is the exclusive pigment.

The colour of the fibre is more conspicuous in whole mounts than in cross-sections because the latter are thinner. Longitudinal distribution of pigment in the shaft of the fibre displays no striking species differences. Fibres unpigmented along their whole length occur prominently between pigmented fibres of three species. The blue wildebeest is the solitary exception: it has no white fibres on trunk and legs. The silvery grey colour of its coat is probably due to a particular way of light reflection (p. 407). In the kudu the colour of the shaft varies from dark reddish-brown to a buff colour while the colour of the tip ranges from reddish-brown to a light yellowish-brown; some tips lack pigment.

The longitudinal distribution of pigment in the impala fibres does not vary much, except that there is a slight increase of pigment towards the tip and an absence thereof at the very apex. The individual fibres vary from dark reddish-brown to light brown. The differences in colour between the ental and ectal sides can be appreciated better macroscopically. In the blue wildebeest there is a similar gradation of colour from base to tip, but there is a remarkable uniformity of colour from fibre to fibre. The grey duiker fibres are paler in colour than those of the other three species, although brown and light brown shafts also occur. A light yellowish-brown band is situated below the tip which is sometimes dark brown in colour. Pigment from all four species occurs in linear or streaky aggregates: a very general type of pigment distribution.

The same pigment types occur in the medulla as in the cortex: this distribution can only be observed in cross-sections of fibres and the medullary pigment is usually lesser in quantity than the cortical pigment. If an admixture of pigment types occurs in the cortex, the medullary pigment follows the same pattern: even the angular particles found in conjunction with pheomelanin occur in cortex and medulla. Medullary pigment, unless the cells are separated (Vasques, 1961), is not so noticeable as cortical pigmentation and plays a minor role in the identification of the fibre. In conclusion, pigmentation—its type and distribution—is of major importance in identification of fibres.

Pigment type and colour of the pigment differentiate the impala fibres from those of the other three species while an admixture of tyrosine and pheomelanin in fibres from the young blue wildebeest distinguishes it from the adults of the group and any of the other individuals of the other three species. Distribution of pigment is *cortical* in pigmented fibres from the four species but the area of concentration varies from ectal in the impala to bilateral in the blue wildebeest and to the periphero-intermedial concentration of kudu and grey duiker. Although the distribution of pigment in kudu and grey duiker is very similar, a slight but noticeable difference in the colour of the granules is observed. A regional variation in density from the darker upper parts of the animal to the paler coloured undersides is noticeable. Usually the fibres with the greatest pigment density occur in the ornamental hairs: those from the blue wildebeest surpassing all the fibres of the other individuals. Intensely pigmented fibres usually have aggregated granules while in sparsely pigmented ones a discrete dispersal of granules is found. This variation from high to low density of pigment may be found in fibres from one and the same site on an animal.

Longitudinal distribution of the pigment as seen in whole mounts of fibres does not display any variation within the species nor in closely related species. Only the colour of the granules, where colour changes occur over the length of a fibre, may give an indication of species differences. The majority of the duiker fibres—having a yellowish-brown colour band situated under a brown or dark brown tip—can be distinguished from individuals of the other three species in this respect. In impala fibres, where the medulla has been infiltrated by the mounting medium, the more densely pigmented ridge is very conspicuous along the length of the fibre: an exclusive characteristic of this species. In densely pigmented fibres details of the pigment distribution will be obscured and for this reason examination of these fibres in whole mounts will have no diagnostic value.

Medullation of fibres varies greatly, not only among species but also between different types of hair occurring on the same animal. In the kudu and grey duiker the outline of the medullae of body hairs in transverse section tends to resemble fibre outline to a great extent, although the unevenness of the cortico-medullary border gives the medulla an irregular shape. Apparently as fibre diameter increases the medullary outline in cross-section becomes more irregular. This trend is very explicit in ornamental hairs where no relationship between fibre and medulla outline exists. Where a medulla does occur in ornamental hairs of kudu and blue wildebeest medullary outline can only be designated as atypical or even shapeless. In body hairs, where the fibre outline as seen in cross-section deviates from the relatively simple shape, such as round and oval, the medullary outline fails to conform to it. This is well exemplified in the impala with its long, flat elliptical medulla in a papillo-convex fibre, as well as in the blue wildebeest where a fabiform fibre contour surrounds a bilaterally crenated medulla. Similarly the lineo-convex outline of many fibres of the blue wildebeest calf is associated with an atypical medulla. On the other hand, the ornamental (tail) hairs of the impala, with the more classical oval or elliptical outline, have medullae of similar shape, despite the larger diameter of these hairs. A high incidence of non-medullated fibres is present among the ornamental hairs of the blue wildebeest.

Striations on the cortico-medullary border and cortex are observed in the kudu and impala fibres; in some more prominently than in others. This feature is not noticeable in the fibres of blue wildebeest and grey duiker.

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Seen in cross-section, the medulla of body and ornamental fibres of kudu and grey duiker is centrally placed whereas that of the impala and blue wildebeest is eccentric. In body hairs of the blue wildebeest the medulla is closer to the groove on the ectal side of the fibre even in those with a lineo-convex outline. The bilaterally notched condition of the medulla ensures its eccentricity in relation to the fibre outline: thus positioning of the medulla also depends upon simplicity of fibre outline. In whole mounts these details are obscured and the medullae of impala and blue wildebeest appear to be centrally situated. When impala fibres are mounted in a lateral position the eccentricity of the medulla is obvious.

Medullary structure in cross-section of circular fibres and those approaching circularity tends to be more cellular with a granulated appearance. This condition is typical of kudu and grey duiker. In fibres with a more flattened type of outline the medullary cells appear to be compressed, giving the medulla a fibrous, granulated appearance. Fibres from the adult impala and blue wildebeest and some fibres from the young of these species have this type of medullary structure.

Medulla diameters in transverse sections vary from wide, medium to narrow with no definite pattern. The tendency for ornamental hair is to have narrow or even medium medullae. In the blue wildebeest the ornamental hairs have narrow medullae while in the other three species the medium type of medulla occurs to a greater extent. Hausman (1930) suggests that in hair the medullae diameter decreases as fibre diameter increases. He was probably impressed by the difference between body hair and ornamental hair. In body hairs generally, medullary width tends to follow fibre diameter. This is illustrated in the case of fibres from the brisket of the blue wildebeest male, which have a greater fibre width than ornamental hairs from the same animal, and also a very wide medulla. Medullary width appears to be a characteristic more of the fibre type in particular, than of the hair in general.

In whole mounts the medulla gives the impression of being wider and thus of largest size than the same medulla seen in cross-section. This could be due to the observation of linear width of the medulla in whole mounts compared to size of medullary area in the cross-sections. In body hairs from all species the medulla is of the simple unbroken type and varies from medium to wide with the sides " erose ". When a medulla is present in the ornamental hairs of kudu and blue wildebeest, it is of the interrupted type, rather narrow, though regular in width, with the sides " entire ". Due to the intense pigmentation of ornamental fibres, especially in the blue wildebeest, medullary details are rather obscure, thus limiting their diagnostic value.

Fibre tips from kudu and grey duiker are mostly flagelliform. Long, medium and short flagelliform types are more or less equally represented among fibres from the kudu, while the tendency for those from the grey duiker is to have more long and medium flagelliform tips. While body hairs from impala and blue wildebeest have acicular tips, the ornamental hairs of both species, however, are flagelliform in shape. As regards body hairs, the kudu and grey duiker appear to be sharply separated in this respect from impala and blue wildebeest.

Of all the fibre characteristics, base and root morphology vary the least. In all four species the root shape varies from medium to long " clavulate ". No medulla is present in the root portion of a fibre as a rule. Very seldom a fragmentary part of the medulla is found entering the root area from the base region. When pigment is present, it appears as discrete granules dispersed throughout the root portion. This lack of variation minimises the value of these regions as a diagnostic aid in fibre identification.

As no published measurements on hair of South African game exist, extensive readings have been taken on fibres from certain body sites on the animals under study. Theoretically one could expect that fibre diameters obtained by measurements on whole mounts would be equal to the greatest diameters of the fibres as measured in cross-sections. In practice, however, not all fibres settle in a position with their longest diameter at an absolute right angle to the observer's line of vision, Moreover, fibres in whole mounts may be twisted along their longitudinal axes, either naturally or as result of preparation procedures. Consequently, differences may be expected between the fibre diameter as measured in whole mounts—briefly referred to as " whole fibre diameter "—and the diameter as measured along the longest axis of the cross-section—referred to as " greatest diameter ". (The " least diameter " referred to in this text is the maximum measurement obtainable at right angles to the greatest diameter). This expectation is borne out by the measurements actually obtained: the greatest diameters are constantly higher than the whole mount diameters in all specimens. For reasons mentioned above the greatest diameter is considered to be the most accurate reflection of fibre thickness. The least diameter is influenced too much by deviations from the more commonly occurring round, oval or elliptical outlines, e.g. fabiform and papillo-convex shapes. However, the remarkable situation is found that both impala male and female fibres have higher mean diameter values than the kudu male and female, the low values for the impala fawn being responsible for the lower group values. From Tables 1 (*a*) and 5 (*a*) it is clear that a highly significant difference ($P = 0{\cdot}01$) exists among the four species as far as mean whole fibre and mean greatest diameters of fibres from all sites are concerned except those from the brisket (difference significant only—$P = 0{\cdot}05$—for the greatest diameters) and those from the throat (difference significant only—$P = 0{\cdot}05$—for the whole fibre diameter). The mean least diameters of the four species [Table 3 (*a*)] differ in highly significant degree only for fibres from the mane, tail, shoulder and throat regions, to a significant level as far as fibres from the thigh are concerned, whilst no significant differences were found for those from the neck, back, belly, legs and brisket. This is due to the peculiar shape of the impala and blue wildebeest fibres.

For determining interspecific differences between kudu, impala, blue wildebeest and grey duiker regardless of age and sex, the mean greatest fibre diameters and mean whole fibre diameters appear to be almost equally reliable, the fibres from the more ventral body surfaces (i.e. throat, brisket and belly) generally being the least reliable indicators, followed by those from the neck, shouider and tail. The most reliable indicators on this basis would be measurements obtained from the legs, mane and back.

The males as a group have hair with the largest mean values for greatest and least fibre diameters, as well as for whole fibre diameters followed by the females and young in that order. The overall differences between the groups are statistically highly significant [Tables 1 (*b*), 3 (*b*) and 5 (*b*)]. This pattern is to be expected on general biological grounds. Nevertheless, no significant difference is found between female and young in the kudu and between male and female in the other three species. As only one animal of a particular species was examined in each group, the latter finding must be accepted tentatively and with great reservation. Obviously, further work must be done on a larger number of individuals of more accurately determined age groups, to establish this point beyond doubt.

Analysis of mean whole and greatest fibre diameters at the various sites reveals highly significant differences among the three groups (male, female and young) for fibres from the mane, back and neck. Differences between values for the thigh position are highly significant with respect to whole fibre diameter. Significant differences for both these measurements are found at the throat, belly and legs as well as at the shoulder with regard to whole fibre diameter, and at the brisket as regards greatest fibre diameter. At the tail no significant differences are found. In respect of mean least fibre diameter a highly significant difference is only found in the mane and significant differences at the back, neck, shoulder, throat, belly and brisket.

Thus the greatest fibre diameter, generally speaking, would be the most accurate indicator of sex and age differences, and these differences are best reflected in the hairs from mane, back and neck, that is, sites which are most conspicuous under natural conditions, whereas the tail is the greatest differential tag in this respect.

In assessing the importance of any one of the above three measurements in species identification, where sex and age are unknown, it would seem best to select those sites whose values are *least* influenced by age and sex differences, yet show highly significant differences among species. In this respect, guided by measurements only, the tail region would appear to be the best site, followed by greatest diameters from the shoulder region. On the other hand, the tail usually has the least typical fibres as far as shape is concerned, whereas the least significant interspecific difference is still comparatively high in the shoulder fibres (*vide supra*).

With regard to all three measurements presently under consideration (mean greatest, least and whole fibre diameters), highly significant differences exist among fibres from the various sites on the kudu and blue wildebeest and no significant difference among those on the impala and grey duiker. The highly significant differences for the mean least fibre diameters obtained in the case of the impala is due to the fact that this measurement is influenced to a great extent by the remarkable ridge (visible as a papilla in cross-sections). Thus, in general, it may be concluded that of the four species, the impala and grey duiker have the more homogeneous coats in respect of fibre diameters, whilse that of the kudu and blue wildebeest is decidedly heterogeneous.

There is no rigid pattern of distribution of fibre thickness (whether measured as whole fibre diameter or greatest or least fibre diameter) over the body common to all four species. Attempts at arranging the various sites in order of fibre thickness reveal major discrepancies between the values for mean greatest and least diameters in the case of the blue wildebeest and impala. This is only to be expected on account of the peculiar shape of the hairs of these species in cross-section, namely fabiform and papillo-convex respectively. Difficult to explain is the breakdown of the hitherto observed close parallelism between greatest fibre diameters and whole fibre diameters. No more can be concluded than from subjective impressions, namely, that the thickest hairs are situated at the throat and mane, and in the case of the blue wildebeest in the tail region. Nevertheless it is remarkable that all fibre thickness measurements at the shoulder region of all four species occupy approximately a similar position in the general range, preceded by the somewhat variable position of the thigh hairs.

Sex differences in the regional distribution of fibre thickness, taking all four species together, are relatively small. The female pattern does not deviate much from the male pattern, except for the predominant coarseness of the mane in the male.

This is only to be expected from what one generally observes in nature. A more critical analysis of pattern of fibre thickness distribution in descending order of magnitude within each species remarkably enough reveals greater discrepancies between the two sexes than when the values for the four species are considered together. There is thus an overall tendency for the two sexes to follow the same pattern, but this is less apparent within each species. This result may be due merely to the small number of individuals examined.

There is little parallelism between the young of each species and the adults in the regional distribution according to fibre thickness. It could be concluded that growth rates as expressed by thickness of fibre are not uniform over the various parts of the body, but once again the small number of individuals—or, conversely, the fact that measurements were not taken consecutively in terms of age from the same individual—makes it impossible to be certain on this point.

The significant differences of medullary measurements among sites and among groups generally are correlated with differences found in respect of fibre diameters. The diagnostic significance of medullary diameters is not very high. In any case morphological variations are distinct and readily observable.

It does not necessarily follow that because statistically significant differences are found among means of the species under study, individual measurements of fibres do not overlap. When a limited number of readings are available, statistical analysis would prove impractical except for cases where the variation between the largest and smallest values of one species is higher—or lower for that matter—than that of the other species under comparison. The mean values of the blue wildebeest calf, for instance, of both greatest fibre diameter and whole fibre diameter are higher than the mean values of male, female and young of the other three species. On statistical grounds it seems possible to separate blue wildebeest fibres from that of the other species. A few readings on a hair sample, e.g. from the brisket region of the male, will indicate that these hairs are definitely not derived from the grey duiker, and probably not from impala and kudu.

