

THE PELAGE OF COLUMBIAN BLACK TAIL DEER  
ODOCOILEUS HEMIONUS COLUMBIANUS (Richardson)

— a Study

by

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## ABSTRACT

The hairs and the follicles in which they arise constitute the mammalian pilary system. It is a dynamic biological system in which the hair follicles undergo cyclically partial regression and redevelopment, producing simultaneously new hairs to replace the old which are due to be shed.

The pelage is important in maintaining the animals thermal equilibrium, protection from abrasion and in display etc. Nonetheless, knowledge of cervid pilary system is extremely limited. The present study covers its development, morphology, moult and the annual hair cycle. Effects on the cervid pelage of experimentally induced adverse nutrition, as well as varying habitat, are also studied.

Morphogenesis of follicles and development stages of the hair follow the general mammalian pattern. The details of anatomy and development have been recorded. Large guard hair follicles, which during development grow faster and attain larger dimensions, have been recorded for the first time in ungulates. They are related to "Tylotrichs" referred to by Straile (1960) and produce longer hair.

Both primary and secondary follicles are present. The first formed secondaries are larger and like the primaries possess a sweat gland, sebaceous gland and arrector pili muscle. Like primaries they too produce medullated hairs. The later secondaries form non medullated woolly underhairs. Paired and branched follicles have been recorded amidst secondaries.

The primaries give rise to the overcoat and the secondaries to the undercoat.

The percentage of non medullated hairs in the birth coat of the fawn is less than in other coats. The hair follicles in which they arise continue to form postnatally and become fully functional in fawn winter coat. Adult winter coat differs from adult summer coat in colouration, length and diameter, here there is a greater development of medulla, and a well developed woolly undercoat is present. The latter is functionally lacking in adult summer coat. The autumn moult (adult) begins on the flanks and spreads cephalad and caudad. In the summer coat moult is caudad. The fawn birth coat moult is caudad. Their details have been documented.

The winter coat is greyish in colour while the summer coat is reddish yellow. The winter colouration is a product mostly of the colour zone in the top 10 mm of hair length. The winter ciat guard hairs stand more erect, because of the padding provided by the woolly undercoat. The adult summer coat has more sloping hairs and its colouration is the product of the top 20 mm of the total hair length. The characteristics of hair scale are recorded for representative hair types.

A morphometric study of hair samples from identical regions in the coats of black tail deer has been attempted and the features recorded. The hair increases in coarseness and diameter from fawn birth coat up to adult winter coat. The hair length increases up to adult summer coat but decreases in adult winter coat. The winter coat exhibited a consistent length to diameter relationship but this was lacking in summer coat. The hairs in



white-spots of the fawn birth coat differed only in respect of colour from the adjoining non-spotted area and not in any other external morphological respect.

Fortnightly skin biopsy samples were taken by means of a trephine; their histological study provided data on the annual hair cycle. The overcoat hairs moult twice while the undercoat hairs are shed only once. The statement by Lyne (1966) that "the rate of follicle development is inversely proportional to the size of the mature follicle" is true for guard hairs. First formed secondaries, however, reach resting stages earlier than do the later formed secondaries. Rate of growth is greater in larger follicles, which though not much advanced developmentally, reach larger size.

Effects of adverse nutrition on pelage have been studied experimentally, on normally growing hairs as well as those induced artificially by plucking resting hairs. Hair length and diameter were reduced in underfed animals and initiation of new hair growth was delayed. Reduction in width of medulla appeared to be responsible for most of the reduction in hair diameter. The medulla is an important insulator, as can be seen from its greater extent in Alaskan forms compared with those from Southern California living in dry hot habitats. Regression analysis indicated that in underfed animals, though actual hair diameter was less, relative increase in diameter for a unit increase of length was greater than that in well fed animals. Thus when nutrients are limited, growth in hair diameter (in turn dependent on size of medulla) enjoys a priority over growth in length.

Finally it is felt that to comprehend properly the phenomenon of hair growth in cervids future investigations could fruitfully concentrate on the biology of cells in the follicle base and the dermal papilla. The role of dermal papilla in hair growth and the process of differentiation of different follicle layers are of great significance but need to be well understood.

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## Chapter I

### GENERAL INTRODUCTION

#### Introduction

Hairs are an important mammalian characteristic. All mammals possess them in varying degrees. They are produced in the hair follicle by cells of epidermal origin.

The most important function performed by pelage appears to be assisting the animal to maintain a thermal equilibrium and to overcome rigours of climatic fluctuations (Scholander et al 1950, Hart 1956). The hair type constituting the pelage, help to trap a cushion of air and build up a thermal gradient from skin to the outer environment (Ling 1965). Mammals inhabiting colder regions possess characteristically thick pelage as opposed to those occurring in warmer regions. The thick pelage so advantageous in winter is a disadvantage during warm seasons, even in colder regions. To obviate this difficulty mammals moult and the pelage differs between cold and hot seasons.

The individual hair constituting the pelage may be coloured differently along their length and together lend characteristic colouration to the pelage. Generally the colouration is darker in winter and lighter in summer.

The pelage is also made use of in the animals behaviour problem and displays; e.g. Cowan and Geist (1961), and Geist (1966).

In addition pelage is responsible for protecting the animal from abrasion and external damage. In many species it also acts as an effective water proofing agent (Flesch 1954).

These attributes in themselves are sufficient to justify investigations of pelage from physiological, anatomical, and ethological point of view. Unfortunately to this date relatively few mammalian species have been investigated. Basically the following have been the objects of research, and the topics investigated range from follicle development, morphology, to annual hair cycles and moulting.

### 1. Humans

Medical dermatology has covered the field of human hair growth and related phenomena well, corroborative observational and experimental evidence has been obtained through work on laboratory animals like mice, rats and rabbits. e.g. Montagna (1956), Butcher (1951), Chase (1954), Collins (1918), Dawson (1930), Hay and Fraser (1954, 1955), Dry (1926), etc.

### 2. Domestic animals of economic importance

#### a) Sheep

Since their wool is of commercial significance, the phenomenon of wool production has been looked at in some detail. e.g. Fraser and Short (1960), Auber (1952), Carter and Clarke (1957), Hardy and Lyne (1956), Carter (1939, 1943, 1955), Duerden (1927, 1929), Duerden and Whitnall (1930), Ryder (1957, 1958), Wildman (1932, 1957), etc.

#### b) Cattle

The skin and pelage of cattle have been investigated to some extent, particularly because of its importance in determining suitability for introduction of temperate zone cattle into areas

of hot climate, and also to arrive at hybrids more suited to new environments. e.g. Carter and Dowling (1954), C&amek (1920), Dowling (1955, 1958, 1959), Bonsma (1943, 1954), Yeates, N.T.M. (1954, 1955), Dowling (1960), Hayman (1956), Dowling and Nay (1960), Nay and Hayman (1963), Hayman and Nay (1961), Schleger and Turner (1960). Most of the work has been done in Australia.

### 3. Animals with economically valuable pelts

The pelts of these mammalian types are of commercial importance. The phenomenon of hair growth has been investigated to some extent in the following species, e.g. Lyne (1956) on chinchilla, Dolnick (1956) on mink, Scheffer (1961), Rand (1956), Ling (1965) on seal.

As regards the rest of mammals very little is known. From what literature is available the following are interesting, De Meijer (1894), Lyne (1957), Carter (1965).

The knowledge gained on the biology of skin and hair growth, has been the subject of several reviews in books, notably those of Hamilton (1951), Montagna (1956), Montagna and Ellis (1958), Rook and Champion (1962), Lyne and Short (1965), Rothman (1954). Admittedly many of the contributors to the above lean heavily on data from medical dermatology — none the less they are of relevance in understanding skin and hair growth of mammals in general.

Studies on morphology of hairs are also important. Hairs themselves present characteristics of scutellation, internal structure and pigmentation that permit the identification of many mammalian higher taxa by this means alone. Important contributions in this respect are from Wildman (1954), Appleyard (1960),

Spence (1963), Mayer (1949), Stains (1958), and Day (1965).

Apart from such studies of the hair fibre itself little is known about the characteristics of the skin, pelage, and pelage cycle of wild species.

The present study is an attempt to provide information on these aspects of the biology of a single species of the large diverse and widely distributed family of ungulates -- the cervidae, for which no detailed information is available.

## Chapter II

THE CERVID PELAGE

Existing descriptions of cervid pelage are general and are more of use in identification and description of the animal. Consequently many important facets have been overlooked. We have very limited information on the types of hairs constituting the cervid pelage, their individual growth cycles, the patterns of moult, and the follicles in which these hairs arise. We also have little information on the phylogenetic, adaptive and behavioural significance of the pelage. We do not know anything definite about the effect of environmental factors of the cervid pelage.

Caton (1877) appears to be the first author to describe at some length the pelage characteristics and trends of moult in North American cervids.

Lydekker (1898) dealt with the cervid genera of the world including a general description of the pelage. In introductory pages however there is an interesting discussion of its adaptive and behaviourally significant features. Murie (1951) and Peterson (1955) in their works on elk and moose respectively touch upon some pelage characteristics and aspects of moult. Linsdale and Tomich (1953) also refer to the coat and moult characters of the mule deer. They mention colouration and moult trends.

Severinghaus and Chaetum in Taylor (1956), discuss adult coat and moult in the white tailed deer — Odocoileus virginianus and quote in detail from Caton (1877). In the same volume material relating to the Columbian black tail deer Odocoileus hemionus

columbianus (Richardson), is contributed by Cowan (1956); who offers a succinct summary of pelage features and moult.

Apart from Lydekker (1898) the only other authoritative contribution dealing with cervid forms over the world is by Flerov (1960). Here the emphasis is more on the palaearctic forms; the material on North American forms being scanty.

The salient features of cervid pelage as they emerge from the above contributions can be briefly summarized as follows:

The hairs on the body vary in length. Those on the dorsal side are normally longer than those on the ventral side. Similarly there is an increase in length from anterior to posterior. Some regions of the body bear specialized hairs. In general hairs in the axilla, inguinum, rump and tail are longer whereas those on face, ears, and extremities of legs are shorter. Also hairs on the under part are softer and paler than those on the exposed body surface.

The pelage generally consists of an overcoat and an undercoat. The overcoat is made of hairs which are longer and thicker than those of the undercoat. They have characteristic colouration — and their distal extremity is mostly responsible for giving the animal its colouration. The guard hairs constitute the outercoat and the bulk of the pelage. In certain cervid forms like Dama Elaphorus, Capreolus (Flerov 1960), a special type of guard hair — occurring uniformly scattered over the body about 2.5 cms. apart — and having almost double the length of normal guard hairs — has been recorded. These may be tactile in function.

The undercoat consists of woolly hairs, which are wavy, smaller in diameter reaching on maturity about three fourths of

the length of guard hairs. These are not visible externally and are present in bulk only in cervid winter coat. However in genus Rusa and sub-genus Przewalskium these hairs are absent in the winter coat (Flerov 1960). The significance of this is discussed subsequently.

In the course of the year the cervid pelage has two phases. The summer phase is of lighter colour and marked by scarcity of woolly under hairs. The winter phase is darker coloured and has an abundance of woolly under hairs.

The change over from one phase into the other is brought about by a process of moulting, involving shedding of old hairs accompanied by growth of new hairs. Flerov (1960) discusses aspects of this process in some detail.

The two main features in the evolution of cervid pelage that attract immediate attention are:

- 1) Primitive forms with spotted pelage that in the advanced forms occurs only in the newborn or not at all.
- 2) Evolution of a winter coat specifically adapted to meet rigours of cold environment.

These will be considered in their respective order.

The spotted nature of the coat is said to be of protective value. By helping to break up the body outline it merges the animal with the patterns of light as they exist in forests, and effectively conceals it.