Using measurements only it would be impossible to differentiate between kudu and impala. The adult kudu, impala and grey duiker of both sexes are also not distinguishable on readings of greatest fibre diameter or whole fibre diameters. The largest mean site value of the greatest fibre diameter of the grey duiker male—the brisket—and that of the female—the neck—overlaps many mean site values of both kudu and impala. The most reliable indicator of sex and age differences would be the greatest fibre diameter which represents the true maximum width of the fibre. Should it be impracticable to obtain this measurement, the whole fibre diameter would be the next reliable reading to be taken. The least fibre diameter and all medulla diameters are less reliable indicators due to the variations and irregularities in fibre and medulla outlines. Normally the diameter of the fibre in a whole mount or in its cross-section as observed through the microscope is just as effective an indicator of size as any of the actual measurements.

Analysis of the three indices, namely fibre index (Table 7) fibre/medulla greatest diameter index (Table 8) and fibre/medulla least diameter index (Table 9) reveals that no significant differences exist for the kudu among the individuals as well as among the various sites, i.e. shape of fibre and the relation of medullary to cortical diameters are relatively constant. In the impala significant differences are found among the individuals as well as among sites in respect of fibre index and highly significant values in respect of fibre/medullary least diameter index; the fibre/medullary greatest

diameter index varies significantly from site to site but not from individual to individual. In the blue wildebeest highly significant differences exist among the sites in the case of all three indices but the individuals differ in a highly significant fashion only in respect of the fibre index; there is a significant difference in respect of the fibre/medullary greatest diameter index and an insignificant difference with regard to the fibre/medullary least diameter index. As in the kudu, no significant differences are found among the three indices calculated for the various sites on the grey duiker. Thus on one and the same individual fibre shape and medullary/cortical relationships are constant. Among the different individuals, however, the fibre index varies significantly, the fibre/medulla least diameter index highly so, but there is no significant variation in respect of fibre/medulla greatest diameter index. The whole mount fibre/medulla index closely resembles that of the fibre/medulla least diameter index, the only difference being a significant value instead of a highly significant one in the case of the grey duiker for the group values.

Where the basic outline of fibre and medulla tends to be regular, the various indices serve as a numerical indicator of the pattern of the fibre as seen in cross-section. Statistical analysis of these index values then serves as an indicator of the homogeneity or otherwise of fibre conformation within the species and on one and the same individual of that species. Visual inspection of the various indices obtained for the kudu and grey duiker, both of which have elliptical or oval fibres seen in cross section, indicates that whatever difference there is would probably not have any statistical significance. It is quite conceivable that certain species differ sufficiently in this respect, but in practice the indices are tedious to compute and the information they serve to impart may be gained with greater ease and rapidity by mere observation. Whenever the fibre outline deviates from the general circular, oval or elliptical shape it becomes increasingly difficult to establish standard measuring points. Moreover, any structural feature (such as the ridge in the case of the impala fibre and the groove in the case of the blue wildebeest fibre) produces such deviations from the above general pattern that the whole index system breaks down. Small differences in size of such structural features produce profound effects on any calculated index and statistical analysis of such indices produces such variable results that no simple generalizations are possible, despite the fact that the basic outline is easily recognisable as typical for the species.

In the final analysis it is apparent that no single factor—except the fibre outline of the impala—can be used as a final identification of any fibre. A combination of as many factors as possible must be considered for every identification of hairs. It can be stated, almost without contradiction, that the cross-sections of fibres yield more information on fibre structure and characteristics than imprints and whole mounts. In this type of preparation it can be seen that the papillo-convex and related shapes of the impala is unique. The fabiform shape of the blue wildebeest fibres, although not typical for the species, is less common than the elliptical and oval shapes of kudu and grey duiker.

Pigment distribution, concentration and type are major diagnostic features. The ectally concentrated pigment of the impala fibre differentiates it from the bilateral concentration of the blue wildebeest and the peripheral and intermedial concentration of kudu and grey duiker fibres. The dominant pigment type in the kudu, blue wildebeest and grey duiker is tyrosine-melanin while in the impala pheomelanin predominates.

The bilaterally crenated medulla of the fabiform fibre of the blue wildebeest differs from the long flat elliptical medulla of the impala and the oval and elliptical medulla shapes of kudu and grey duiker. Striations on the cortico-medullary border are only found in kudu and impala fibres. The fibrous and granular medullary structure of impala and blue wildebeest fibres differs from the cellular and granular structure of those of the kudu and grey duiker. In impala and blue wildebeest fibres the medulla is eccentrically placed while in those of the kudu and grey duiker it is centrally situated.

Cuticular imprints and whole mounts have lesser diagnostic features than cross-sections. Scale patterns in the imprints show minor differences among the four species. Distribution of the patterns, however, are more characteristic. In the kudu and grey duiker the base tends to have an irregular mosaic pattern, alternating with an irregular wave pattern towards the tip. In the impala an irregular mosaic pattern is mostly found on the ectal and ental sides of the fibre with an irregular wave pattern occurring on the ridge while in the blue wildebeest an irregular wave pattern is found ectally and entally on the fibre with an irregular mosaic pattern in the groove.

In whole mounts slight differences in the scale profiles are noted amoung the four species. Dispersal of pigment follows an identical pattern in these species but a variation in colour is noticeable. Blue wildebeest fibres are generally darker in colour than those from the other three species; the grey duiker fibres again show more colour variation along their length.

When measurements are made it is found that the greatest fibre diameter is constantly higher than whole fibre diameter. The greatest fibre diameter is also considered to be the most accurate reflection of fibre thickness: the least fibre diameter is influenced too much by any deviation from the more common fibre shapes.

For determining interspecific differences, regardless of age and sex, the mean greatest fibre diameter and mean whole fibre diameter appear to be equally reliable. Fibres from the ventral aspect of the body (throat, brisket and belly) are usually found to be the least reliable indicators, while the most reliable indicators were obtained from legs, mane and back.

The males as a group have hair with the largest mean values for greatest and least fibre diameters as well as whole fibre diameter, followed by females and young respectively. Mean whole and greatest fibre diameters reveal highly significant differences among males, females and young for fibres from mane, back and neck.

Thus the greatest fibre diameter could generally be considered as the most accurate indicator of sex and age differences. Guided by measurements only the sites, whose values are influenced the least by sex and age differences yet show highly significant differences among species, appear to be the tail area followed by the shoulder region. The tail, however, has the least typical fibres where outline is concerned; the shoulder seems to be the region where the importance of the three cross-sectional measurements can be assessed best. No rigid pattern of distribution of fibre thickness could be observed from the three measurements under consideration. Nevertheless it is noteworthy that all fibre thickness measurements at the shoulder site occupy similar positions in the general range.

Sex differences in regional distribution of fibre thickness, considering all four species together, are relatively small. In this respect, however, there is little parallelism between the young and adults of each species.

Although a general correlation exists between significant differences of medullary and fibre measurements in respect of the various sites and among individuals, the diagnostic significance of medullary diameters is not high.

Individual measurements of fibres may overlap, although means may differ significantly. In certain cases, making use of measurements alone, it would, e.g. be possible to differentiate between fibres of the blue wildebeest and grey duiker. This would not be possible between kudu and impala. With the blue wildebeest on one hand and kudu and impala on the other hand a certain number of individual measurements are going to overlap, thus making a diagnosis on fibre measurement alone impossible. The same situation will be encountered when kudu and impala measurements are compared to those of the grey duiker.

The value of the various indices as numerical indicators of fibre shape is reduced by any deviation of fibre outline from the more common oval or elliptical shapes.

VI.—Summary and Conclusions

1. A brief review of the present knowledge of hair and its structure is given.

2. Classification schemes for the various fibre and medulla outlines as seen in cross-sections, pigment characteristics and medullary structure have been drawn up. Existing classifications of fibre and medullary structure as seen in whole mounts have been extended.

3. The hairs from kudu, impala, blue wildebeest and grey duiker are all described separately within the framework of these classifications.

4. Macroscopically, colour differences between fibres of the four species have been observed. Fibres from the grey duiker have a yellow band near the tip in most cases, differentiating them from those of the kudu, impala and blue wildebeest. Yet macroscopic determination of colour of a single fibre is highly unreliable.

5. The different types of fibres usually described do not occur in these species. Only body hairs and ornamental hairs can be distinguished, with certainty.

6. There are differences in scale pattern between the kudu and grey duiker: the base tends to have an irregular mosaic pattern alternating with an irregular wave pattern towards the tip. In the impala an irregular mosaic pattern is mostly found on the ectal and ental sides of the fibre with an irregular wave pattern occurring on the ridge, while in the blue wildebeest an irregular wave pattern is found ectally and entally on the fibre with an irregular mosaic pattern in the groove. The cuticle as seen in cross-section has no particular diagnostic value. In whole mounts its appearance is of some use.

7. On the shape of its fibre outline (papillo-convex) alone the impala can be identified. The blue wildebeest fibre is totally different in outline (fabiform) from those of the kudu, impala and grey duiker. A great similarity in fibre contour, elliptical and oval, is found between the kudu and grey duiker.

8. No conspicuous differences in fibre outline have been found between male and female. The young animals differ from the adults in this respect.

9. Differences in distribution and characteristics of the pigment are evident among the four species. Differentiation in dispersal of the pigment is found between base and shaft, and shaft and tip in whole mounts. Usually the base is of a lighter colour, the shaft darker in colour and the tip the darkest region of all. No noticeable differences in pigmentation occur between the two sexes. Fibres at the same sites in the young animal usually are not so intensely pigmented. Medullary pigment is generally similar to that of the cortex in the same fibre but only less in amount.

10. Medullary outlines of body hairs in the kudu and grey duiker follow a similar pattern to that of the fibre outline, although the shape is sometimes more irregular. In the impala and blue wildebeest the medullary outline usually differs from fibre outline.

11. In body hairs, medullary diameter parallels fibre diameter. The thicker the fibre the more irregular does the medullary outline become. Ornamental hairs have a relatively smaller medulla, or it may be entirely absent (frequently the case in the blue wildebeest). When a medulla is found in ornamental hairs, its outline does not conform to the fibre outline.

12. Striations on the medullary-cortical border are present in the kudu and impala only.

13. Fibre tips in whole mounts are flagelliform in the kudu and grey duiker. The blue wildebeest and impala body hairs have acicular tips while their ornamental hairs have flagelliform apices.

14. In all species the extreme apical region is usually of a lighter colour than the rest of the tip. Only the grey duiker has a yellowish band below the tip.

15. Shapes of base and root have no particular dianostic value, due to the lack of interspecific variation in these regions.

16. Statistical analysis of the measurements of the greatest and least fibre and medullary diameters as well as whole fibre and medullary diameters reveals that:

(*a*) The greatest fibre diameter is constantly higher than whole fibre diameter.

(*b*) The greatest fibre diameter is considered to be the most accurate reflection of fibre thickness: the least fibre diameter is influenced too much by deviation from the more common fibre shapes (oval and elliptical).

(*c*) For determining interspecific differences regardless of age and sex, the mean greatest fibre diameter and the mean whole fibre diameter appear to be equally reliable.

(*d*) The males of the group have hair with the largest mean values for greatest and least fibre diameters as well as whole fibre diameter following by females and young in that order.

(*e*) The shoulder appears to be the best region for assessing the importance of the three fibre diameter measurements where sex and age are unknown: highly significant differences are shown between species.

(*f*) Sex differences in regional distribution of fibre thickness taking all four species together are relatively small. The female pattern does not deviate much from the male pattern but there is little parallelism in this respect between the young of each species and the adults.

(*g*) The diagnostic value of medullary diameters is not high although a general correlation exists between significant differences of fibre and medullary measurements.

17. The value of the indices (fibre, fibre/medulla-, greatest, least and whole diameter) as numerical indicators of shape is limited by any deviation of fibre outline from the more common round, oval or elliptical shapes. In practice these indices are arduous to compile and unreliable in application.

18. Generally speaking it is impossible to identify a fibre on a single factor either morphologically or statistically (with the impala as an exception). For a conclusive identification of any fibre all relevant factors must be considered together. On this basis it is possible to distinguish between fibres from kudu, impala, blue wildebeest and grey duiker with certainty.

VII.—Acknowledgements

Grateful acknowledgement is made to Professor H. P. A. de Boom for suggesting the subject and for his invaluable aid in preparing the manuscript: to the Chief, Veterinary Research Institute for permission to carry out these investigations and to my promotor Professor F. C. Eloff, head of the Zoology Department, University of Pretoria for his interest and helpful suggestions.

In addition my thanks are due to Mr. J. S. du Plessis, without whose aid the statistical analysis would not have been possible, to Mr. D. J. Coetzer for some of the illustrations, Messrs. M. J. van Wyk and G. Swartz for their technical assistance and Mr. A. M. du Bruyn and his able staff of the Photographic Department of Onderstepoort for the excellent photographs produced.

I am also indebted to the Department of Nature Conservation of the Transvaal Province and the many private persons for donating the hides and skins used in this study: and last but not least my sincere appreciation goes to my wife without whose aid and unflagging interest this study could not have been completed.