The spotted coat is present throughout the life of certain cervid forms e.g. Axis axis, or it may be present only in the fawn birth coat and adult summer coat — being very weak or absent in the adult winter coat. e.g. Cervus nippon the Japanese Sika deer. In the relatively recent forms like Odocoileus the spots

are retained only in birth coat, Caton (1878) however refers to faint spots exhibited in summer coat of some Odocoileus virginianus forms. Cowan (1965) states that only the fawn "black tail" are spotted and that these spots disappear with loss of the fawns<sup>①</sup> hiding instinct in the field. Also recent forms like Cervus canadensis and Alce alces have fawns and adults devoid of any spots on the pelage. There is thus a definite evolutionary trend towards loss of spots, the reason for which is not clear.

The evolution of a thick winter coat is also interesting. It is generally assumed that deer first evolved in warm tropical forests and possessed a brownish coat equivalent of present day cervid summer coat. This coat, in addition, was spotted along the flanks, Lydekker (1898). The present day summer coat is reminiscent of it. With the gradual spread of cervid forms to areas of colder climate the need for a winter coat arose and factors leading towards it appear to have been selected for, these consist of development of woolly undercoat and thicker guard hairs. Such a heavy coat however is a liability in summer and thus the process of moulting twice a year has been selected for by which appropriate coats (summer and winter) are assumed during the course of the year in consonance with the season.<sup>0</sup>

The sub genus Przewalskium a cervine form occurring in cold Tibetan highlands is interesting in this respect. Though it possesses a winter and summer coat, its winter coat is devoid of woolly underhair Flerov (1960). Instead its winter coat is constituted of hairs which are long and twice as thick as the summer hairs. There are thus at least two different evolutionary routes to development of winter adapted pelage.



When only one type of coat was present presumably the moulting took place only once a year replacing a coat affected by normal wear and tear during the year. With two types of coat — two moults a year were necessary. Males generally are first to moult and fawns and unbred females follow. Females with fawn generally moult a month or so later. Sufficiently detailed information on cervid patterns of moult is not available — nor the sequence in which various hair types are shed.

Flerov (1960) also refers to the occurrence of whorls in pelage of many cervid form e.g. Przewalskium, Elaphorus, Dama, Mazama, etc.

The selection value of these structural oddities is not clear. Parnell (1951) discusses the basis for these whorls in two main types.

- a) "factors influencing growth of embryo such as tension and pressure of thin surface, its thickness and pressure or absence of the structure beneath it".
- b) "intrinsic factors in growing hair germ such as a physiological gradient or in the genetical make up of the individual".

Behaviourally cervid pelage presents interesting features. The increased growth of hair on the neck leading, to the formation of a mane, particularly in breeding season, is believed to be of protective and display value, as at this time combats are frequent.

The underside of the tail, as well as the posterior margin of thighs is generally white (Odocoileus, Axis). When excited as when fleeing, such forms raise their tails, and its white underside in conjunction with white posterior margins of thigh forms a very noticeable white area — enabling animals to follow

each other. In Axis and Odocoileus the white hairs of this region are erectile. In forms like Capreolus and Cervus, a white rump patch is formed; for Capreolus this is only in the winter coat. In species having a rump patch the tail is reduced and is not raised when the animals are excited or fleeing.

The hairs surrounding the tarsal and metatarsal glands are much coarser than the adjoining hairs and are capable of erection.

Though not a part of the pelage the 'velvet' covering the antlers of deer is also of great interest. It bears short and soft hairs arising in follicles which lack the sweat gland and the A. pili muscle. When the antlers mature the velvet becomes necrotic and is shed; only to be formed again 'de novo' to cover a new set of growing antlers, the following year. This is the only case of hair follicle neogenesis in adult mammals supported by irrefutable evidence, Billingham (1958).

## Chapter III

### PRENATAL DEVELOPMENT OF THE PILARY SYSTEM IN DEER

#### INTRODUCTION

Though interest in the general phenomenon of hair growth is increasing, observations on prenatal development of hair follicles are related structures continues to be limited. Known examples of significant work done in the field are guinea pig, (Seagall 1918); mouse, (Hardy, 1949); bandicoot (Lyne, 1957); mink (Dolnick 1959); cattle (Lyne and Heideman, 1959, 1960); sheep (Wildman, 1932 and Hardy and Lyne, 1956); goat (Margolena, 1959); and elephant seal (Ling, 1965). In general these workers have traced the development of hair follicles and suggested boundaries and criteria of a useful approach to standardize stages, in the continuous process.

No study of follicle development appears to have been made in wild ungulates. The present work reports the course of development of the pilary system in the black tail deer Odocoileus hemionus columbianus (Richardson), a North American cervid, and thus provides for the first time a basis for comparison between two of the major families of the artiodactyla — the cervidae and the bovidae.

#### MATERIALS AND METHODS

This study is based upon a series of fetuses taken from wild does collected in the course of a study of reproduction in this species. Preservation was in formol saline.

TABLE 1

## Basic Data on Foetuses Sampled

Foetus	Date	Forehead Rump
Numbers*		Length (mm)
T80 A M*	15 Jan. 65	46.2
T27 F*	29 Jan. 64	89.5
T36 F*	3 Feb. 64	112.5
T41 A M*	19 March 64	181.5
T46 B M*	22 March 64	202.0
T54 M*	6 May 64	211.5
T40 A M*	18 March 64	235.0
T56 A M*	7 May 64	236.0
M <sub>1</sub> F*	8 April 63	269.0
T82 M*	16 April 66	287.0
T63 A F*	11 May 64	321.0 <sub>1</sub>
T60 B M*	11 May 64	335.0
T66 F*	13 May 64	366.0
T69 M*	12 June 64	422.0
T70 A M*	12 June 64	438 mm

\*f= Female

\*m= Male

Fifteen representative fetuses each of a different developmental stage were selected for sampling purposes. All but one i.e. (M<sub>1</sub>) were from Northwest Bay, Vancouver Island, B.C. Skin samples were taken from each at predetermined locations, dorsally on the base of the neck.

The material so obtained was histologically processed (see Appendix I) and 8  $\mu$  thick sections were cut parallel to the skin surface as well as across it. These were stained in Haematoxylin and Eosin and used for further observations.

### OBSERVATIONS

The development of hair follicles can be studied in two main aspects namely the development of the individual hair follicle — and the development of the follicle groups and population. In the ungulates investigations of this aspect appear to be restricted to sheep and cattle.

Wildman (1932) has discussed the prenatal development of a wool follicle in some of the British breeds of sheep. Hardy and Lyne (1956) have charted development of merino follicles and proposed recognition of eight developmental stages, the final stage of which is reached when the hair emerges on the skin surface. Lyne and Heideman (1959) in course of their work on follicle development in cattle have proposed ten stages rather than eight, the final stage being reached when the hair growth ceases and the follicle rests. These stages of follicle development have proved applicable to those species investigated to date and provide a useful framework for the study of other species. They can be stated as follows (Fig. 1)

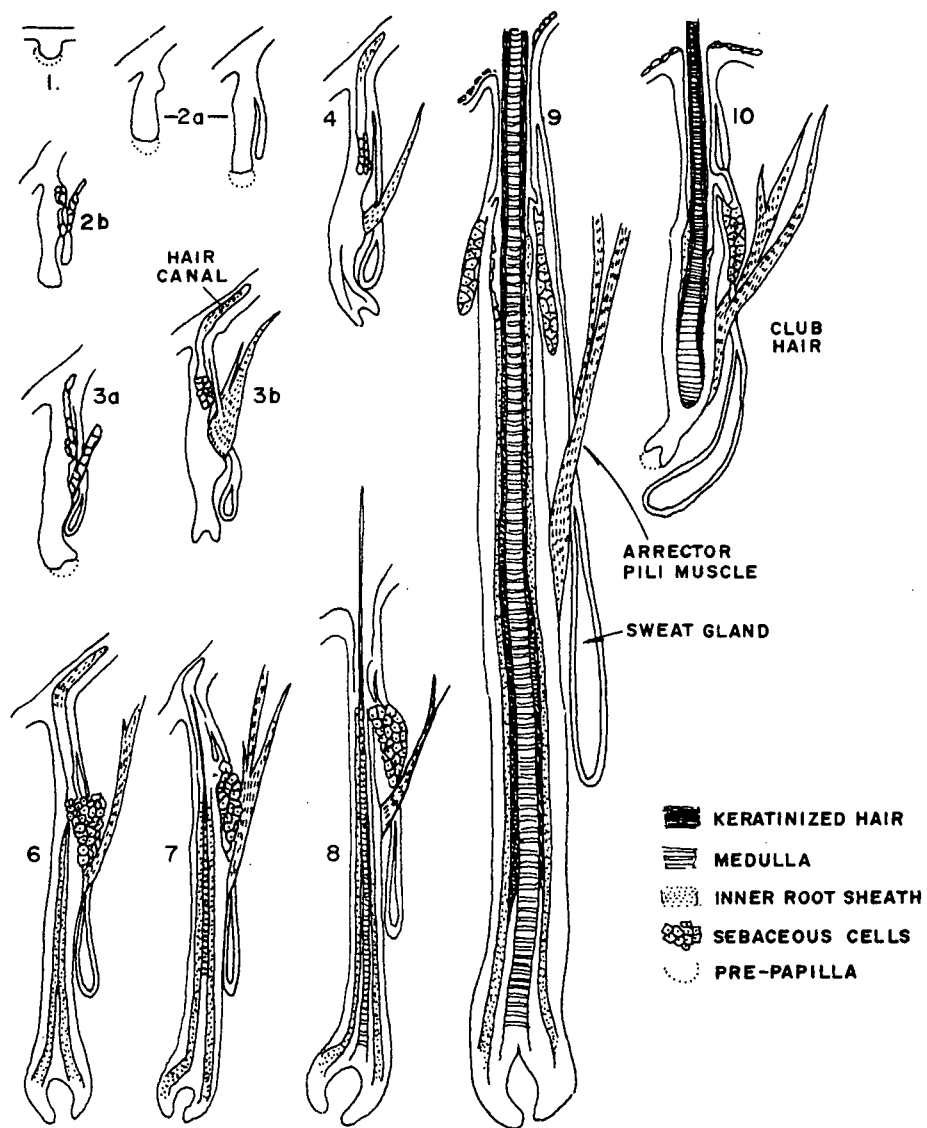


FIG. 1 STAGES 1 TO 10 IN THE DEVELOPMENT OF MAMMALIAN HAIR FOLLICLES AS SHOWN IN CATTLE

AFTER LYNE AND HEIDEMAN (1959)

### Stage I. Follicle plug

This is divided into two stages.

- a) when length of plug is less than its diameter.
- b) when length is equal to or greater than diameter.

### Stage 2. Pre - papilla

- a) Follicle length more than twice its diameter, the base of epidermal plug flattened, sweat gland appears at higher levels of follicle in form of a solid bud located on ental side.
- b) First trace of arrector pili muscle now appears in dermis; A swelling is also noticed halfway down on ental side of follicle. This is the ental swelling. Sebaceous cells begin to differentiate below junction of sweat gland and constitute rudiments of sebaceous gland. First stages of hair canal formation noticed.

### Stage 3. Papilla

The differentiation of sub stages here is based on the shape of the dermal papilla.

- a) Follicle base becomes concave and dermal papilla is greater in diameter than in depth. Arrector pili muscle extends from upper part of dermis up to ental swelling. Hair canal formation is noted. Sweat gland has now reached in depth the region between ental swelling and bulb of follicle, and contains a lumen at its distal end.
- b) Length of dermal papilla equal or greater than its diameter. Ental swelling has reached maximum size and hair canal development is almost complete and its part in epidermis is lying almost parallel to skin surface.

### Stage 4. Hair cone

The ental swelling now becomes a little less prominent and the deeper end of the follicle exhibits the presence of a hair cone.