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APPENDIX

TABLE 1 (*a*).—*Diameters of Fibres at Base Level as Measured in Cross-sections*

Means, levels of significance and l.s.d. for sex and age groups among four species. Comparison of Greatest Fibre Diameters (in microns)

Sites	Male	Female	Young	Significance	l.s.d. (5%)	Kudu	Impala	Blue Wildebeest	Grey Duiker	Significance	l.s.d. (5%)
Mane	172·2	118·3	107·0	**	14·6	135·8	114·6	180·5	†	**	14·6
Back	122·5	118·4	80·9	**	21·3	104·3	94·5	155·7	74·5	**	24·7
Tail	136·6	129·5	110·6	—		123·4	80·0	210·4	88·3	**	34·2
Neck	165·1	134·1	81·6	**	38·1	124·3	111·2	189·2	82·9	**	44·1
Shoulder	112·3	111·4	74·9	—		89·9	89·1	156·9	62·1	**	39·8
Thigh	129·2	122·6	82·7	**	24·8	120·8	94·3	160·2	70·8	**	28·7
Throat	179·0	138·3	99·2	*	50·1	143·4	129·9	202·6	79·4	**	57·9
Belly	131·2	132·3	73·9	*	41·1	82·2	127·9	175·1	64·5	**	47·6
Legs	118·9	104·6	88·0	*	21·0	98·2	95·6	138·1	83·5	**	24·3
Brisket	153·5	126·4	80·6	*	56·9	80·5	126·1	181·8	92·1	*	65·9

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 1 (*b*).—*Diameters of Fibres at Base Level as Measured in Cross-sections*

Means, levels of significance and l.s.d. for sex and age groups within four species. Comparison of Greatest Fibre Diameters (in microns)

Sites/Species	Kudu	Impala	Blue Wildebeest	Grey Duiker
Mane	135·8	114·6	180·5	†
Back	104·3	94·5	155·7	74·5
Tail	123·4	80·0	210·4	88·3
Neck	124·3	111·2	189·2	82·9
Shoulder	89·9	89·1	156·9	62·1
Thigh	120·8	94·3	160·2	70·8
Throat	143·4	129·9	202·6	79·4
Belly	82·2	127·9	175·1	64·5
Legs	98·2	95·6	138·1	83·5
Brisket	80·5	126·1	181·8	92·1
Significance	**	—	**	—
l.s.d. (5 per cent)	29·2		26·6	
Male	133·3	134·1	202·1	90·5
Female	105·8	124·1	188·5	82·5
Young	91·8	60·8	134·6	59·8
Significance	**	**	**	**
l.s.d. (5 per cent)	18·5	17·7	16·8	14·6

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 2 (*a*).—*Diameters of Medullae at Base Level as Measured in Cross-sections*

Means, levels of significance and l.s.d. for sex and age groups among four species. Comparison of Greatest Medulla Diameters (in microns)

Sites	Male	Female	Young	Significance	l.s.d. (5)%	Kudu	Impala	Blue Wildebeest	Grey Duier	Significance	l.s.d. (5%)
Mane	58·7	59·9	48·8	**	31·0	82·0	76·8	8·6	†	*	31·0
Back	76·4	77·2	48·7	*	19·7	72·8	66·0	77·9	52·9	—	
Tail	58·7	58·9	57·9	—		107·8	49·5	24·4	52·3	**	21·1
Neck	98·8	83·7	47·9	*	29·6	81·9	73·1	99·6	52·7	—	
Shoulder	68·9	73·6	43·1	—		62·1	67·5	78·2	39·7	—	
Thigh	84·3	82·2	50·2	*	20·3	86·8	72·5	78·2	51·4	*	23·5
Throat	69·1	76·5	34·8	—		62·1	96·9	28·3	53·1	—	
Belly	82·1	92·8	43·8	*	38·6	49·8	106·2	90·9	44·6	*	44·7
Legs	69·8	65·1	51·8	—		69·2	74·7	55·0	50·1	—	
Brisket	96·8	82·5	46·6	—		49·8	98·4	88·5	64·4	—	

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 2 (*b*).—*Diameters of Fibres at Base Level as Measured in Cross-sections*

Means, levels of significance and l.s.d. for sex and age groups within four species Comparison of Greatest Medulla Diameters (in microns)

Sites/Species	Kudu	Impala	Blue Wildebeest	Grey Duiker
Mane	82·0	76·8	8·6	†
Back	72·8	66·0	77·9	52·9
Tail	107·8	49·5	24·4	52·3
Neck	81·9	73·1	99·6	52·7
Shoulder	62·1	67·5	78·2	39·7
Thigh	86·8	72·5	78·2	51·4
Throat	62·1	96·9	28·3	53·1
Belly	49·8	106·2	90·9	44·6
Legs	69·2	74·7	55·0	50·1
Brisket	49·2	98·4	88·5	64·4
Significance	**	—	**	—
l.s.d. (5 per cent)	16·2	—	29·6	—
Male	78·3	94·7	70·7	63·9
Female	76·4	95·7	77·2	50·7
Young	62·6	44·0	42·8	39·2
Significance	**	**	**	*
l.s.d. (5 per cent)	10·2	18·4	18·7	18·1

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 3 (*a*).—*Diameters of Fibres at Base Level as Measured in Cross-sections*

Means, levels of significance and l.s.d. for sex and age groups among four species. Comparison of Least Fibre Diameters (in microns)

Sites	Male	Female	Young	Significance	l.s.d. (5%)	Kudu	Impala	Blue Wildebeest	Grey Duiker	Significance	l.s.d. (5%)
Mane	140·8	124·2	87·5	**	19·6	119·2	76·5	157·5	†	**	19·6
Back	72·6	67·5	49·9	*	16·9	73·0	65·1	63·8	51·4	—	
Tail	117·5	107·2	94·1	—		107·8	64·8	185·4	67·1	**	28·3
Neck	97·3	90·4	50·1	*	37·2	86·8	55·8	91·2	64·5	—	
Shoulder	62·9	63·1	47·6	*	9·6	66·5	52·5	70·6	41·8	**	11·1
Thigh	71·2	65·8	51·2	—		81·1	56·1	70·6	43·0	*	30·4
Throat	131·1	96·4	86·5	*	35·7	114·5	75·3	174·0	54·8	**	41·3
Belly	68·7	65·3	39·9	*	18·4	66·4	61·0	56·0	48·5	—	
Legs	66·7	53·1	55·3	—		64·5	50·6	61·8	56·5	—	
Brisket	86·1	67·4	49·9	*	22·5	60·9	69·8	79·4	61·2	—	

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 3 (*b*).—*Diameters of Fibres at Base Level as Measured in Cross-sections*

Means, levels of significance and l.s.d. for sex and age groups within four species. Comparison of Least Fibre Diameters (in microns)

Sites/Species	Kudu	Impala	Blue Wildebeest	Grey Duiker
Mane	119·2	76·5	157·5	†
Back	73·0	65·1	63·8	51·4
Tail	107·8	64·8	185·4	67·1
Neck	86·8	55·8	91·2	64·5
Shoulder	66·5	52·5	70·6	41·8
Thigh	81·1	56·1	70·6	43·0
Throat	114·5	75·3	174·0	54·8
Belly	66·4	61·0	56·0	48·5
Legs	64·5	50·6	61·8	56·5
Brisket	60·9	69·8	79·4	61·2
Significance	**	**	**	—
l.s.d. (5 per cent)	25·7	12·7	25·7	
Male	103·6	79·3	110·6	64·7
Female	76·0	72·0	104·4	61·4
Young	72·6	42·4	88·0	36·8
Significance	**	**	*	**
l.s.d. (5 per cent)	16·3	8·0	16·3	9·1

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 4 (*a*).—*Diameters of Medullae at Base Level as Measured in Cross-sections*

Means, levels of significance and l.s.d. for sex and age groups among four species. Comparison of Least Medulla Diameters (in microns)

Sites	Male	Female	Young	Significance	l.s.d. (5%)	Kudu	Impala	Blue Wildebeest	Grey Duiker	Significance	l.s.d. (5%)
Mane	30·1	35·4	29·5	—		66·9	22·8	5·3	†	**	18·9
Back	38·2	33·8	27·9	—		44·3	26·9	31·2	30·8	—	
Tail	40·7	30·9	34·0	*	7·7	56·9	34·4	16·5	33·0	**	8·9
Neck	40·0	46·9	23·3	—		44·3	19·8	46·4	36·4	—	
Shoulder	34·5	32·9	25·8	—		40·3	22·5	35·4	25·9	**	7·6
Thigh	36·5	32·6	29·0	—		48·3	25·0	35·1	22·4	—	
Throat	27·8	32·0	24·1	—		44·0	20·4	16·7	30·6	—	
Belly	32·8	31·8	20·8	—		35·9	22·3	24·8	30·8	—	
Legs	25·1	23·8	28·4	—		36·1	19·7	22·8	24·3	—	
Brisket	37·7	31·2	27·1	—		32·2	22·2	38·4	35·2	—	

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 4 (*b*).—*Diameters of Medullae at Base Level as Measured in Cross-sections*

Means, levels of significance and l.s.d. for sex and age groups within four species. Comparison of Least Medulla Diameters (in microns)

Sites/Species	Kudu	Impala	Blue Wildebeest	Grey Duiker
Mane	66·9	22·8	5·3	†
Back	44·3	26·9	31·2	30·8
Tail	56·9	34·4	16·5	33·0
Neck	44·3	19·8	46·4	36·4
Shoulder	40·3	22·5	35·4	25·9
Thigh	48·3	25·0	35·1	22·4
Throat	44·0	20·4	16·7	30·6
Belly	35·9	22·3	24·8	30·8
Legs	36·1	19·7	22·8	24·3
Brisket	32·2	22·2	38·4	35·2
Significance	**	**	**	—
l.s.d. (5 per cent)	13·4	5·3	12·8	—
Male	50·8	23·2	24·7	39·6
Female	44·1	25·9	30·4	31·7
Young	40·5	22·1	26·7	18·5
Significance	—	—	—	**
l.s.d. (5 per cent)	—	—	—	7·8

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 5 (*a*).—*Diameters of Fibres at Base Level as Measured in Whole Mounts*

Means, levels of significance and l.s.d. for sex and age groups among four species. Comparison of Whole Fibre Diameters (in microns)

Sites	Male	Female	Young	Significance	l.s.d. (5%)	Kudu	Impala	Blue Wildebeest	Grey Duiker	Significance	l.s.d. (5%)
Mane	153·6	147·5	101·8	**	24·2	121·6	82·7	198·7	†	**	24·2
Back	112·6	104·9	64·9	**	21·6	94·8	64·8	149·8	67·1	**	25·0
Tail	121·2	122·5	99·2	—		117·2	78·2	188·7	73·1	**	43·1
Neck	164·7	122·8	71·9	**	32·0	109·1	108·1	177·4	84·4	**	37·1
Shoulder	101·7	96·3	60·3	*	31·0	77·9	78·9	137·6	49·9	**	35·9
Thigh	113·7	105·4	74·0	*	24·2	93·7	85·9	146·5	64·7	**	28·0
Throat	175·1	132·0	90·1	*	51·1	127·9	119·2	197·5	84·9	*	59·1
Belly	119·0	111·2	64·1	*	39·6	70·4	107·7	164·4	49·8	**	45·8
Legs	94·1	92·7	66·4	*	18·0	85·2	72·9	122·8	56·7	**	20·8
Brisket	130·7	111·7	73·1	—		71·6	104·1	179·8	65·0	**	57·5

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 5 (*b*).—*Diameters of Fibres at Base Level as Measured in Whole Mounts*

Means, levels of significance and l.s.d. for sex and age groups within four species. Comparison of Whole Fibre Diameters (in microns)

Sites/Species	Kudu	Impala	Blue Wildebeest	Grey Duiker
Mane	121·6	82·7	198·7	†
Back	94·8	64·8	149·8	67·1
Tail	117·2	78·2	188·7	73·1
Neck	109·1	108·1	177·4	84·4
Shoulder	77·9	78·9	137·6	49·9
Thigh	93·7	85·9	146·5	64·7
Throat	127·9	119·2	197·5	84·9
Belly	70·4	107·7	164·4	49·8
Legs	85·2	72·9	122·8	56·7
Brisket	71·6	104·1	179·8	63·8
Significance	**	—	**	—
l.s.d. (5 per cent)	28·4		26·0	
Male	117·2	117·5	191·5	80·7
Female	93·8	106·9	180·0	70·3
Young	79·8	46·4	127·2	47·5
Significance	**	**	**	*
l.s.d. (5 per cent)	18·0	18·2	16·4	15·9

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

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TABLE 6 (*a*).—*Diameters of Medullae at Base Level as Measured in Whole Mounts*

Means, levels of significance and l.s.d. for sex and age groups among four species. Comparison of Whole Medulla Diameters (in microns)

Sites	Male	Female	Young	Significance	l.s.d. (5%)	Kudu	Impala	Blue Wildebeest	Grey Duiker	Significance	l.s.d. (5%)
Mane	46·8	49·6	30·3	—		77·4	48·9	0·4	†	**	20·7
Back	69·8	65·6	38·4	**	16·1	69·1	37·8	74·8	49·9	**	18·7
Tail	46·1	39·9	42·6	—		69·2	45·5	10·5	46·3	**	27·2
Neck	107·7	74·3	43·0	**	25·9	72·3	80·8	91·5	55·5	—	
Shoulder	67·4	57·8	36·8	*	21·8	54·6	55·3	68·3	37·9	—	
Thigh	78·8	55·3	46·1	*	22·2	68·8	68·9	77·6	48·3	—	
Throat	62·2	62·7	28·6	—		50·2	95·5	0·8	58·1	—	
Belly	82·6	77·7	38·7	—		43·2	91·8	97·0	33·3	*	45·4
Legs	50·9	63·0	36·5	—		59·0	56·2	52·4	32·9	—	
Brisket	88·2	79·4	43·7	—		46·4	85·1	101·9	48·3	—	

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 6 (*b*).—*Diameters of Medullae at Base Level as Measured in Whole Mounts*

Means, levels of significance and l.s.d. for sex and age groups within four species. Comparison of Whole Medulla Diameters (in microns)

Sites/Species	Kudu	Impala	Blue Wildebeest	Grey Duiker
Mane	77·4	48·9	0·4	†
Back	69·1	37·8	74·8	49·9
Tail	69·2	45·5	10·5	46·3
Neck	72·3	80·8	91·5	55·5
Shoulder	54·6	55·3	68·3	37·9
Thigh	68·8	68·9	77·6	48·3
Throat	50·2	95·5	0·8	58·1
Belly	43·2	91·8	97·0	33·3
Legs	59·0	56·2	52·4	32·9
Brisket	46·4	85·1	101·9	48·3
Significance	—	*	**	—
l.s.d. (5 per cent)	—	29·3	29·8	
Male	64·7	88·3	67·6	60·9
Female	65·1	83·3	64·7	45·6
Young	53·2	30·1	40·3	30·3
Significance	—	18·5	18·8	14·1
l.s.d. (5 per cent)	—	**	**	**

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 7.—*Fibre Index*

Groups	Kudu			Impala			Blue Wildebeest			Grey Duiker		
Sites	Male	Female	Young	Male	Female	Young	Male	Female	Young	Male	Female	Young
Mane....	88	87	88	64	72	63	88	85	88	†	†	†
Back....	68	65	78	73	67	66	37	37	53	76	76	49
Tail.....	85	85	92	87	71	86	86	90	88	86	74	70
Neck....	75	79	51	66	64	77	35	57	56	76	79	79
Shoulder.	73	68	82	50	63	67	43	40	57	70	83	49
Thigh....	74	55	71	53	59	74	35	45	56	65	86	48
Throat....	77	71	93	58	52	74	83	83	93	68	69	70
Belly....	83	73	87	46	43	65	29	36	30	82	77	61
Legs.....	68	51	79	48	60	52	50	31	53	70	48	60
Brisket...	85	79	63	56	47	76	43	36	56	63	74	59
Means...	77·6	71·3	78·4	60·1	59·8	70·0	52·9	54·0	63·0	72·9	71·8	60·6
Groups...		—			*			**			*	
Sites.....		—			*			**			—	

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 8.—*Fibre/Medulla Index* (*Greatest Diameters*)

Groups	Kudu			Impala			Blue Wildebeest			Grey Duiker		
Sites	Male	Female	Young	Male	Female	Young	Male	Female	Young	Male	Female	Young
Mane.....	55	63	64	62	65	79	0	4	14	†	†	†
Back....	70	72	67	60	69	76	52	54	40	77	65	71
Tail.....	64	57	55	55	70	61	11	8	17	56	57	64
Neck....	60	67	75	64	68	45	47	52	46	59	71	55
Shoulder.	68	74	67	66	87	74	49	56	40	71	50	68
Thigh....	88	76	70	77	78	73	48	55	45	77	68	73
Throat...	25	69	54	72	79	70	11	27	3	73	63	61
Belly....	54	71	57	85	84	76	52	60	51	75	64	67
Legs.....	68	77	66	78	77	79	28	50	42	62	73	68
Brisket...	51	66	69	76	83	69	52	50	41	76	63	69
Means...	60·3	60·2	64·4	69·5	76·0	70·2	35·0	41·6	33·9	69·6	63·8	59·6
Groups..		—			—			*			—	
Sites.....		—			*			**			—	