Stage 5. Advanced hair cone

The tip of hair cone is retractile.

Stage 6. Hair formation

Hair cone lies at about level of sebaceous gland. Hair tip is keratinised. All follicle layers are by now formed.

Stage 7. Hair in canal

Tip of the hair has emerged into hair canal.

Stage 8. Hair emerged

Hair has emerged on surface.

Stage 9. End of follicle growth

Follicle reaches its maximum growth.

Stage 10. Club hair formation

- a) Bulb contracts and connective tissue around it gets crinkled.
- b) Club hair formulation with typical brush end is first recognised.
- c) Club hair is keratinised in full.

In stage ten the formation of the medulla comes to an end followed later by the hair cuticle and the inner root sheath. The follicle is simultaneously decreasing in length and the bulb and dermal papilla undergo degeneration till they somewhat resemble their morphology in stage three.

It must be noticed that these stages refer to the development of individual hair follicles and not the follicle population.

All the above stages can be identified in the sequence of development of follicles in Odocoileus. There are minor variations and these will be detailed later.

Another aspect of follicle development is that of the origin of groups and populations of follicles. Different



categories of follicles arise that give origin to hairs of distinct types. Furthermore the arrangement and spacing of follicles present features that may be of importance in the elucidation of systematic positions or ecological adaptation.

De Meijere (1894) was one of the first to investigate arrangement of hair follicles and the hair arising in them. His work stands out as a pioneering classic of its kind, in which he brought out the fact that basically the first formed follicles in mammals are arranged in groups of three of which the central follicle is larger than the two follicles lying lateral to it.

The hair follicles have also been classified in relation to their sequence of origin and development. Noback (1951) has discussed this succinctly as follows:

"The first follicles to differentiate are the central trio follicles. If these follicles appear at two different times as in opossum (Gibbs 1938), then the follicles are called "primary X" and "primary Y". The essential point is that each of these primary follicles will be the central follicles of different groups. Later in development other follicles of the hair group differentiate in relation to these central trio follicles. The trio is formed when two follicles are differentiated lateral to the primary follicles. The lateral follicles associated with "primary X" or "primary Y" are called respectively "primary X" or "primary Y". If only one lateral follicle is formed adjacent to a primary follicle (X or Y) then a couplet follicle is formed. If no lateral follicles differentiate a primary (X or Y) is called solitary follicle. Later another generation of follicles is differentiated — the secondary follicles. In the opossum these follicles are located between the central trio follicle and the

lateral trio follicle. The ontogenetic studies of follicle arrangement have added confirmatory evidence to De Meijere's basic concept that in mammals there is a universal and regular grouping of hair follicles. (Hardy 1946)".

#### Follicle and Hair development

The hair follicles of the black tail deer can be divided on the basis of their origin into two types — the primary and the secondary. The primaries are the first to form and develop in groups of three (trio grouping), of these the central follicle of the trio is the first to form — and is akin to "primary X". The later formed primaries which form the two lateral follicles of trio grouping are akin to "primary X" of Noback (1951). There is no occurrence of "primary 'Y'" follicles nor any of 'primary Y' types. Each of the primaries possesses a sweat gland, sebaceous gland and arrector pili muscle. In contrast to the primaries which start developing around 112 mm. stage, the secondary follicles begin developing around 269 mm. stage. The secondary follicles are much smaller than the primaries and are located in groups between the primaries. The first formed secondaries are larger than those subsequently formed and possess sweat gland, sebaceous gland and arrector pili muscle. The rest of the secondaries bear only sebaceous gland and the smaller of them may even lack these.

The follicle types bear a close relationship to the hairs that are produced in them. We know that the black tail pelage consists of an overcoat and a woolly undercoat which is well developed during winter. The overcoat consists of hairs produced

FIGURE 2

Grouping of primary and secondary follicles in deer. Transverse section. Notice the typical 'five' grouping; of primary and secondary follicles. H. & E.

FIGURE 3A

Deer primary follicle. Longitudinal section. General view of the lower end of the follicle. Notice well developed medulla. H. & E.

FIGURE 3B

Deer secondary follicle. Longitudinal section. General view of the lower end of the follicle. Notice hyaline membrane on both sides of ext. root sheath and absence of the medulla. H. & E.

FIGURE 4.1

Developing skin and hair follicles. 112 mm. stage. Longitudinal section. Notice the thin epidermis and the hair follicle anlage being formed. H. & E.

For explanation of abbreviations used please see Appendix IV, Page 214.

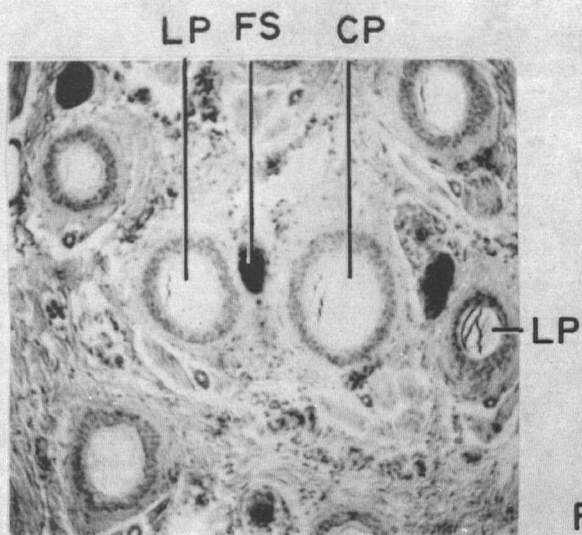


FIG 2

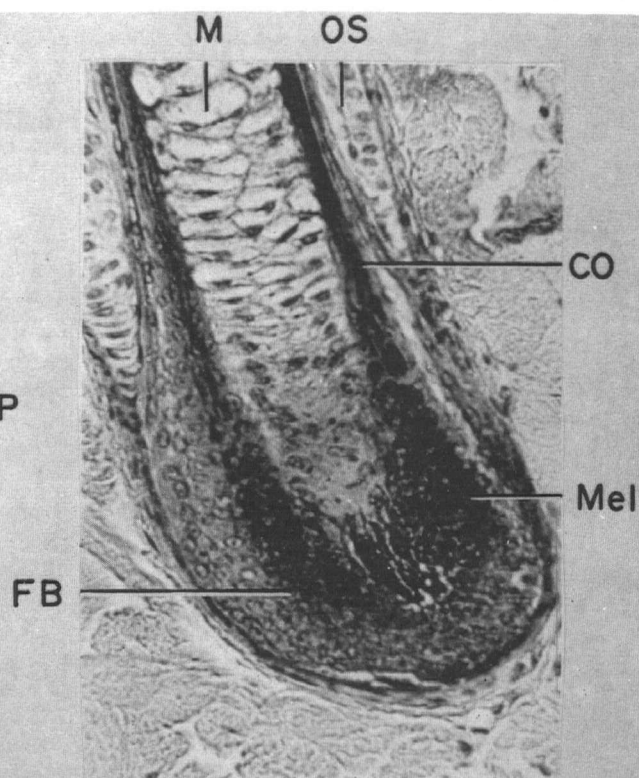


FIG 3A

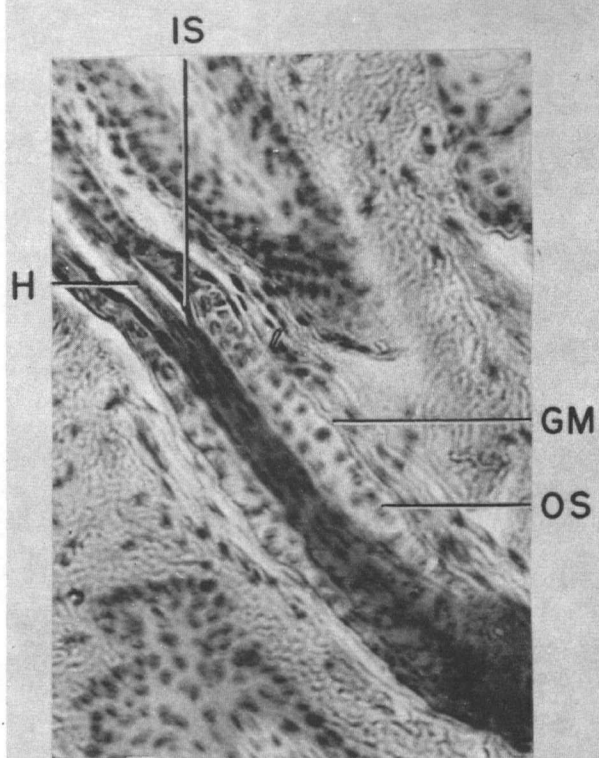


FIG 3B

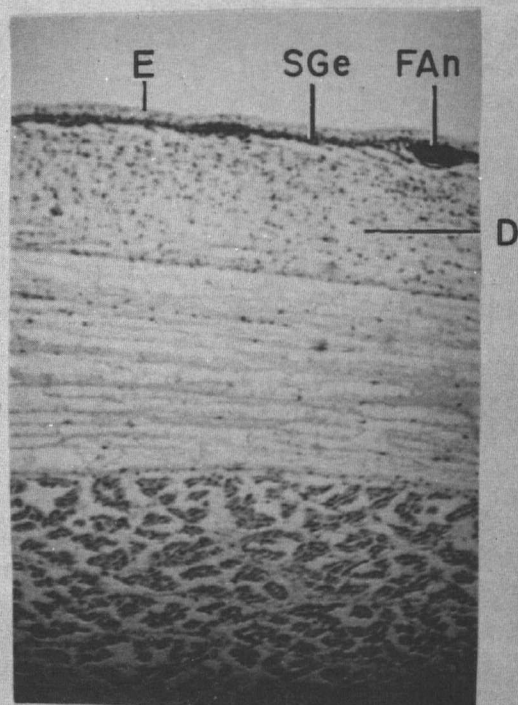


FIG 4.1

in primary follicles. Some of these are almost double the length of the other overcoat hairs and are scattered on the body about 2.5 cms. apart. I have referred to them as the large guard hairs. They are produced by some of the central primary follicles. The rest of the central primary follicles and all of the lateral primary follicles give rise to what I call intermediate guard hairs. These constitute the rest of the overcoat. Of course there is a good deal of variation in size of the intermediate guard hairs but consistently in a trio those produced in the central primaries are larger than those produced by the lateral primaries. All the hairs produced by primary follicles are medullated.

The black tailed fawns are characterized by possession of white spots on their body. These are formed by the occurrence in these sites of hair possessing white distal extremities. These hairs appear to be produced mostly in central primary follicles and some in lateral primaries. The white tipped part has a greater development of the cortex and a medulla devoid of intracellular cavities. In subsequent hair cycles these hairs are replaced by normal outercoat hairs. This phenomenon by which a hair follicle produces one type of hair at one stage and another type at a different stage is not unusual. Wildman (1927), reports this occurring in some sheep, including fine woolled merino.

The secondary follicles of the black tail deer give rise to the undercoat. This is not visible externally but is woolly and is pronouncedly developed in the animal's winter coat. It is interesting and important to note that the first formed secondary follicles produce medullated hairs, whereas the rest of the

secondaries produce non medullated hairs. The bulk of the undercoat consists of the latter.

In the course of this study I have also classified follicles on the basis of hair types produced by them. This makes the study of their individual development easier. The classification is as follows:

a) Large guard hair follicles. These are some of the central primaries producing large guard hairs.

b) Central intermediate guard hair follicles. These are the rest of the central primaries, which produce intermediate guard hairs. The hairs produced by them are longer and larger than those produced by lateral intermediate guard hair follicles i.e. lateral primaries.

c) Lateral intermediate guard hair follicles. They are the same as the lateral primaries and produce intermediate guard hair follicles.

d) First formed secondary follicles. These are larger than the later formed and produce medullated hairs. These follicles like the primaries possess sweat gland, sebaceous gland and arrector pili muscle.

e) Later formed secondary follicles. These are small. Possess only sebaceous glands (the smallest may even lack these) and produce non medullated woolly underhair — constituting the bulk of the undercoat.