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 9.—*Fibre/Medulla Index* (*Least Diameters*)

Groups	Kudu			Impala			Blue Wildebeest			Grey Duiker		
Sites	Male	Female	Young	Male	Female	Young	Male	Female	Young	Male	Female	Young
Mane....	52	58	60	20	31	46	0	3	9	†	†	†
Back....	61	60	61	32	43	55	47	48	52	72	51	52
Tail.....	59	48	50	54	52	53	8	6	14	53	42	52
Neck....	49	60	56	23	28	46	44	53	55	50	66	47
Shoulder.	59	63	59	38	40	55	53	48	50	63	46	50
Thigh....	60	60	59	32	44	64	48	49	52	67	57	54
Throat...	22	59	49	19	26	46	6	20	2	63	50	51
Belly....	47	64	54	32	35	51	42	42	50	72	59	53
Legs.....	55	55	58	30	42	51	19	47	52	49	38	42
Brisket...	44	59	57	24	30	53	46	48	52	64	51	57
Means...	50·8	58·6	56·3	30·4	37·1	52·0	31·3	36·4	38·8	61·4	51·1	50·9
Groups...		—			**			—			**	
Sites.....		—			**			**			—	

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

TABLE 10.—*Fibre/Medulla Index* (*Whole Mount Measurements*)

Groups	Kudu			Impala			Blue Wildebeest			Grey Duiker		
Sites	Male	Female	Young	Male	Female	Young	Male	Female	Young	Male	Female	Young
Mane....	55	70	68	55	64	50	0	0·2	0·5	†	†	†
Back....	72	77	69	49	65	62	52	50	47	82	69	68
Tail.....	66	51	61	64	55	64	7	0	11	54	64	69
Neck....	62	68	73	79	71	68	53	52	48	75	58	60
Shoulder.	69	74	67	80	83	65	51	51	45	77	63	90
Thigh....	70	77	74	80	86	74	57	54	46	83	70	68
Throat....	14	69	60	80	89	62	0	1	0·3	76	65	52
Belly....	56	71	58	87	81	67	63	57	57	73	61	66
Legs.....	65	76	66	78	81	68	16	58	57	71	61	33
Brisket...	57	67	71	81	86	72	58	61	58	82	72	63
Means...	58·6	70·0	66·7	73·3	76·3	64·2	35·7	38·4	35·4	74·8	64·8	63·2
Groups..		—			**			—			*	
Sites.....		—			**			**			—	

— Not significant.
* Significant at 5 per cent level.
** Highly significant at 1 per cent level.
† Mane absent.

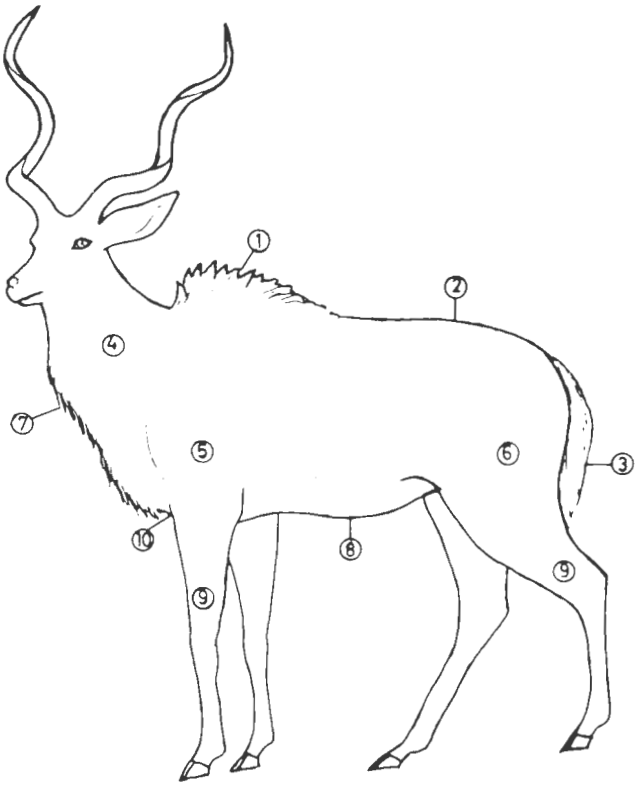

Fig I

Sampling areas.

1	Mane	6	Thigh
2	Back	7	Throat
3	Tail	8	Belly
4	Neck	9	Foreleg & gaskin
5	Shoulder	10	Brisket

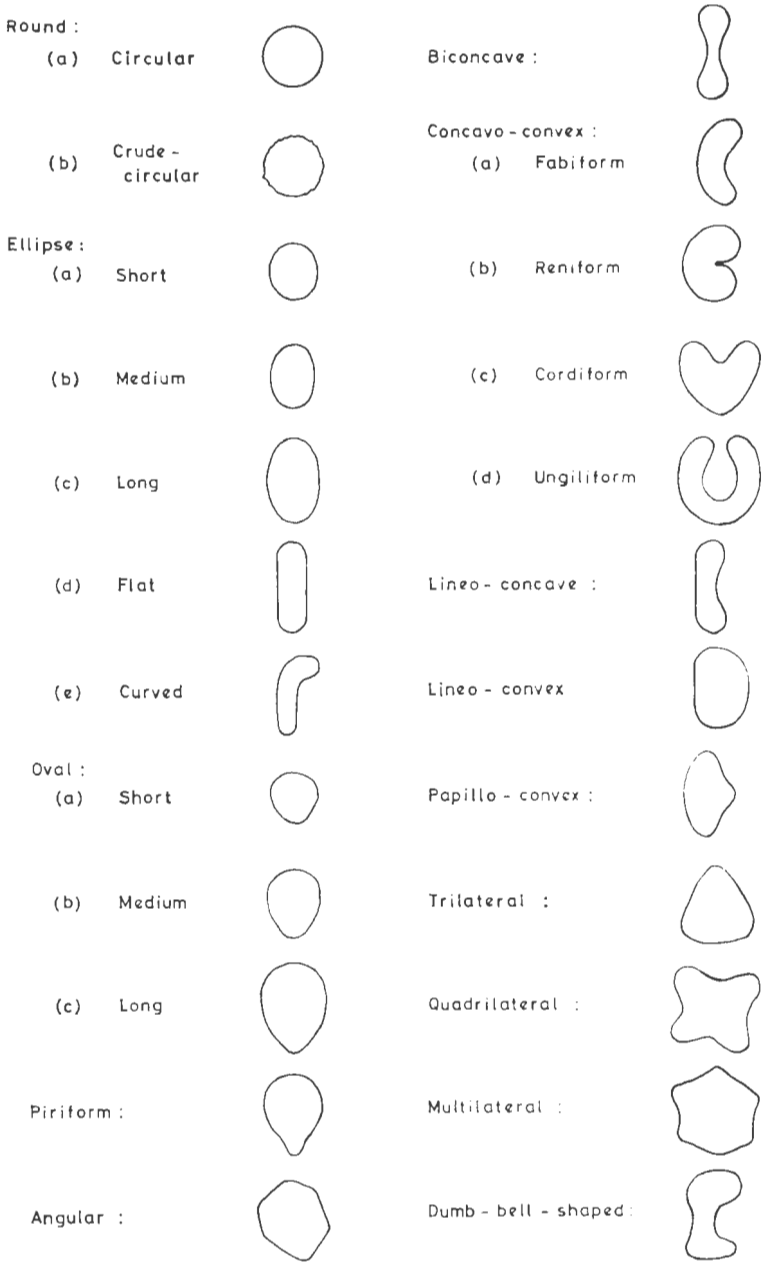

Fig. 2

Classification of terminology and outlines of fibre cross-sections.

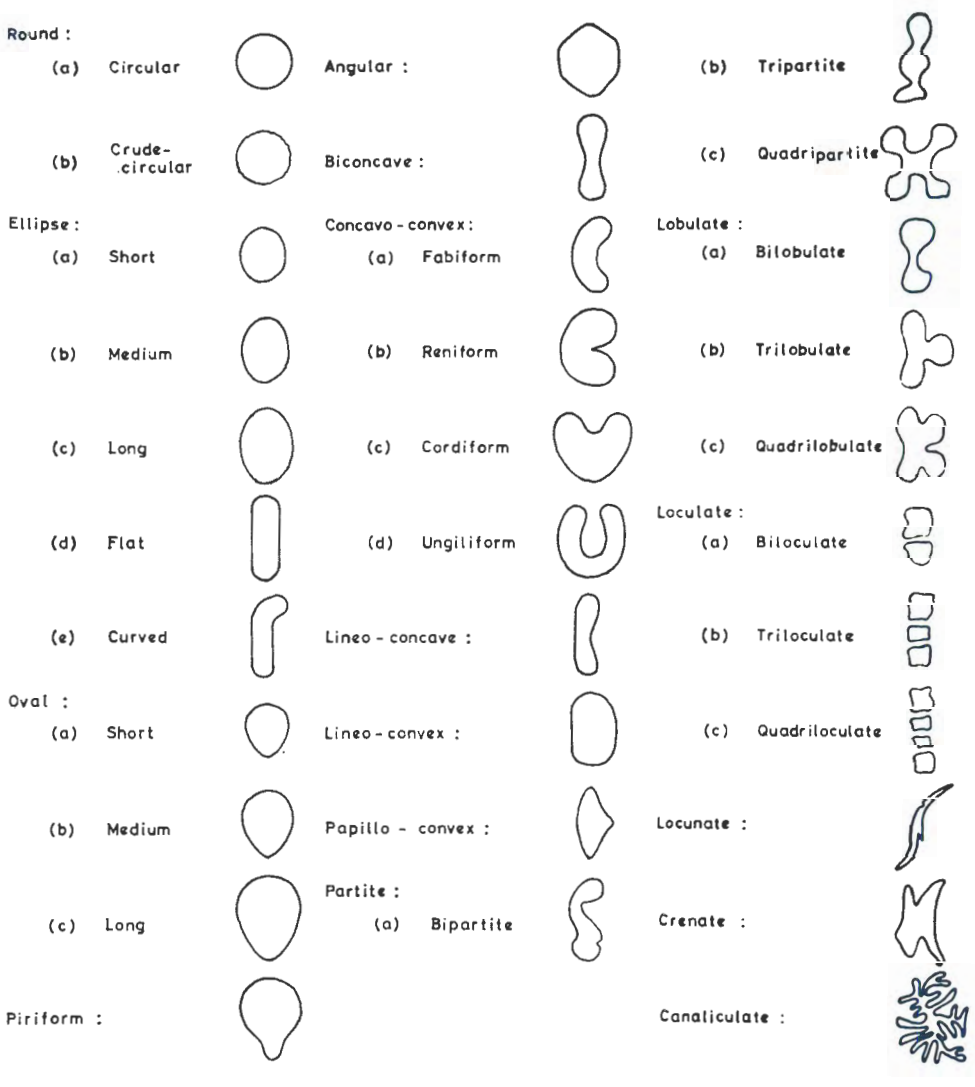

Fig. 3.

Classification of terminology and outlines of medullary cross-sections.

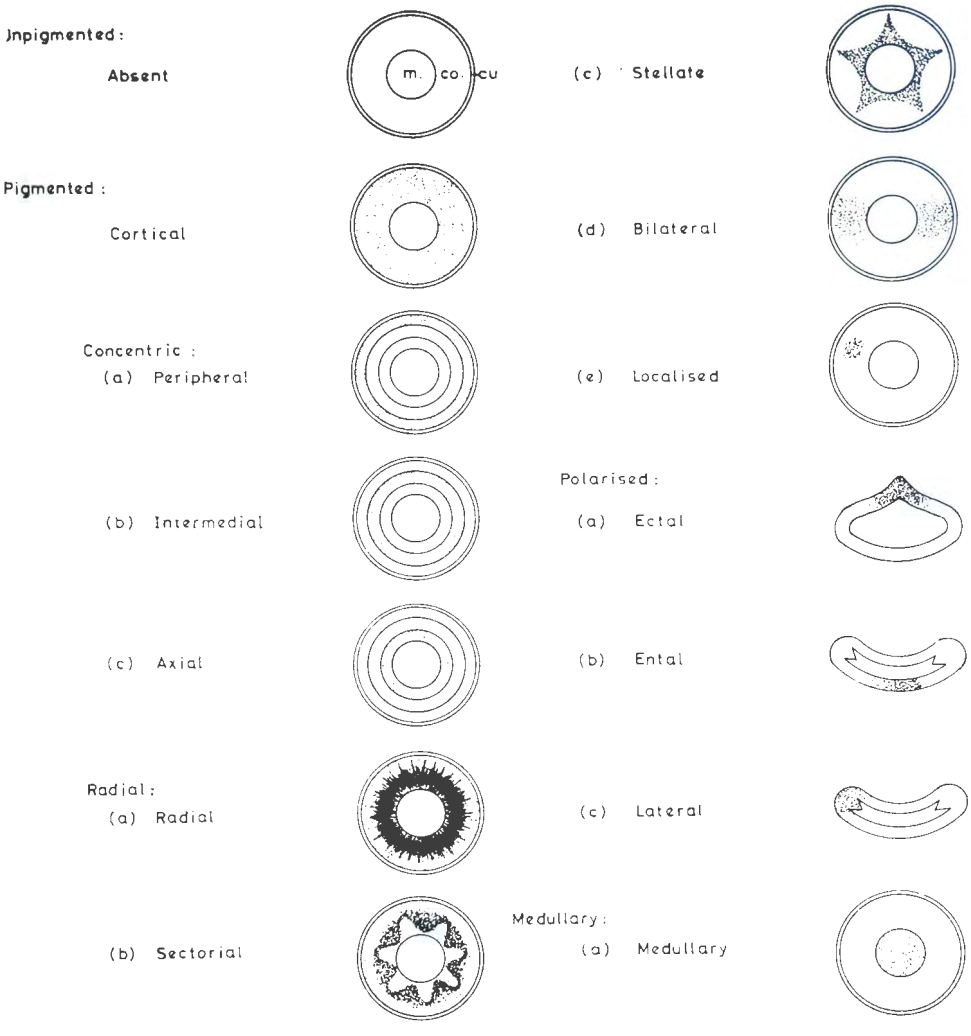

Fig. 4.

Distribution of pigment in cross-sections of hair-fibres
m.= medulla, co = cortex, cu.= cuticle.