At this stage it should be noted that in the fawn birth coat some of the central primaries and lateral primaries give rise to guard hairs with white tips. These hairs are characterized by greater thickness of the cortex, and by possessing a

medulla devoid of intracellular cavities, so characteristic of the medulla of other overcoat hairs. On the other hand the medullary cells appear to be full of droplets — perhaps of trichohyaline.

The observations on follicle development that I have been able to make are as follows: The general mammalian stages of follicle development are noticed in the black tail deer. However variations from the normal have been documented in a number of places.°

#### Large guard hair follicles

These are the earliest follicles to develop and can be identified by their greater depth of penetration into the dermis. Where present they constitute the central follicle of the primary trio grouping. These follicles give rise to the large guard hairs. They are beginning development in a 112 mm. foetus; are actively producing hair in a new born fawn, and are generally resting in a five week fawn. They possess sweat gland, sebaceous gland, and arrector pili muscle. The external root sheath is well developed and prominently nucleated. The follicle bulb is large and oval. The inner root sheath is also prominent — particularly the Henle's layer. Compared to the size of the follicle the sebaceous gland is small. Just below the junction of the sebaceous gland the follicle appears to dilate in the form of a bulbous cavity, the lining of which (made of inner root sheath) has a folded appearance. These "follicular folds" are supposed to be part of the break down of the inner root sheath and have also been noticed in case of the common american goat, Sar . . .

Developing skin and hair follicles. 202 mm stage.

FIGURE 5.1

The epidermis has increased in size and periderm is distinct. The sweat gland is developing and follicle base is half enveloping the dermal papilla. The fibrous deposition in dermis is also noticed. H. & E.

FIGURE 5.2

Transverse section of above. Notice sweat gland developing adjoining the hair follicle. H. & E.

Developing skin and hair follicle. 235 mm stage.

FIGURE 6.1

Longitudinal section. Notice well developed stratum spinosum. Periderm is peeling and below it granular layer (stratum granulosum) is forming. Sweat gland has no lumen. Sebaceous gland and hair canal formation is also present. Dermis is more compact. Rudimentary arrector pili development is seen. H. & E.

FIGURE 6.2

Transverse section of above. Sweat gland follicle relationship is seen. H. & E.

For explanation of abbreviations used please see Appendix IV, Page 214\*.



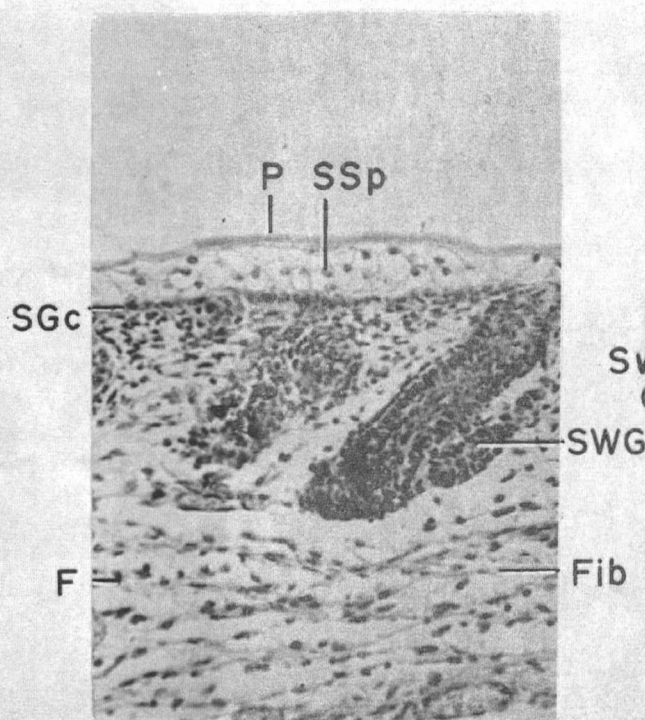


FIG 5.1

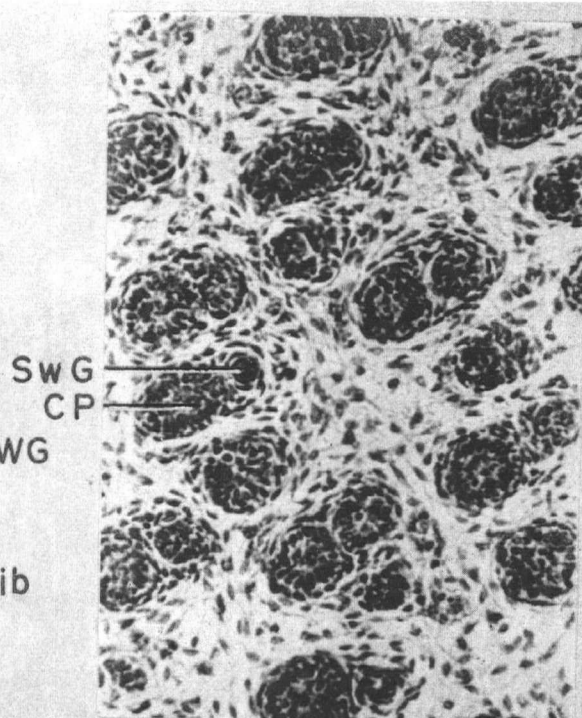


FIG 5.2

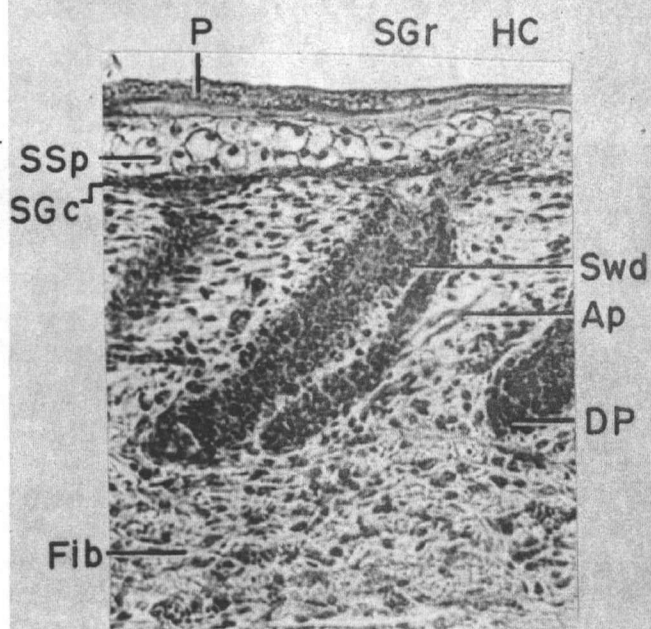


FIG 6.1

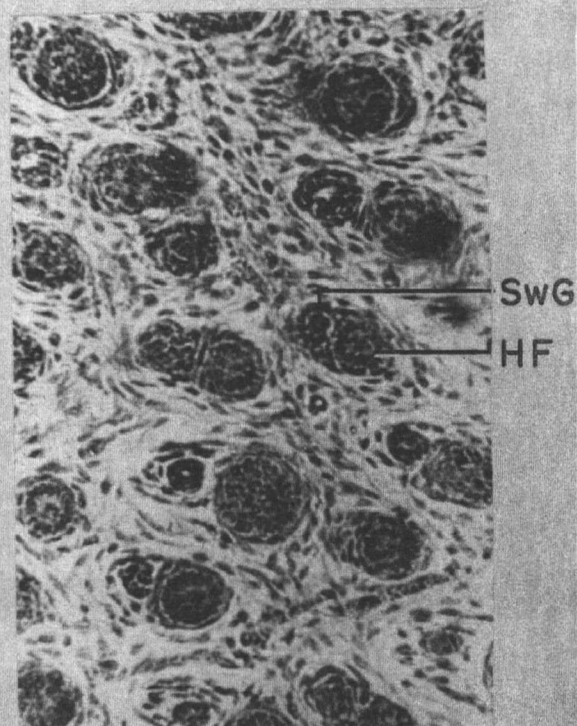


FIG 6.2

Developing skin and hair follicles. 269 mm stage.

FIGURE 7.1

Longitudinal section. Notice the compact epidermis and the distinctive stratum corneum. Sebaceous gland is distinctive so also its position vis a vis sweat gland. Dermis more compact and fibrous. Ental swelling and arrector pili muscle present. H. & E.

FIGURE 7.2

Transverse section of above. Large guard hair follicle distinct with hair. Sweat gland and bilobed sebaceous gland seen. First formed secondaries developing. H. & E.

Developing skin and hair follicles. 287 mm stage.

FIGURE 8.1

Longitudinal section. White tipped hair follicles clearly seen. Secondary follicles forming. H. & E.

FIGURE 8.2

Transverse section of above. Central primaries have larger hairs than lateral primaries. H. & E.

For explanation of abbreviations used please see Appendix IV. Page 214.