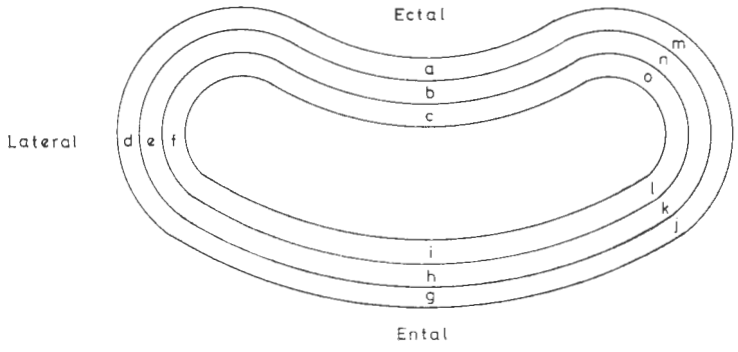

Fig. 5

	(a) peripheral		(d) peripheral		(g) peripheral
Ecto-	(b) intermedial	Latero-	(e) intermedial	Ento-	(h) intermedial
	(c) axial		(f) axial		(i) axial

	(m) peripheral		(j) peripheral
Ectal-latero-	(n) intermedial	Ental-latero-	(k) intermedial
	(o) axial		(l) axial

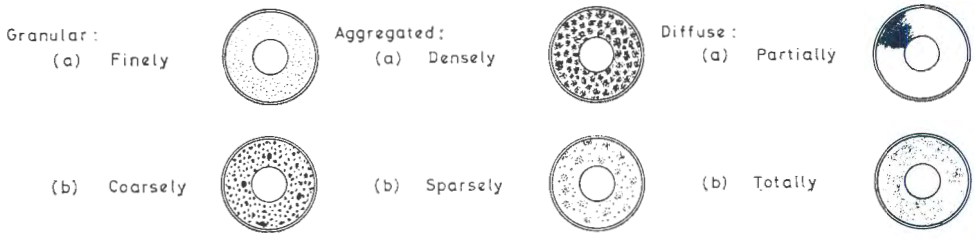

Fig. 6.

Appearance of pigment in cross-sections of hair-fibres.