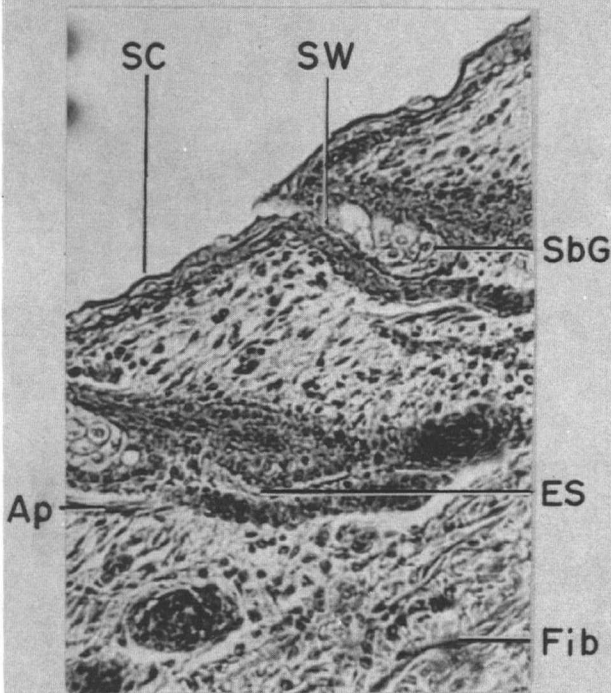


FIG 7.1

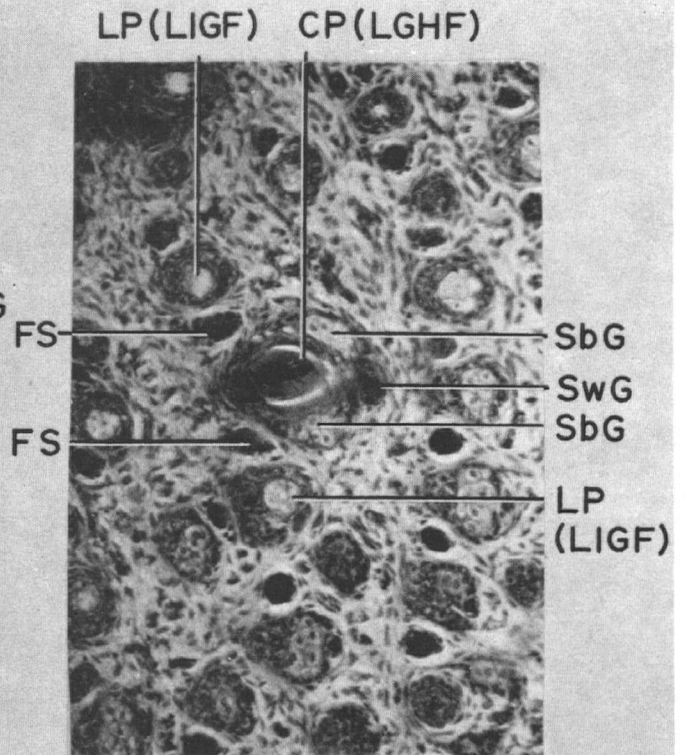


FIG 7.2

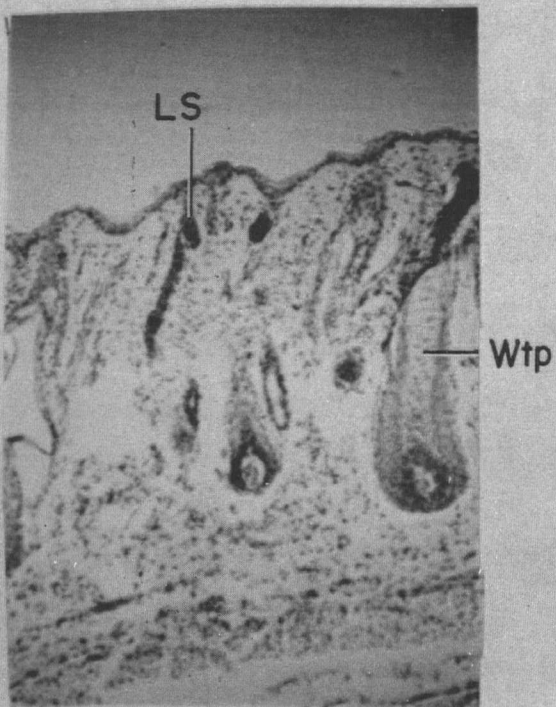


FIG 8.1

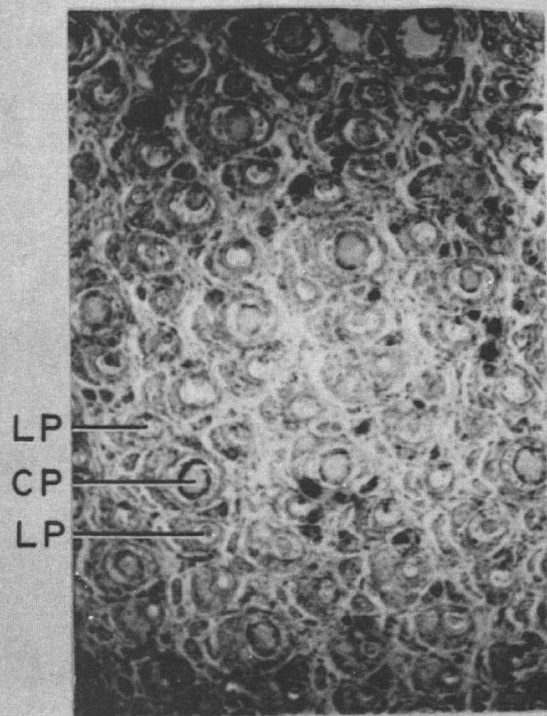


FIG 8.2

Developing skin and hair follicles. 321 mm stage

FIGURE 9.2

Longitudinal section. Notice size relationship of central primary to later formed secondaries still forming. H. & E.

FIGURE 9.2

Transverse section of above. H. & E.

Developing skin and hair follicles. 448 mm stage

FIGURE 10.1

Longitudinal section. General view. H. & E.

FIGURE 10.2

Transverse section of above. Notice white tipped hair follicles in section. H. & E.

For explanation of abbreviations used please see Appendix IV, Page 214.





FIG 9.1

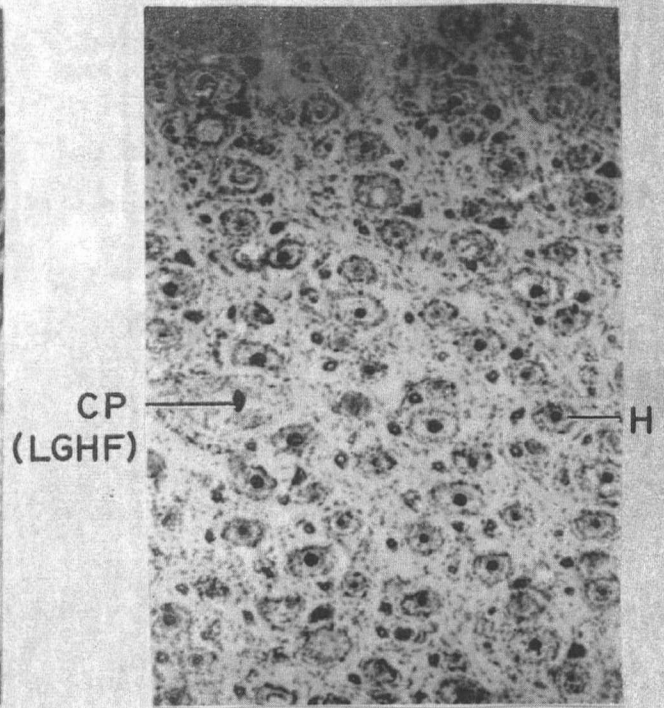


FIG 9.2

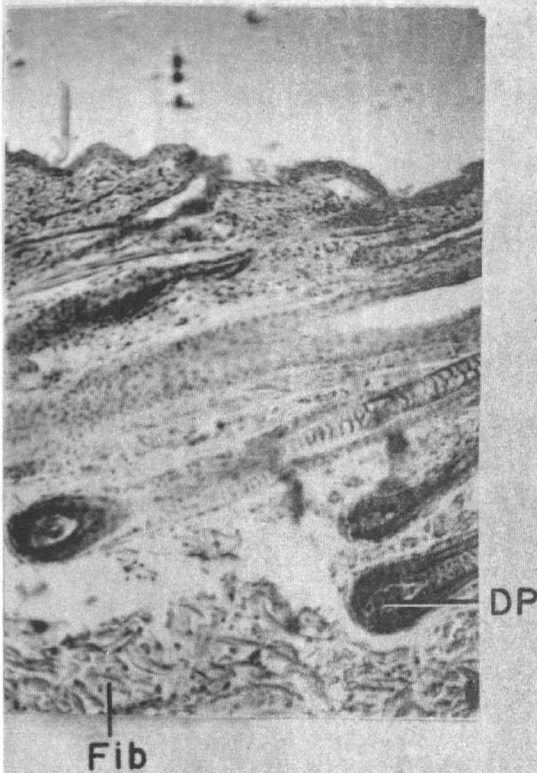


FIG 10.1

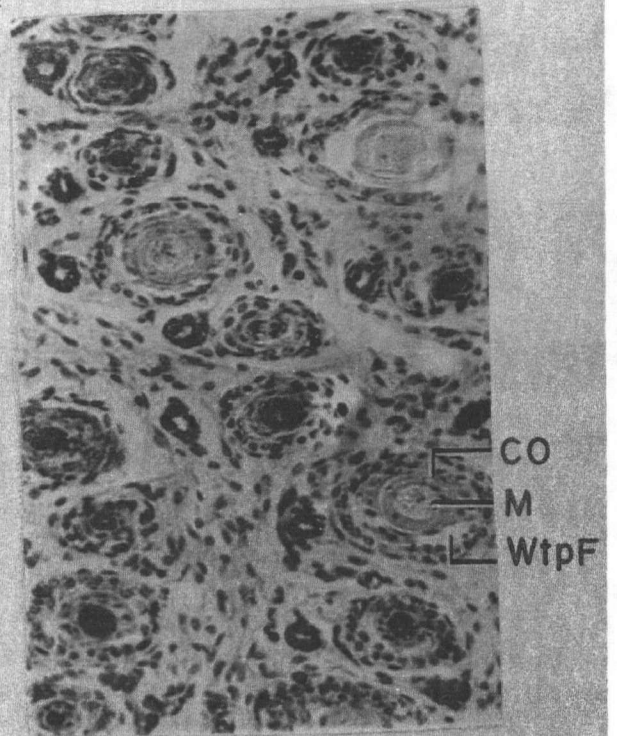


FIG 10.2

Large guard follicle. 287 mm stage

FIGURE 11.1

Longitudinal section. Notice large size of large guard hair follicle vis a vis other types and well developed external root sheath. H. & E.

FIGURE 11.2

Transverse section of above. Notice follicle arrangement. H. & E.

FIGURE 11.3

Longitudinal section. Close up of dilated upper part of large guard hair follicle and hair passing through it. Dermis is very compact now. H. & E.

FIGURE 11.4

Longitudinal section. Close up of the follicle bulb. Notice heavy melanin deposition in follicle and well developed external root sheath. H. & E.

For explanation of abbreviations used please see Appendix IV, Page 214.