FIG. 7.—Kudu, male

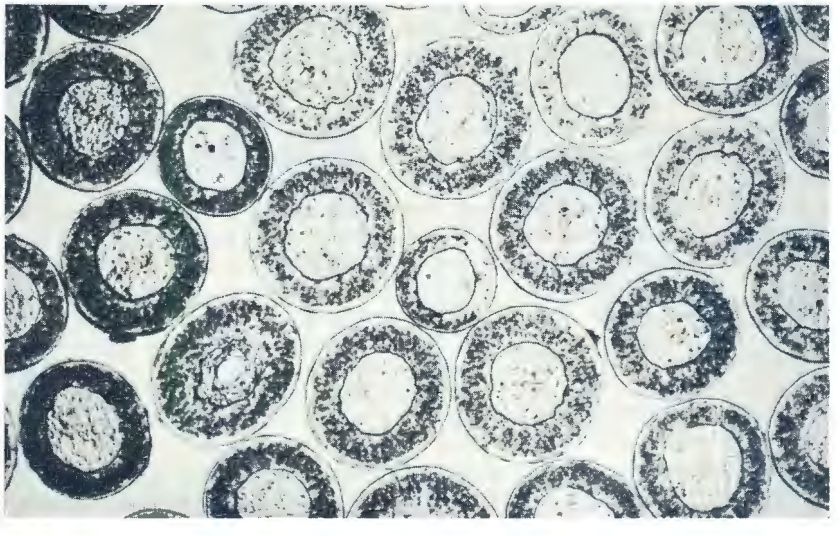

FIG. 8.—Kudu male. Mane hair. Cross-sections. 80×

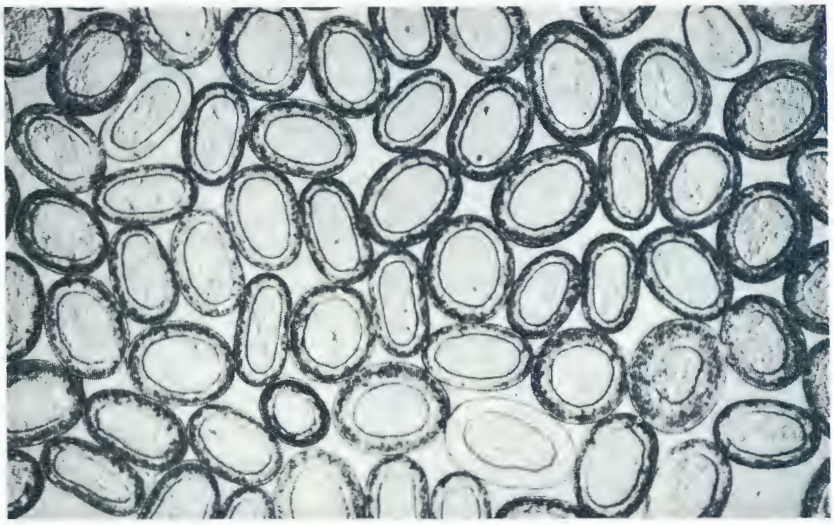

FIG. 9. Kudu male. Black hair (short). Cross-sections. 80×

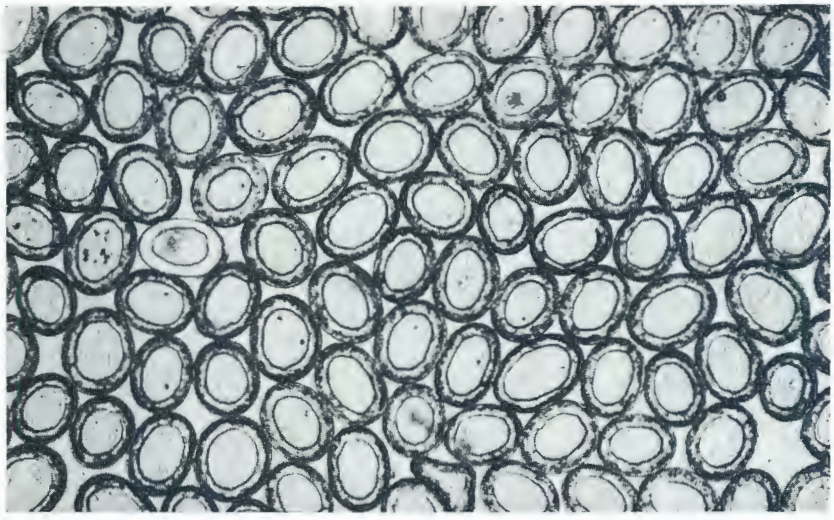

FIG. 10.—Kudu calf. Back hair (short). Cross-sections. 80×

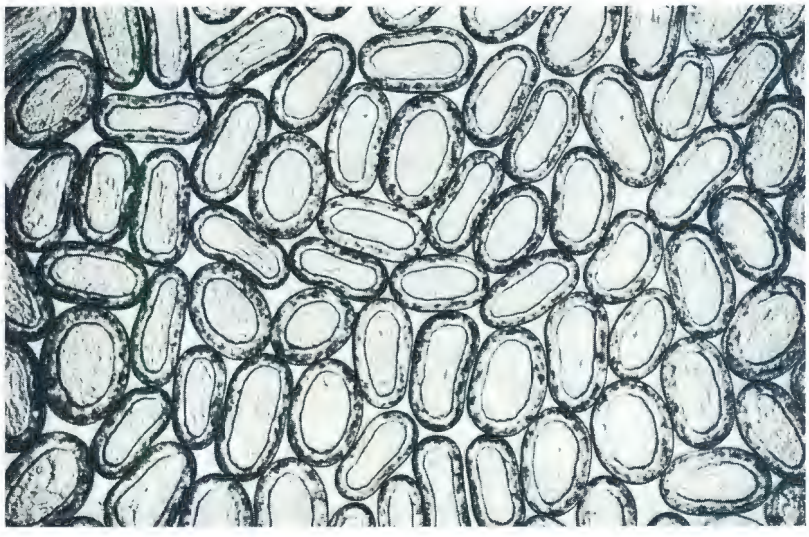

FIG. 11.—Kudu female. Thigh hair. Cross-sections. 80×

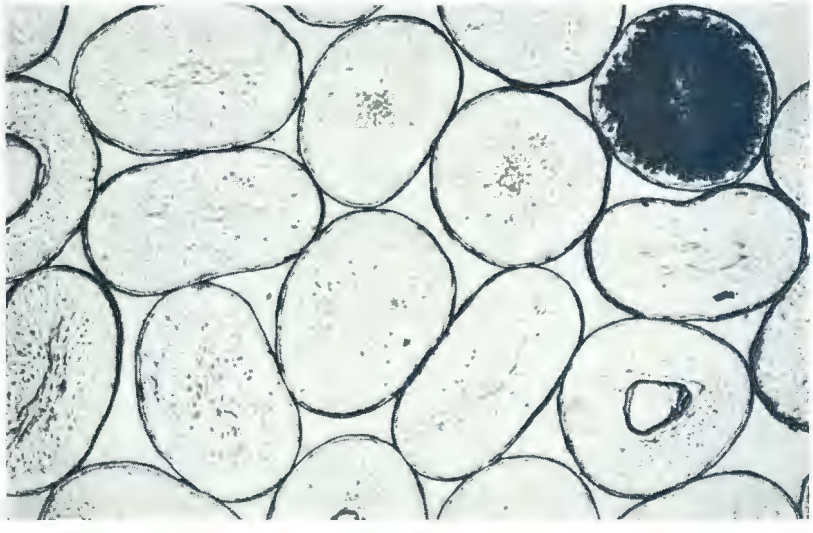

FIG. 12.—Kudu male. Throat hair. Cross-sections. 80×

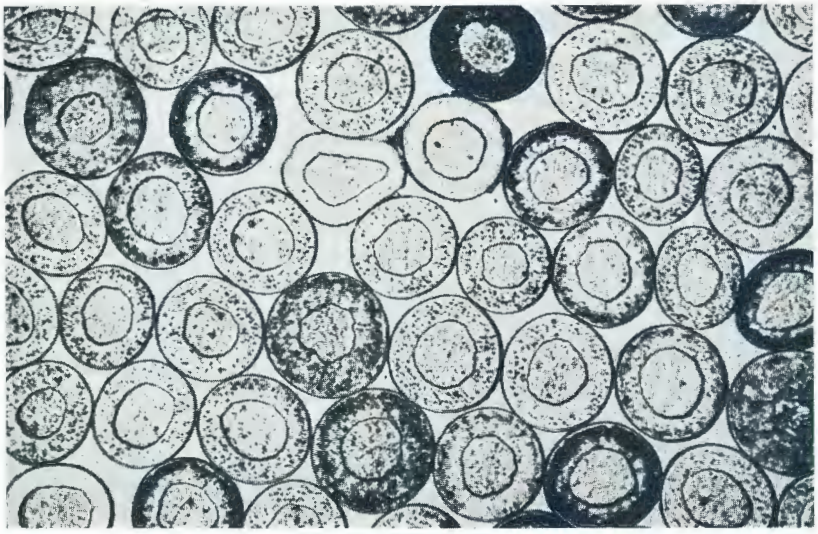

FIG. 13.—Kudu calf. Throat hair. Cross-sections. 80×

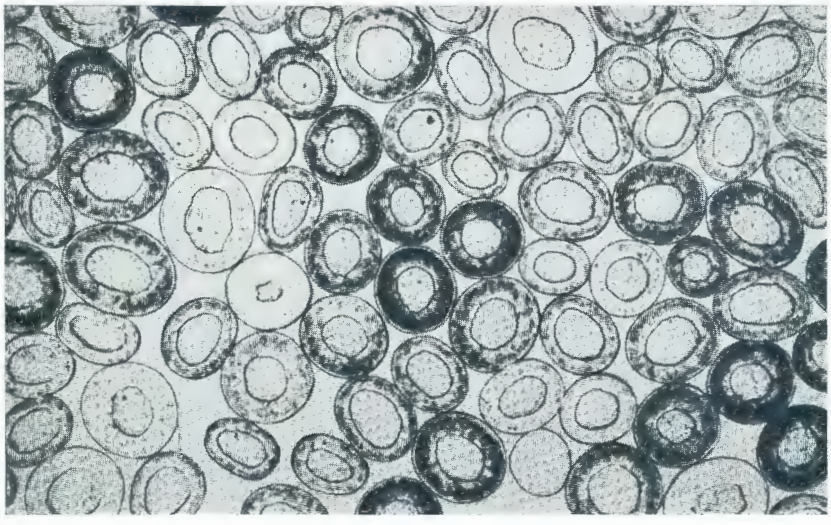

FIG. 14.—Kudu male. Belly hair. Cross-sections. 80×

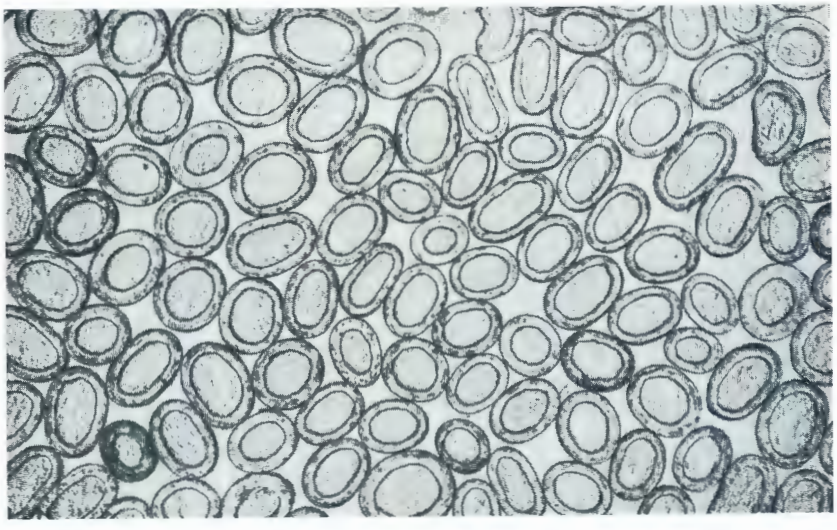

FIG. 15.—Kudu female. Belly hair. Cross-sections. 80×

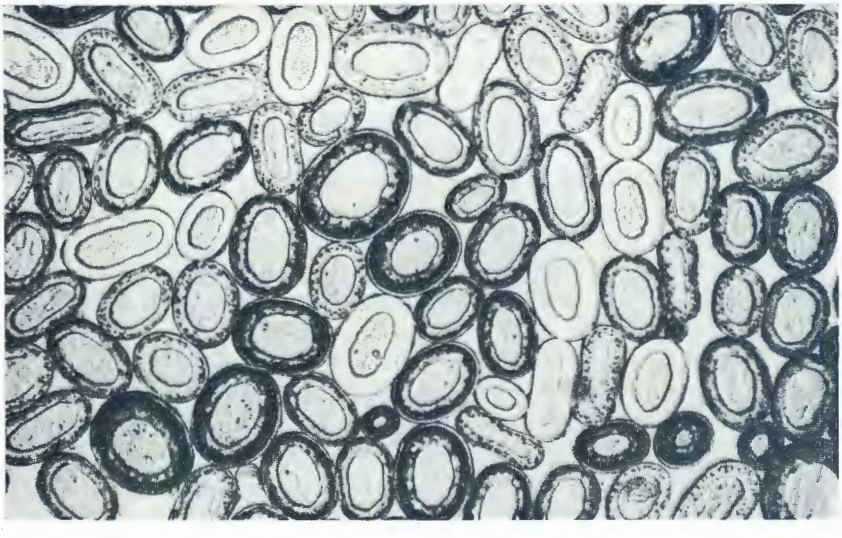

FIG. 16.—Kudu male. Leg hair. Cross-sections. 80×

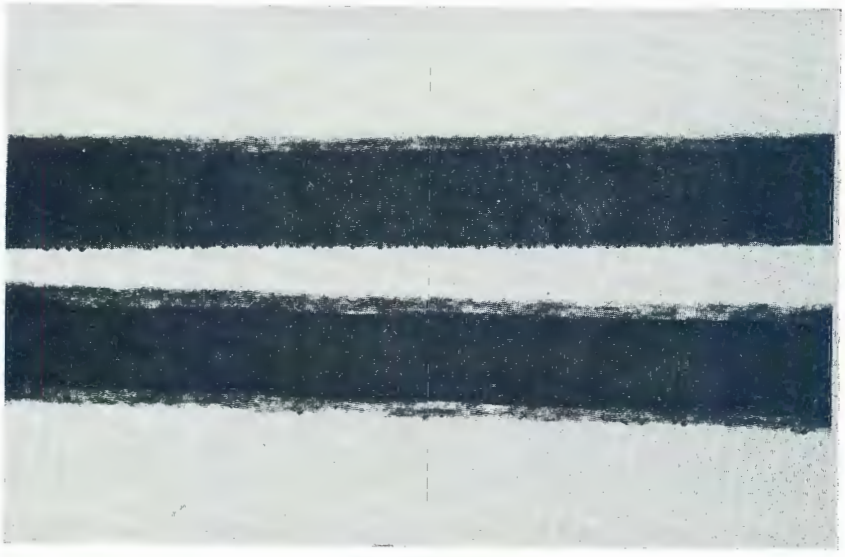

FIG. 17.—Kudu male. Mane hair. Whole mount. 80×

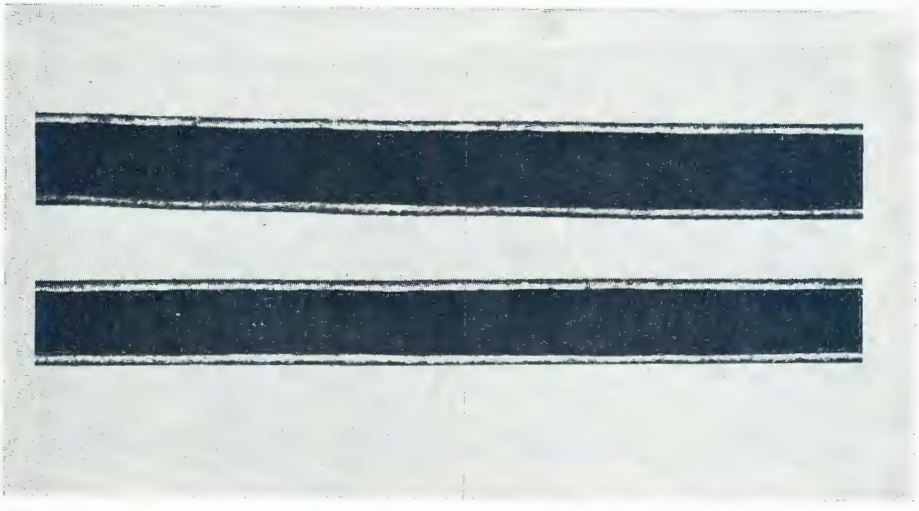

FIG. 18.—Kudu female. Shoulder hair. Whole mount. 80×

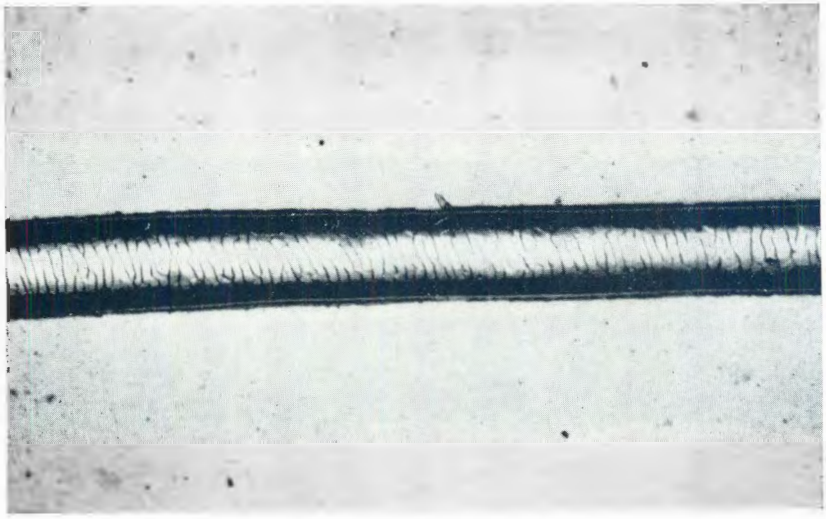

FIG. 19.—Kudu male. Thigh hair. Cuticular imprint. Irregular mosaic pattern. 80×

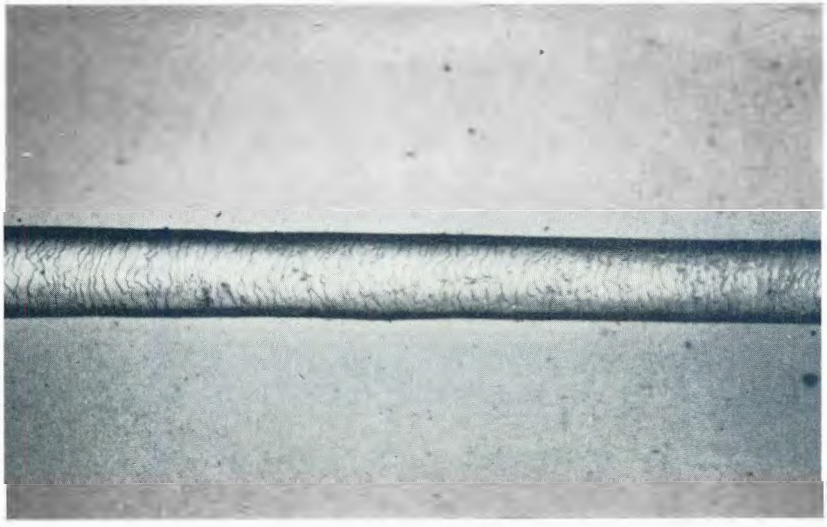

FIG. 20.—Kudu male. Thigh hair. Cuticular imprint. Irregular wave pattern. 80×

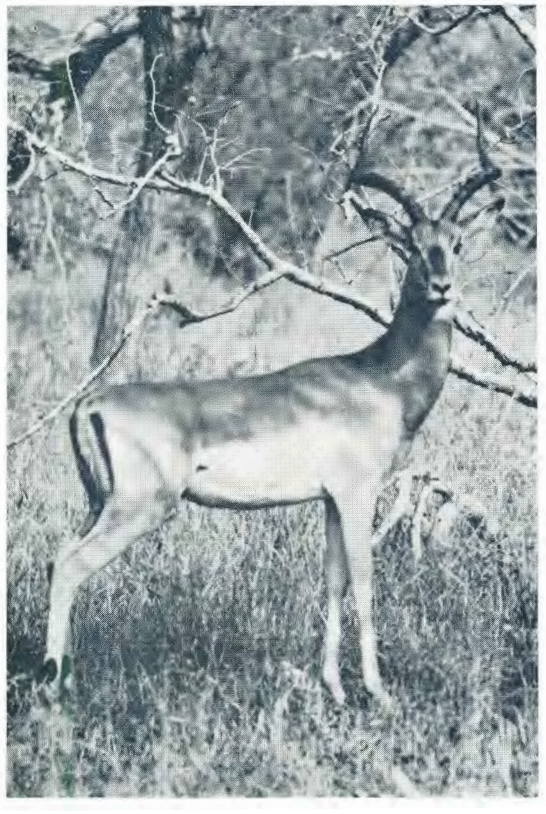

FIG. 21.—Impala male

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FIG. 22.—Impala male. Mane hair. Cross-sections. 80×

FIG. 23.—Impala fawn. Mane hair. Cross-sections. 80×

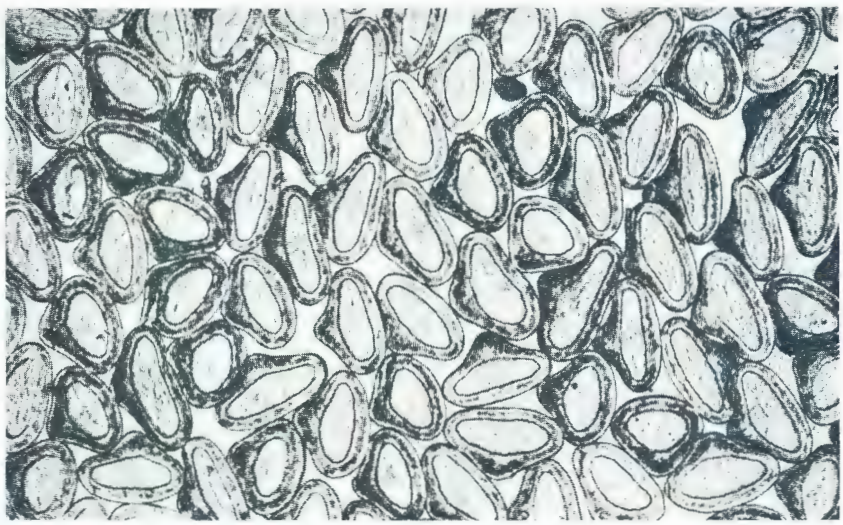

FIG. 24.—Impala female. Back hair. Cross-sections. 80×

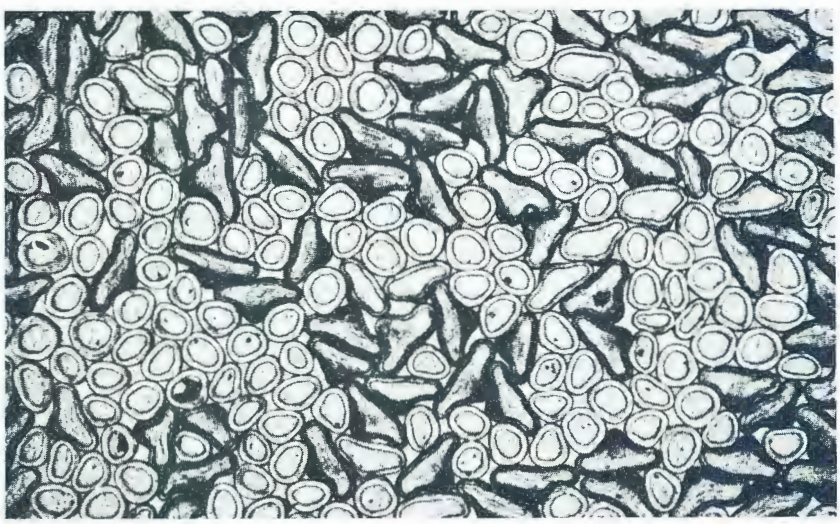

FIG. 25.—Impala fawn. Back hair. Cross-sections. 80×

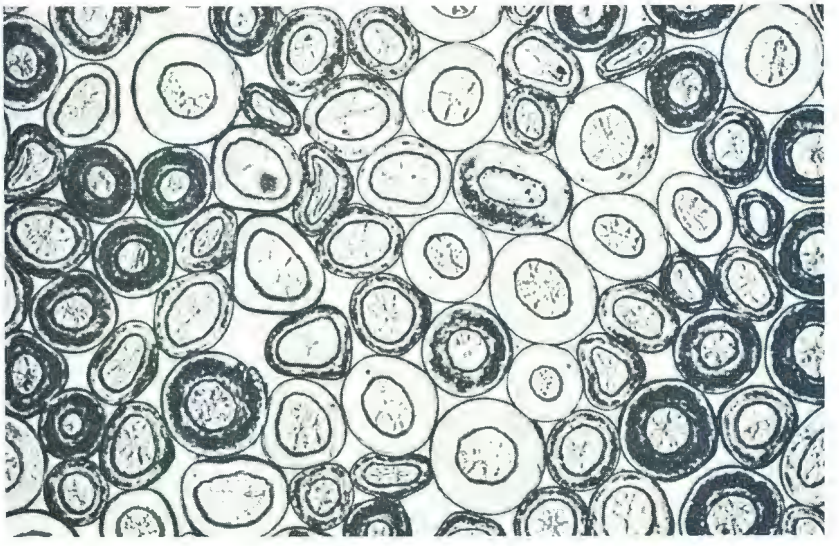

FIG. 26.—Impala male. Tail hair. Cross-sections. 80×

FIG. 27.—Impala male. Throat hair. Cross-sections. 80×

FIG. 28. Impala male. Shoulder hair. Cross-sections. 80×

FIG. 29.—Impala female. Shoulder hair. Cross-sections. 80×

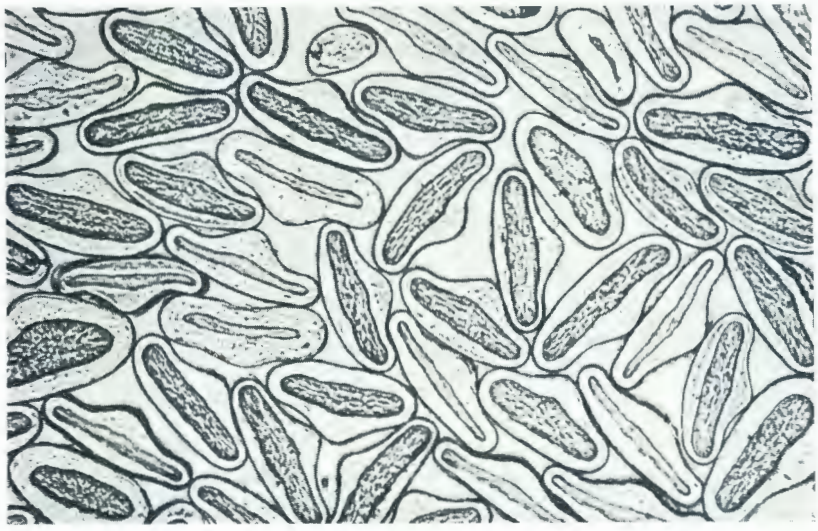

FIG. 30.—Impala female. Belly hair. Cross-sections. 80×

FIG. 31.—Impala male. Leg hair. Cross-sections. 80×

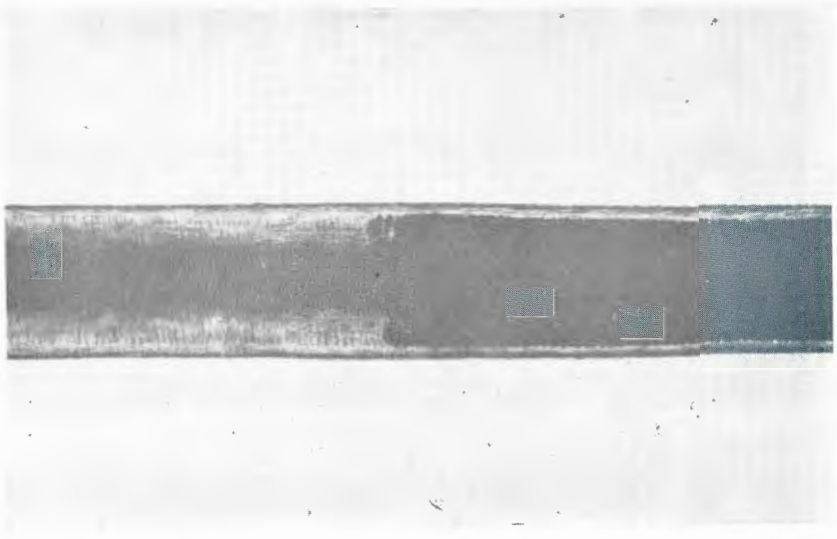

FIG. 32.—Impala male. Mane hair. Whole mount. 80×

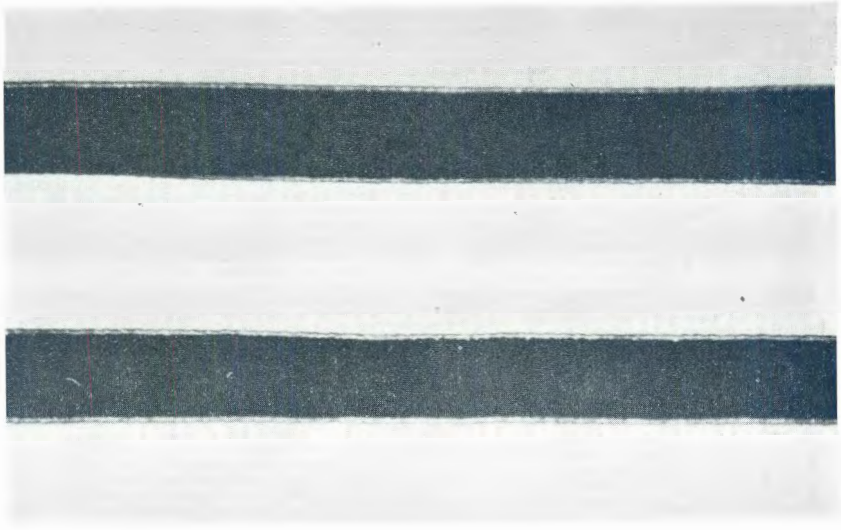

FIG. 33.—Impala female. Shoulder hair. Whole mount. 80×

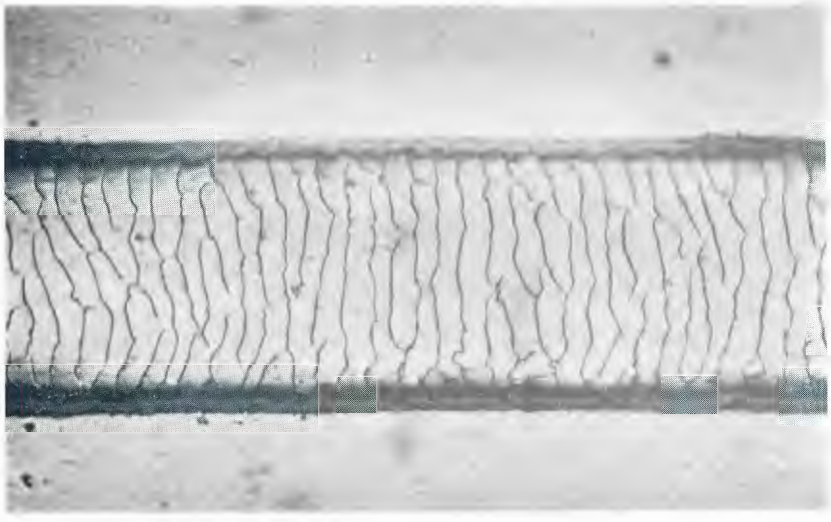

FIG. 34.—Impala male. Back hair. Cuticular imprint. Irregular mosaic pattern. Ental view. 80×

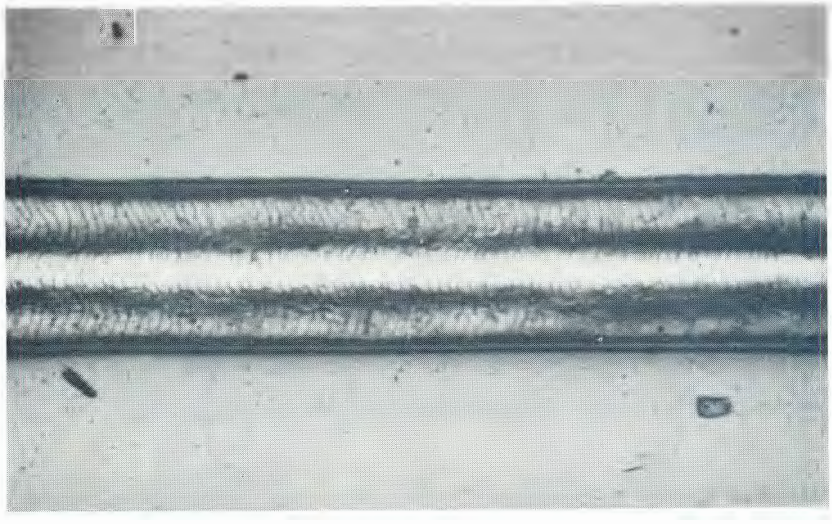

FIG. 35.—Impala male. Brisket hair. Cuticular imprint. Ectal view. 80×

FIG. 36.—Blue Wildebeest male

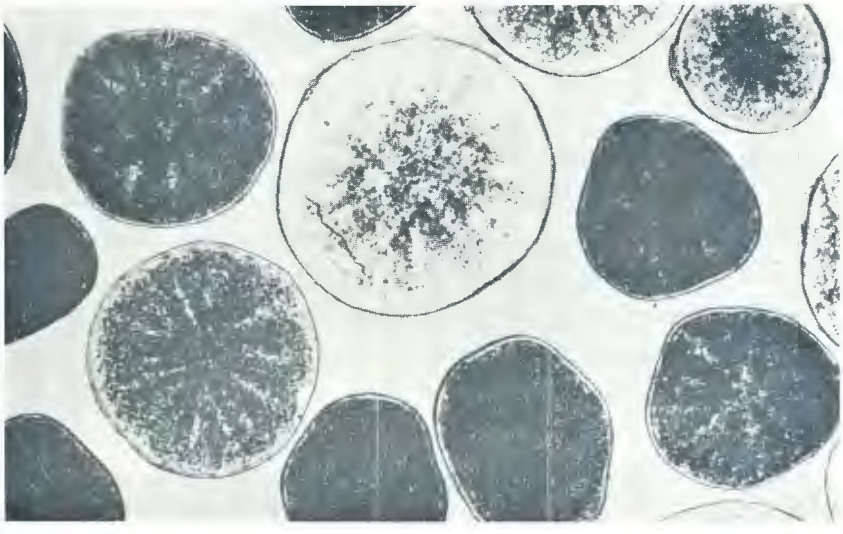

FIG. 37.—Blue Wildebeest female. Mane hair. Cross-sections. 80×

FIG. 38. Blue Wildebeest male. Back hair. Cross-sections. 80×

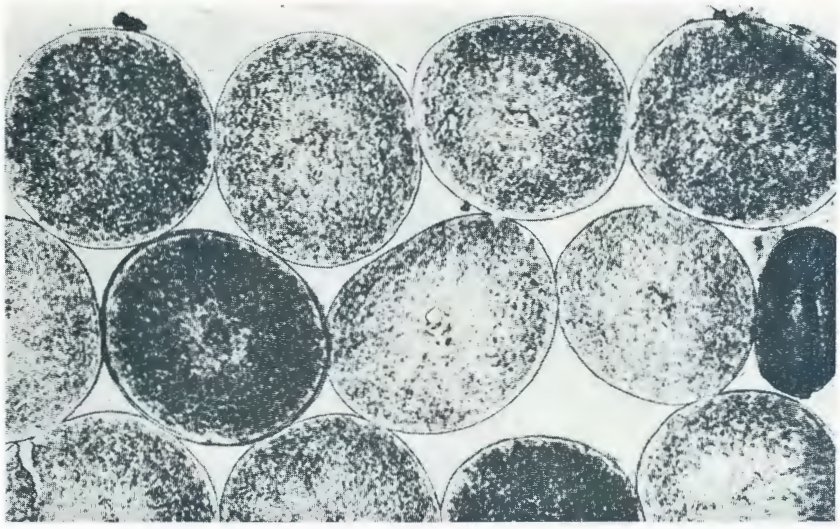

FIG. 39.—Blue Wildebeest male. Throat hair. Cross-sections. 80×

FIG. 40.—Blue Wildebeest calf. Shoulder hair. Cross-sections. 80×

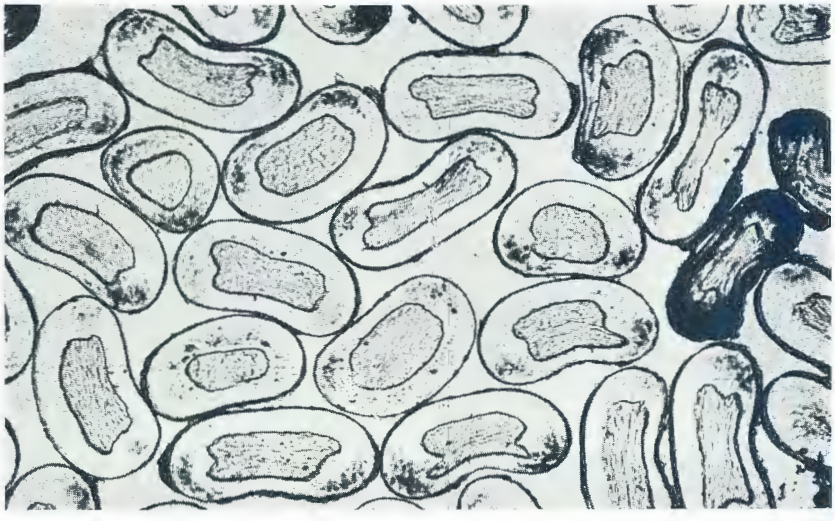

FIG. 41.—Blue Wildebeest female. Thigh hair. Cross-sections. 80×

FIG. 42.—Blue Wildebeest male. Leg hair. Cross-sections. 80×

FIG. 43.—Blue Wildebeest female. Leg hair. Cross-sections. 80×

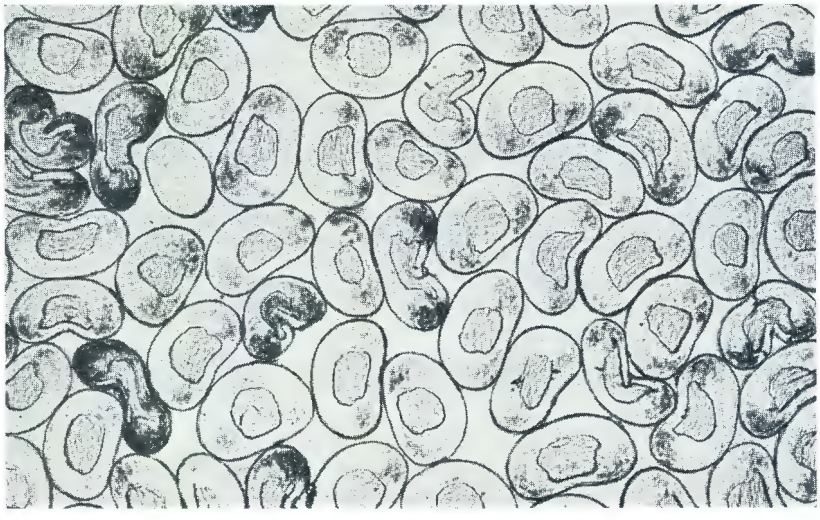

FIG. 44.—Blue Wildebeest calf. Leg hair. Cross-sections. 80×

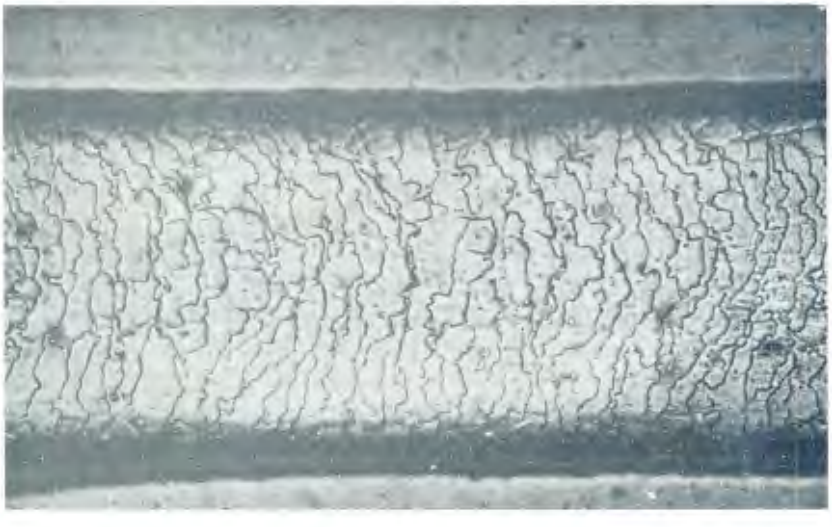

FIG. 45.—Blue Wildebeest male. Thigh hair. Cuticular imprint. Irregular wave pattern. Ental view. 80×

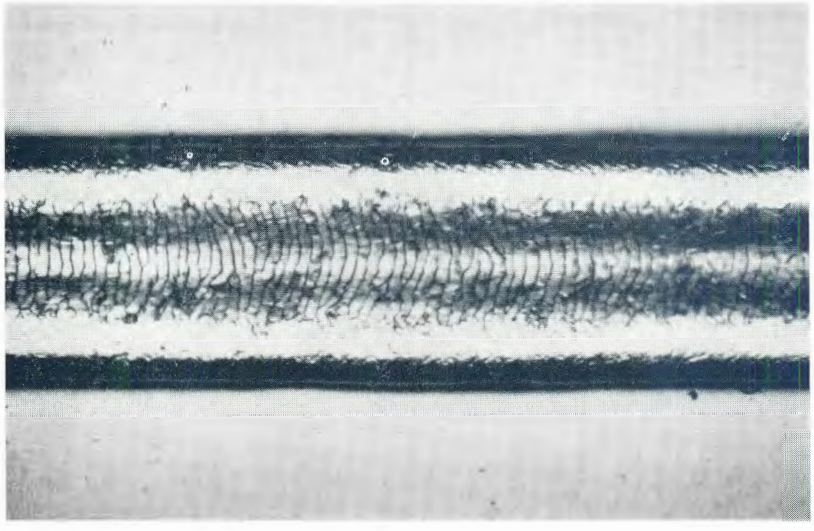

FIG. 46.—Blue Wildebeest female. Thigh hair. Cuticular imprint. Irregular mosaic pattern in groove. Ectal view. 80×