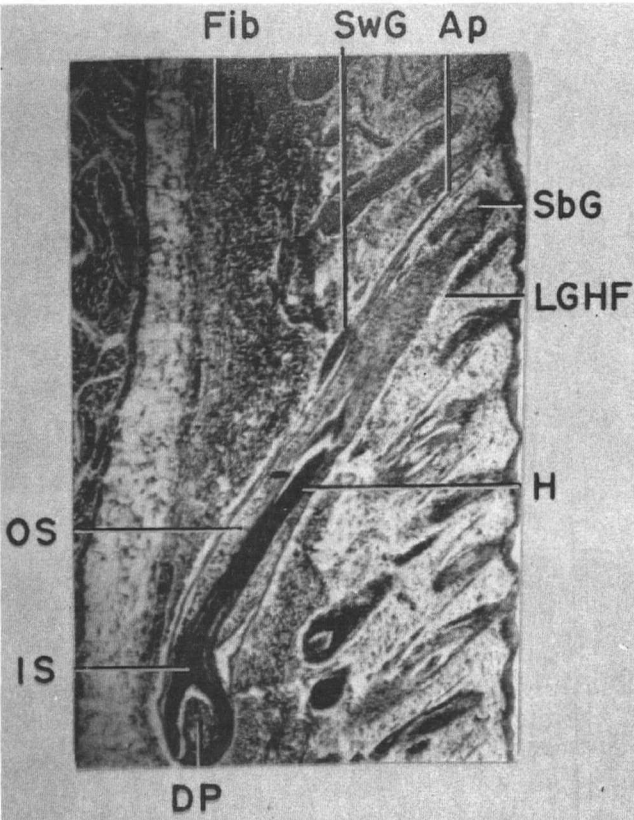


FIG II.1

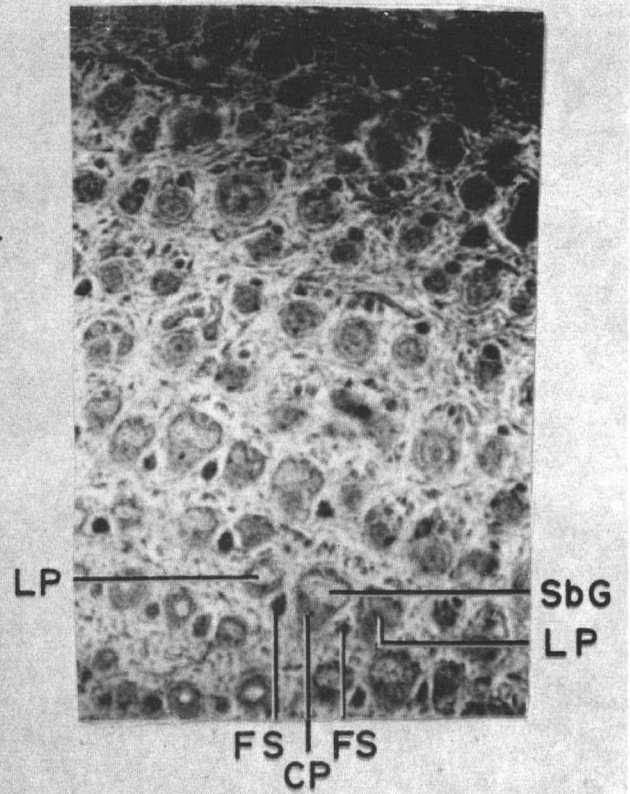


FIG II.2

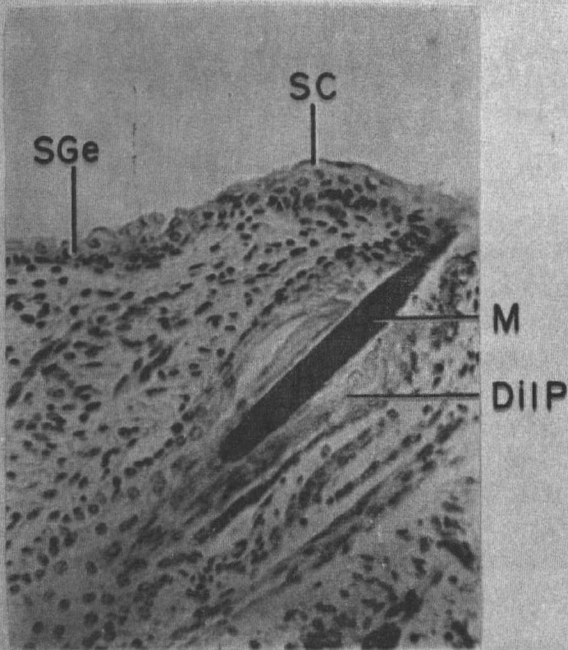


FIG II.3

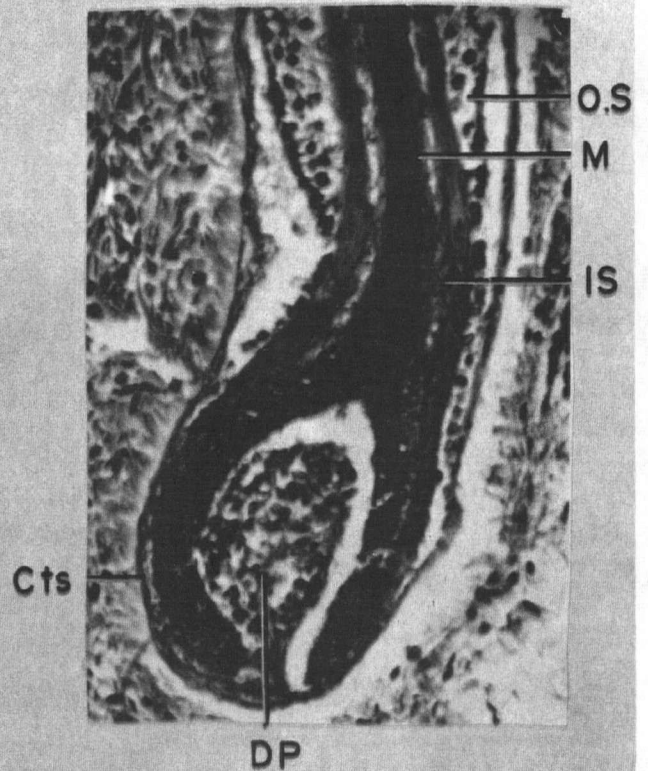


FIG II.4

and Calhoun (1966). It is pertinent to remark that the species studied by these authors is not known as they have used a meaningless name.

With the exception of Flerov (1960), who refers to occurrence of large guard hairs in the cervid genera Dama, Capreolus, and Elaphorus, no reference has been made to occurrences of such hairs or the large guard hair follicles in the ungulates. Straile (1960) discusses the occurrence of tylotrich in mammals (Mice, Rats and Rabbits) and their function. The tylotrichs are much larger than the surrounding guard hairs and are sparsely distributed. They are sensory hair types arising in follicles which possess, amongst other things, an "Annular complex" consisting of connective tissue, capillaries and nerve endings, surrounding the follicle below the level of sebaceous gland. The orifice of the follicle is also characterized by possession of a special thickened area of the epidermis called "Haarschiebe" surrounding the orifice. The tylotrich follicle is sensory and is intermediate in size between the vibrissa follicle and the normal hair follicle.

In the living adult Odocoileus the large guard hairs are scattered over the body and are prominently longer than other outercoat hairs. If they are touched in the living animal the skin is twitched in response. This is not true with the hairs of other types. Thus the large guard hair follicles appear "prima facie" to be possessed of greater sensory function than normal hairs. In Odocoileus they start development slightly earlier than other primary follicles but grow to much greater length because of greater rate of growth during the follicle development, and a longer hair growth period. Their upper part was



occasionally dilated. The hairs produced by them are the first to emerge on the surface. No distinctive "Annular complex" or "Haarschiebe" have been detected in tylotrich follicles of Odocoileus.

The developmental stages undergone, as observed (Table II) are similar to the standard mammalian stages (Lyne and Heideman, 1959) but owing to faster rate of embryonic growth are a stage or two ahead of other central primaries. They differ in some anatomical features already discussed and in the longer period of hair growth — thus they are the first to rise and last to come to rest.

All in all the present evidence suggests that the large guard follicles of Odocoileus, though morphologically a little different, are developmentally and functionally related to tylotrichs of Straile (1960).

#### The intermediate guard hair follicle

The overwhelming majority of follicles giving rise to the overcoat of Odocoileus belong to this category. They consist of central primaries (i.e. all other than those giving rise to large guard hairs) and all the lateral primaries. The lateral primaries are smaller in size than the central primaries and the difference is also reflected in the hairs produced.

Due to relative abundance of this type of follicle — their development has been studied in greater detail, particularly so in case of central primaries because of their large size.

TABLE II

Follicle types and their development stages

No.	Forehead Rump Length	A	B	C	D	E
		Central primary Large guard hairs	Central primary Intermediate Guard hairs	Lateral primary Intermediate Guard hairs	First formed Secondary	Later formed Secondary
T80A	46.2					
T27	89.5					
T36	112.0	1A*	1A	1A		
T41A	181.5	2B	2B	2A		
T46B	202.0	2B	2B	2A		
T54	211.5	3A-3B	2B-3A	2B		
T40A	235.0	3B-4	3B-3A	2B-3A		
T56A	236.0	4-5	4	3B		
M <sub>1</sub>	269.5	6,7,8	5-6	4	1A-2A	
T82	287.0	8	8	7-8	3a-3B	
T63A	321.0	8	8	8	8	1a-2A
T60B	335.0	8	8	8		
T66	366.0	8	8	8		
T69	422.0	8	8	8		
T70A	448.0	9	9	9	9	
Fawn	5 weeks	10B-10C	10B-10C	10B-10C	10C	Still forming

\*Details of stages given on pp 15-16

Central intermediate guard hair follicles (central primary type)

A 112 mm foetus shows these follicles in stage 1a. The developing follicle anlagen are located at intervals of approximately  $250\mu$  to  $294\mu$ . At this stage the diameter of this papilla is greater than its depth. These anlagen are formed by the proliferative activity of the basal layer of epidermis and make indentation in the dermo-epidermal junction. They are about  $70\mu$  wide and  $16\mu$  in depth. The dermal elements also are more thickly located below these anlagen -- thus the association of dermal elements with the hair follicle starts very early.

By 181 mm stage the follicles have reached the prepapilla stage i.e. is stage 2b. The growing follicles appear as rods of undifferentiated cells, enclosed in an organized cell layer of one cell thickness. The distal end of these growing follicles is marked by the presence of a mass of cells of dermal origin. These latter constitute the dermal papilla of the growing follicles. In addition to this a sheath of dermal origin covers the growing hair follicle and the dermal papilla. This is akin to the connective tissue sheath of the mature follicle. The dermal papilla at this stage is  $16\mu$  deep while the follicle depth varies from  $150\mu$  to  $117\mu$ .

At 236 mm stage the follicles have reached stages varying from 3b to 4. The base of the follicle has begun to envelop the dermal papilla. The ental swelling is present there. The depth of follicle penetration is  $226\mu$  to  $235\mu$ .

At 269 mm stage the follicles are in stages 5 to 6 and have reached depths from  $252\mu$  to  $268\mu$ .

At 287 mm stage all follicles of this type have reached

Central intermediate guard hair follicles

FIGURE 12.1

Longitudinal section. H. & E.

FIGURE 12.2

Transverse section. Notice sweat gland and sebaceous relationship and arrector pili muscle. H. & E.

White tipped hair follicles and lateral intermediate guard hair follicles

FIGURE 13.1

Longitudinal section white tipped hair. Notice greater development of cortex. H. & E.

FIGURE 13.2

Transverse section. Notice greater development of external root sheath in large guard hair. In white tipped hairs cortex is better developed. H. & E.

For explanation of abbreviations used please see Appendix IV, Page 214.