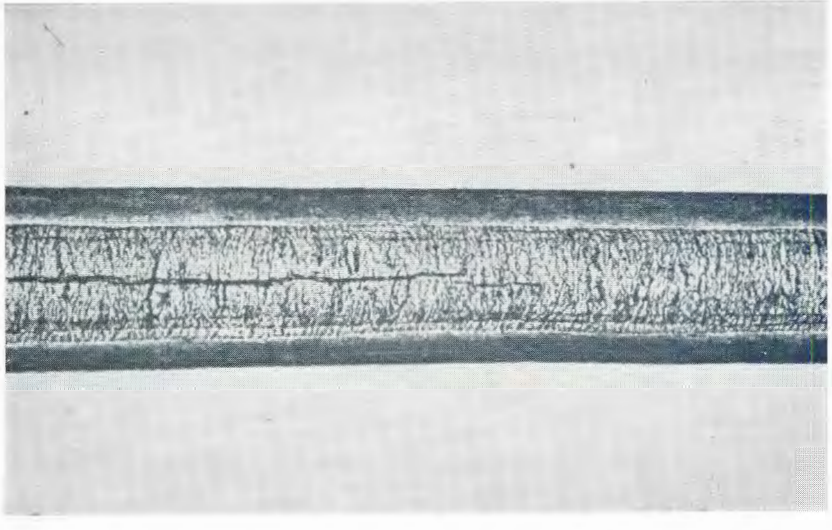

FIG. 47.—Blue Wildebeest female. Shoulder hair. Whole mount. 80×

FIG. 48.—Grey Duiker female

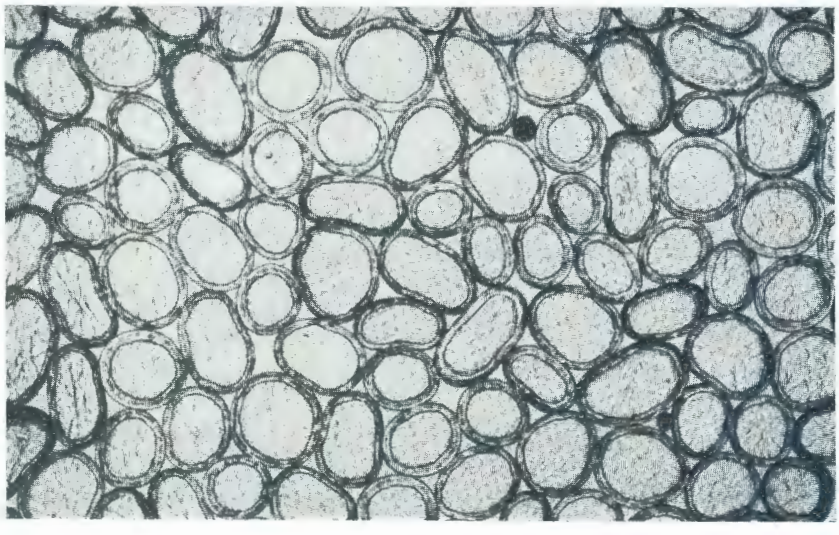

FIG. 49.—Grey Duiker male. Back hair. Cross-sections. 80×

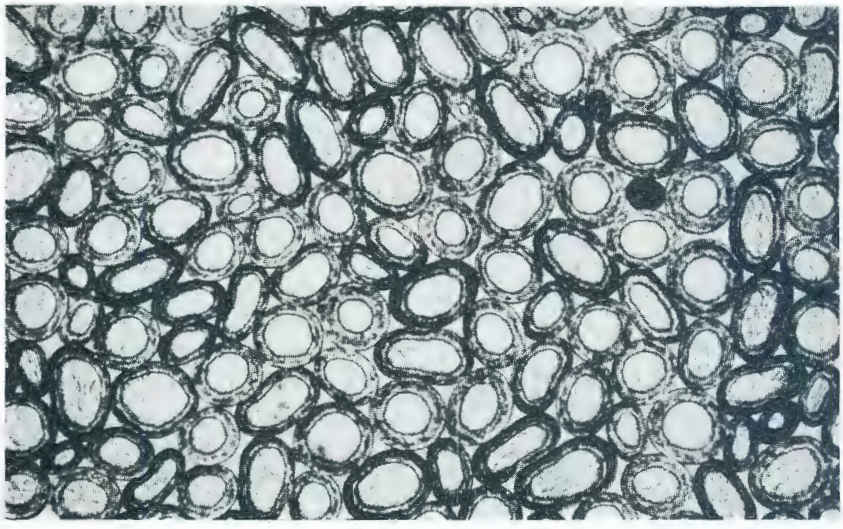

FIG. 50.—Grey Duiker female. Back hair. Cross-sections. 80×

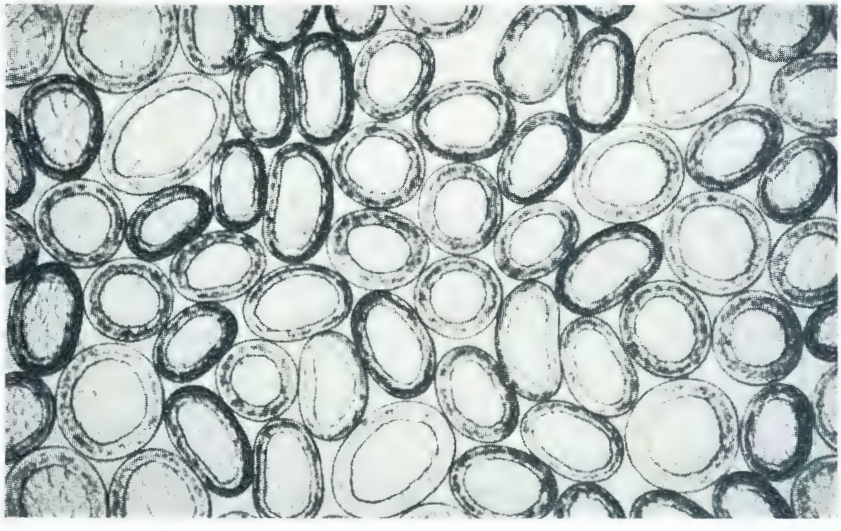

FIG. 51.—Grey Duiker male. Neck hair. Cross-sections. 80×

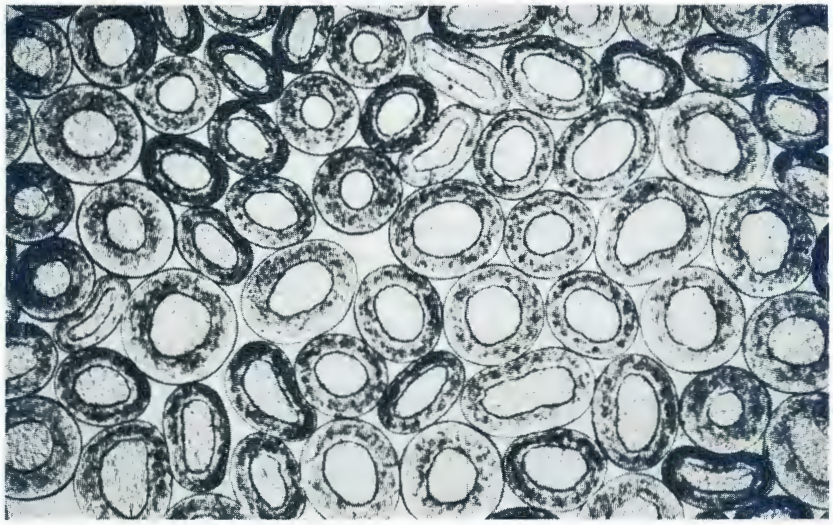

FIG. 52.—Grey Duiker female. Neck hair. Cross-sections. 80×

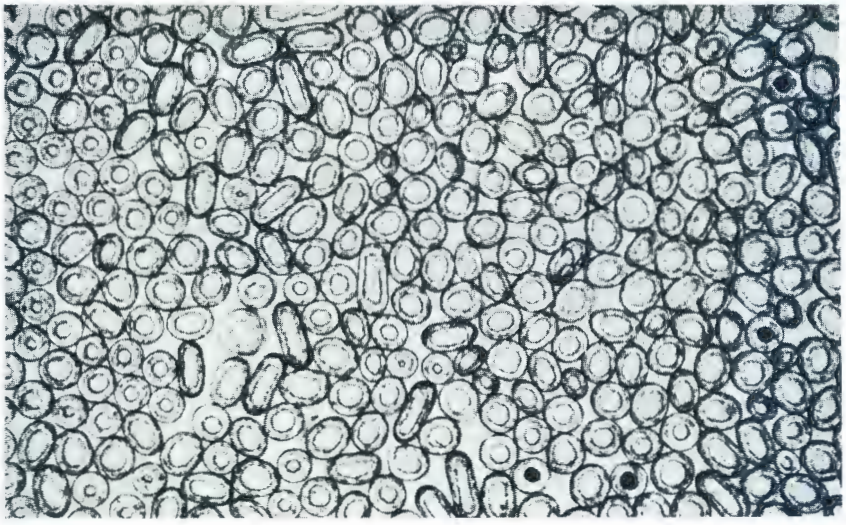

FIG. 53.—Grey Duiker fawn. Neck hair. Cross-sections. 80×

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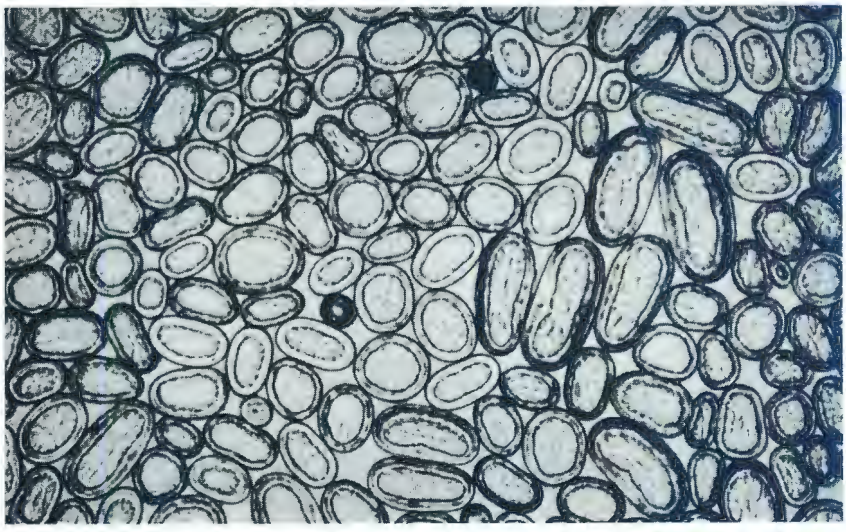

FIG. 54.—Grey Duiker male. Shoulder hair. Cross-sections. 80×

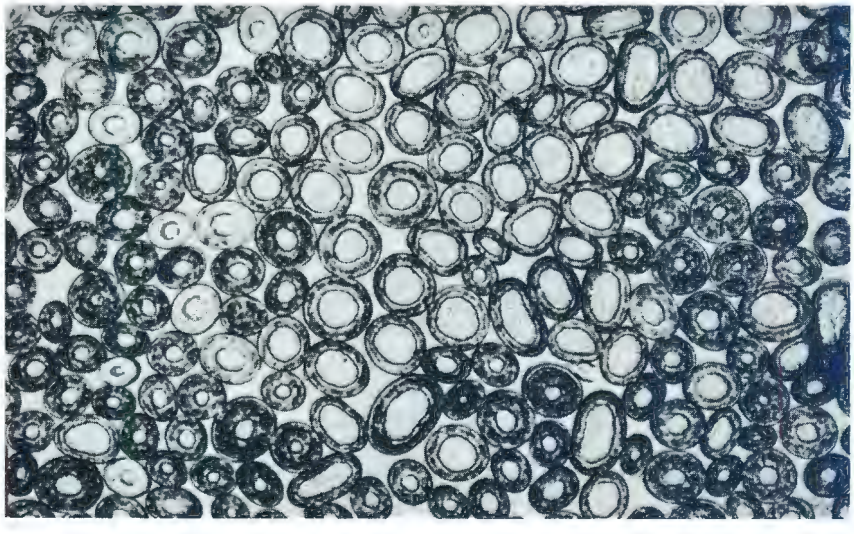

FIG. 55.—Grey Duiker female. Shoulder hair. Cross-sections. 80×

FIG. 56.—Grey Duiker fawn. Shoulder hair. Cross-sections. 80×

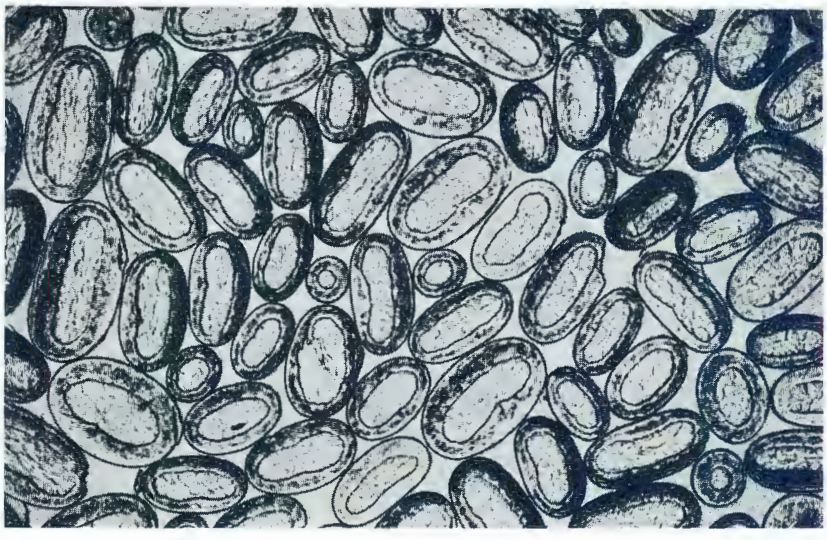

FIG. 57.—Grey Duiker male. Leg hair. Cross-sections. 80×

FIG. 58.—Grey Duiker female. Back hair. Whole mount. 80×

FIG. 59.—Grey Duiker male. Belly hair. Whole mount. 80×

FIG. 60.—Grey Duiker female. Thigh hair. Cuticular imprint. Irregular wave pattern. 80×

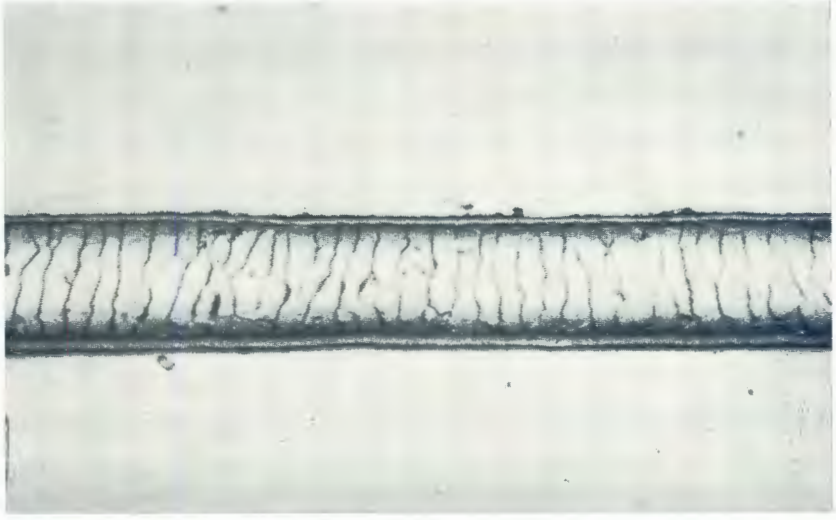

FIG. 61. Grey Duiker male. Throat hair. Cuticular imprint. Irregular mosaic pattern. 80×