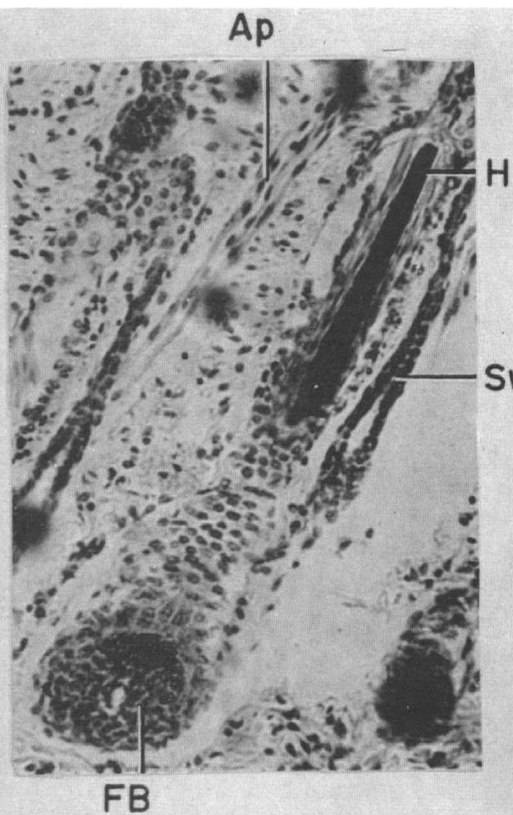


FIG 12.1

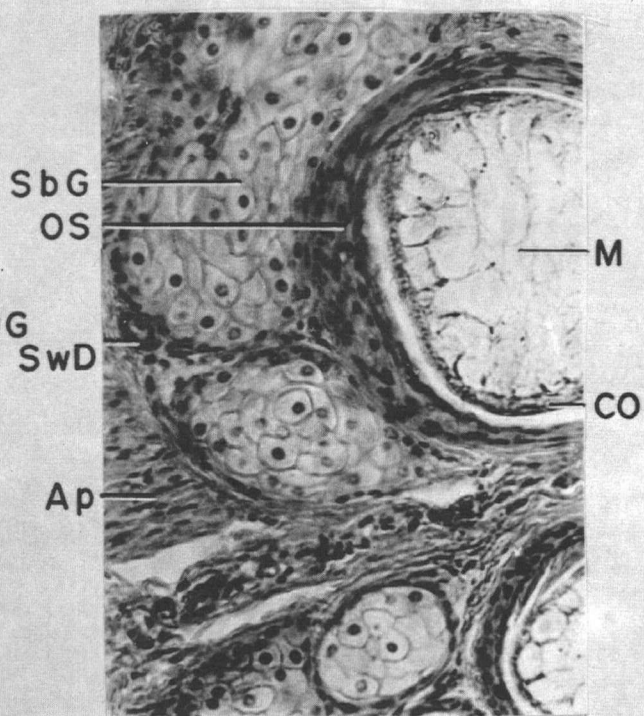


FIG 12.2

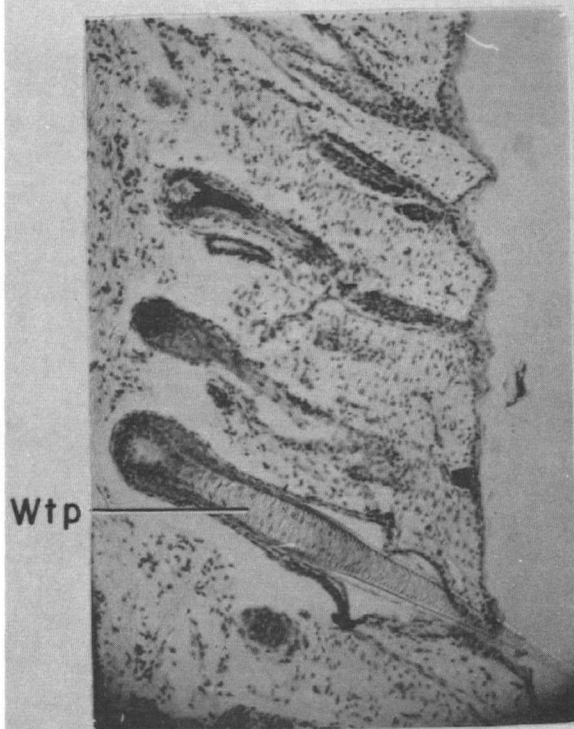
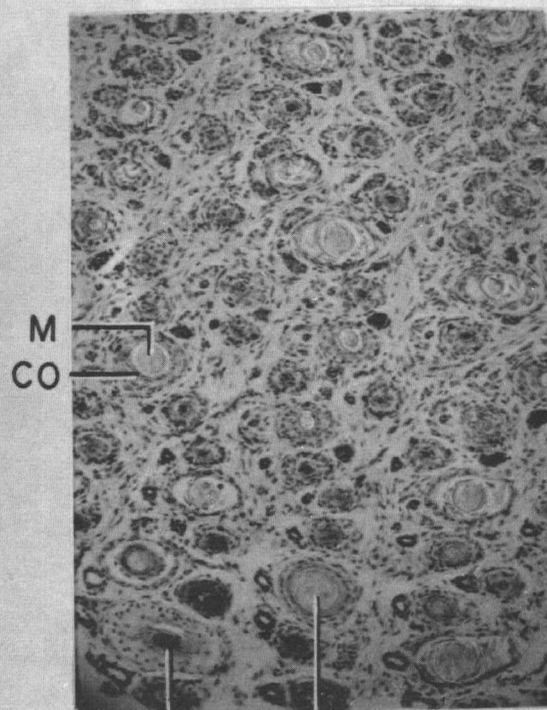


FIG 13.1



LGHF WtpF

FIG 13.2

stage 8 i.e. hair emerged. These follicles are still growing hair actively when the fawn is born, i.e. 448 mm stage (about) and stage nine is not reached until few weeks after birth.

Lateral intermediate guard hair follicles (lateral primaries)

These resemble the central intermediate guard hair follicles in all major respects — but are smaller in size. They are initiated a little later than the central primaries, and consequently lag behind 2 to 3 stages in development. For example in 287 mm stage the central intermediate guard hair follicles have reached stage 8 i.e. hair emerged, the lateral intermediate guard hair follicles appear to be in stages varying from 5 to 4, as noticed from Table II.

At this stage one would recollect that the fawn birth coat has white spots — caused by white tipped hairs occurring in that region. These are intermediate guard hairs arising in some of the central primaries and lateral primaries. Anatomically the follicles in which they arise are similar to the other intermediate guard hair follicles — except in the following:

- a) The dermal papilla has a pointed apex and is not of the normal spatulate type.
- b) The cortex is two to three times thicker than in the normal intermediate guard hair.
- c) The medulla is made up of cells which are filled with granular (trichohyalin) deposits. No intracellular cavities are formed. These cells are reminiscent of normal medullary cells at a stage just prior to formation of intracellular cavities. It would thus appear that in white tipped hairs the formation of intracellular medullary cavities is arrested.
- d) Melanocytes are present in the follicles — and they are confined to the cortical region. The portion of cortex above the bulb appears dark — but subsequently the pigmentation dilutes and the cortex appears, whitish-yellow.

In many mammals hair is not uniformly coloured but it has a terminal or subterminal band containing pheomelanin, and the base has melanin (agouti pattern). The white tipped hairs of Odocoileus, as well the winter coat guard hairs are of this type. In bicoloured hairs each follicle secretes all the pigments, occurring in a hair, the type of pigment secreted varying with stage of hair growth cycle. Systemic conditions may alter the intensity of the pigment present in any locality. Fitzpatrick et al (1958).

In biochemical activity in relation to pigment is thus different in white tipped hair and the variation in this activity in relation to the follicle producing pigmented hairs is an interesting biochemical problem in itself.

#### Woolly under hair follicles (secondary follicles)

These are secondary follicles and are of two types, the first formed — possessing sweat gland, sebaceous gland, arrector pili muscle and producing a small but medullated hair, and the later formed possessing only sebaceous gland and producing a non medullated woolly-type hair. The follicles of first type are fully formed and have emergent hairs prenatally. Those of the second type continue to form prenatally as well as postnatally — and become fully functional and effective in the fawn winter coat. As the material investigated is prenatal my emphasis is on development of first formed secondary follicles.

In a 269 mm foetus these arise singly. They are the first formed woolly follicles and are in developmental stage 1a to 2a.

In 287 mm stage the first formed woolly follicles have

developed a full complement of accessories. The later formed secondary follicles are forming by now and they arise in pairs or groups and individually are of varying sizes and in developmental stages 2 to 3a. There is no trace of the sebaceous gland as yet. In 231 mm stage the cells constituting the core of later formed secondaries show "upward streaming" appearance. Melanocytes are also noticed. By 335 mm stage the hairs have definitely emerged in all of the first formed secondaries. Later formed secondaries are still developing and new ones forming. The first formed secondaries often possess a bent bulb end — the external root sheath being slightly thicker in the angle of the bend.

At 336 mm stage — some of the first formed secondaries have started reaching resting stage, but the later formed secondaries still appear to be developing through stages 2b to 3a. This trend is continued in subsequent samples. In a five week fawn all first formed secondaries are in resting stage but later formed secondaries are still forming and developing. I have not established the age at which all follicles are complete.

#### Follicle anatomy

Montagna (1956) and Montagna and Ellis (1958) have summarized the current concepts about structure of the hair follicle and its function. Studies of Straile (1965), Priestly and Rudall (1965), Cohen (1965), have also furthered our understanding of some of its structural aspects. My material did not permit study of cellular and intracellular detail. Auber's (1950) contribution on follicle anatomy is of particular importance here as it deals with an ungulate hair follicle (sheep). Anatomically the hair follicle can be considered in the following parts.



## Secondary follicles

### FIGURE 14.1

Developing secondary follicles. Longitudinal section. Notice the developing follicle and the dermal papilla. H. & E.

### FIGURE 14.2

Paired secondary follicles developing. Longitudinal section. One member is larger than the other. H. & E.

### FIGURE 14.3

Branching secondary follicles. Longitudinal section. H. & E.

### FIGURE 14.4

First formed and later formed secondaries. Longitudinal section. Notice the arrector pili muscle in first formed secondary follicle. H. & E.

For explanation of abbreviations used please see Appendix IV. Page 214.

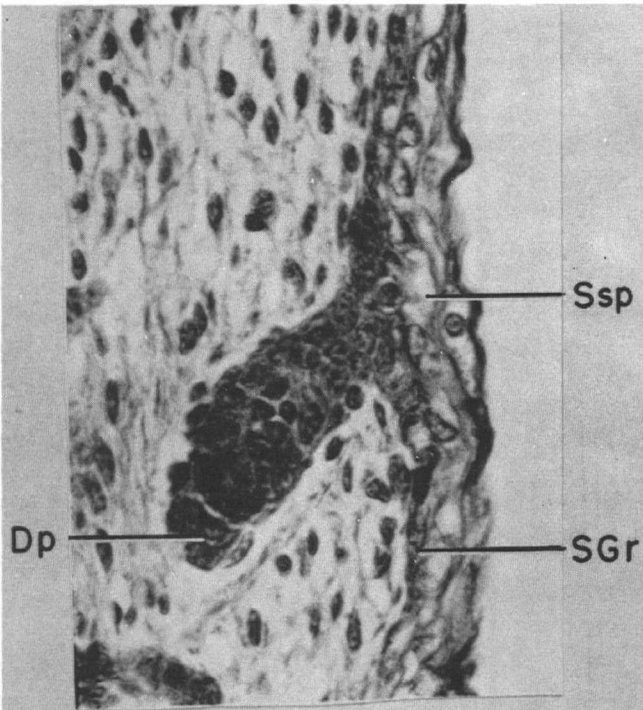


FIG 14.1

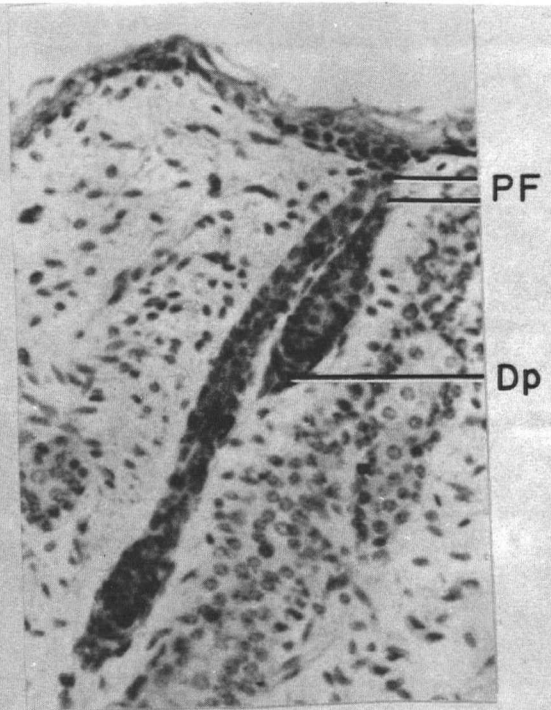


FIG 14.2



FIG 14.3

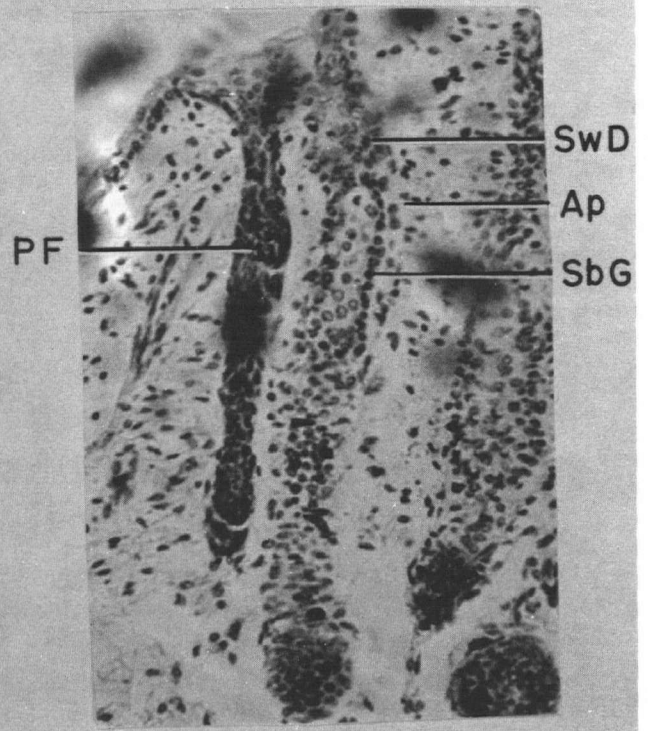


FIG 14.4

FIGURE 14.5

Paired secondary follicles in adult material. Longitudinal section. Notice the compact epidermis, the peeling stratum corneum and the non medullated hairs in follicles. H. & E.

FIGURE 14.6

Secondary follicles, adult material, longitudinal section, of lower part. Notice the well developed external root sheath and its membranes. The hair produced is non medullated. H. & E.

For explanation of abbreviations used please see Appendix IV, Page 214.

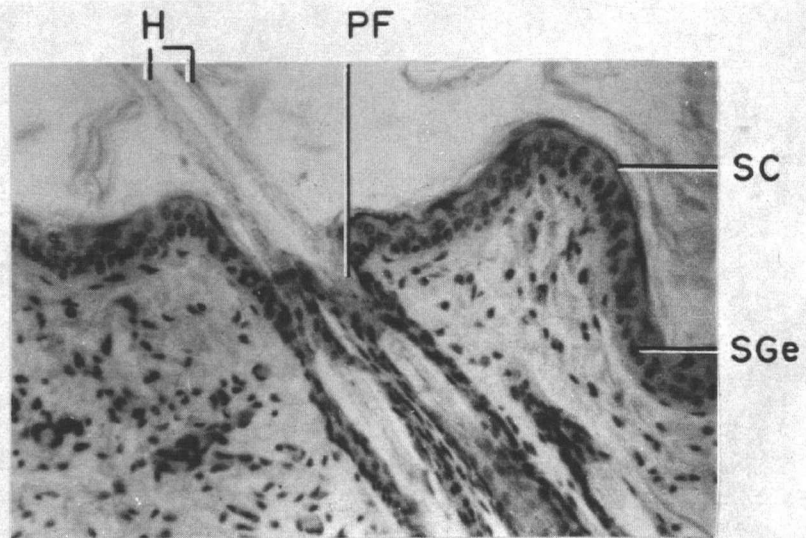


FIG 14.5

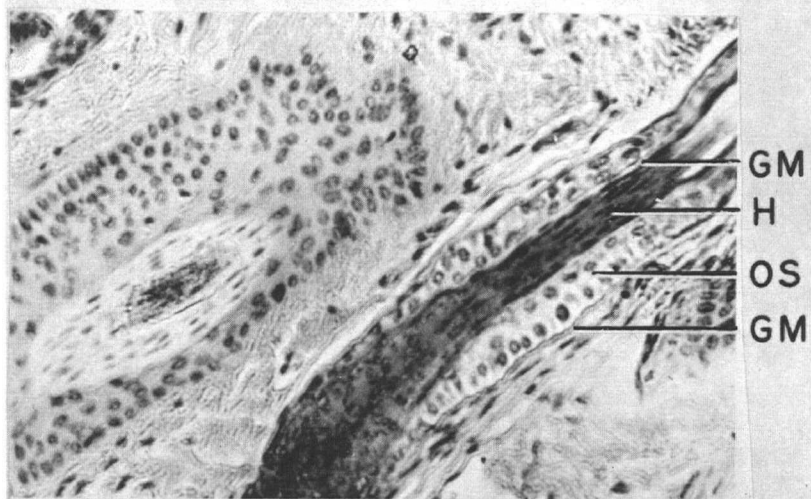


FIG 14.6

Fig. 15. Details of follicle anatomy.

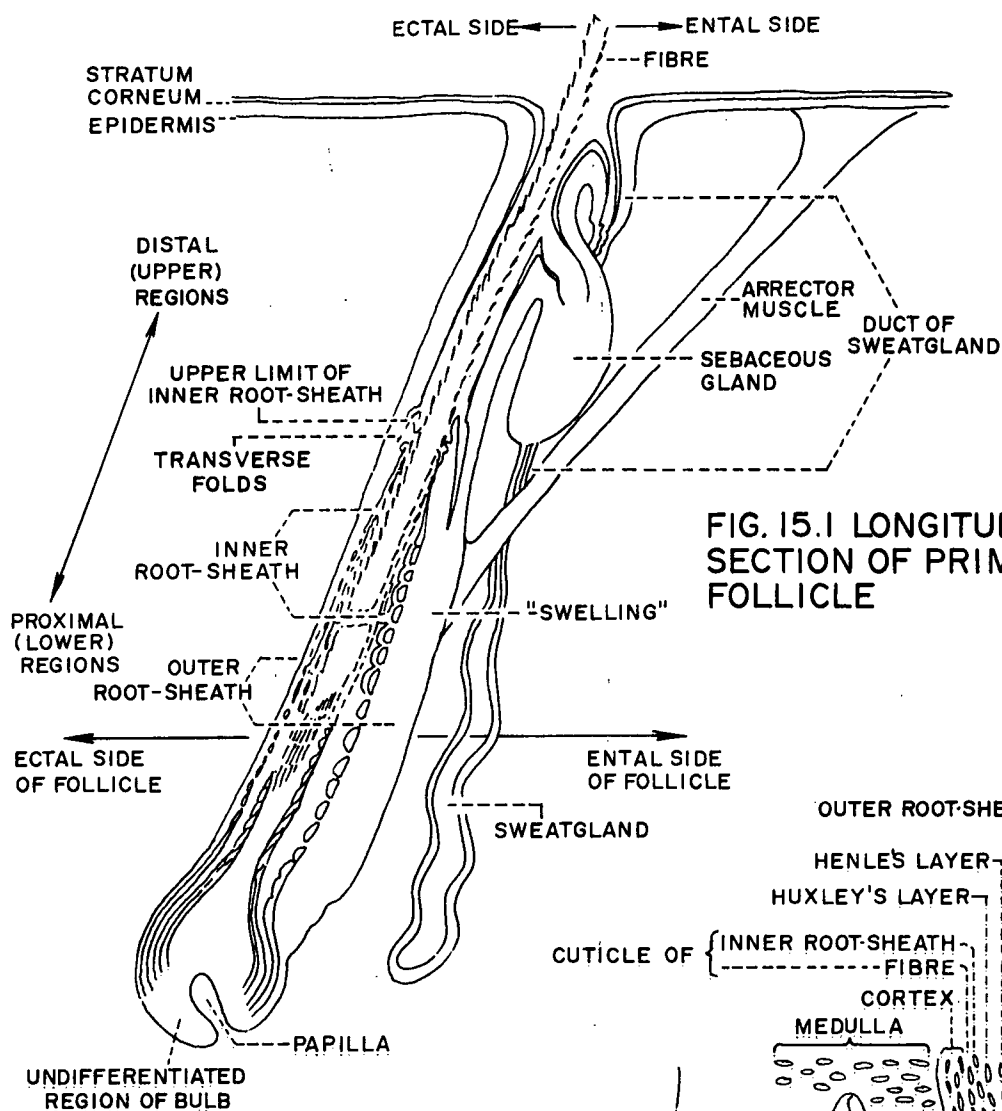


FIG. 15.1 LONGITUDINAL SECTION OF PRIMARY FOLLICLE

FIG. 15.2 DETAILS OF BULB, LONGITUDINAL SECTION

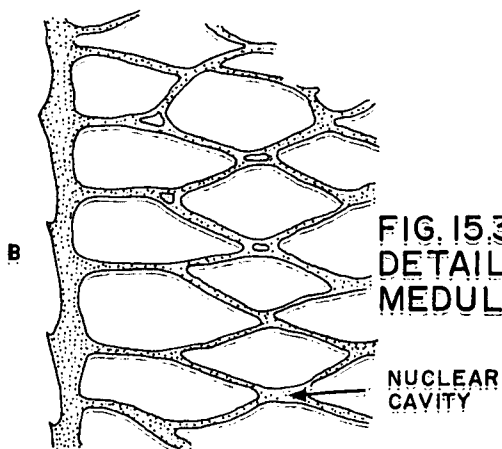
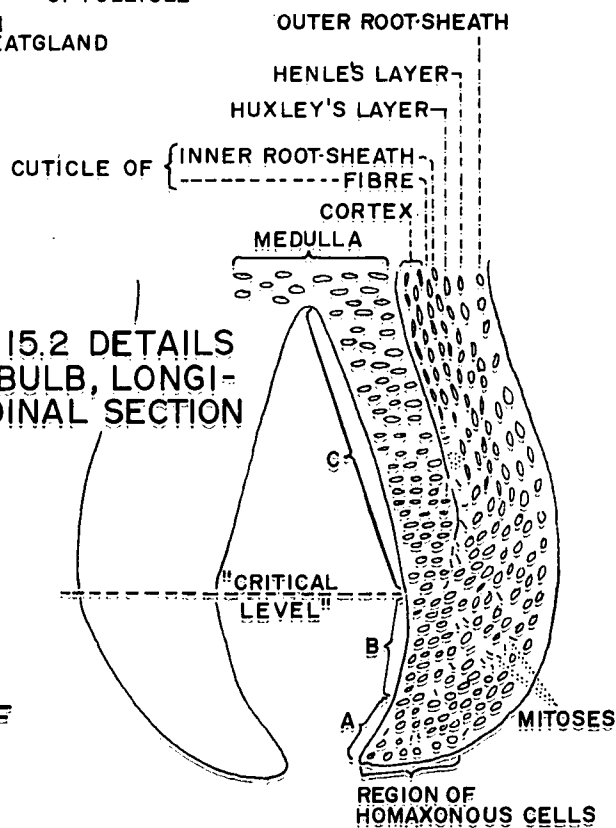


FIG. 15.3 DETAILS OF MEDULLA

### The connective tissue sheath

This is common to all types of follicles. The dermal elements are associated with the follicles since stage 1a. In subsequent developmental stages there is a definite connective tissue layer enclosing the follicle and dermal papilla. In earlier stages it is continuous with the dermal papilla — in later stages it is distinct from it. In mature follicles it's cells are compactly arranged.

### The glassy membrane

This is a characteristic feature of all follicles but is visible only in those that are mature but actively growing, then only in the lower segment. It is a hyaline glassy membrane located between the external root sheath and connective tissue sheath. This membrane is more prominent, almost double the thickness in the secondary follicles, than in the primary. Curiously a similar membranous structure has also been detected between the external root sheath and the inner root sheath. Such a membrane has not been referred to in any other follicles and may be a characteristic cervid feature. It is not always clearly visible none the less is a facet worthy of further investigation.

### External root sheath

In the early foetal stages this is distinguished by its larger cells and nuclei and by the fact that it forms the boundary of the follicle. In the 287 mm stage onward the external root sheath attains its characteristic form and the cells have a clear cytoplasm and prominent nuclei.

Anatomically the external root sheath can be divided into three regions.

- a) As a covering of the follicle bulb it is one celled in thickness and it is made up of compact well nucleated cells.
- b) In the part of follicle above the bulb it has a stratified structure, here it becomes two to three layered. The cells adjoining the inner root sheath are irregular in outline with oval nuclei. Those towards the periphery are oriented in a direction perpendicular to the axis of the follicle and bear elongated nuclei.
- c) Towards the apex of the follicle the external root sheath becomes reduced in thickness and merges with the epidermis.

This is noticed in all the follicle types. The external root sheath of the large guard hair follicle is thicker and has larger cells when compared to the other follicles. In the case of later formed secondaries the external root sheath appears at times thicker on one side than on the other, but this is not uniform at all.

#### The inner root sheath

Starting from the periphery the inner root sheath consists of the following layers:

- a) Henle's layer
- b) Huxley's layer
- c) Inner root sheath cuticle

In Odocoileus the inner root sheath does not show any radical departure from the general mammalian features. The inner root sheath components are not clearly observable in the pre-natally developing follicles. They are best studied in the upper half of the bulb of the adult follicle when actively producing hair, and my observations on them are as follows:



Deer primary follicle bulb

FIGURE 16.1

Close up of follicle bulb. Longitudinal section. Notice the dermal papilla and its stalk, so also other follicle components. H. & E.

FIGURE 16.2

Cell layers in the inner root sheath. Longitudinal section. Notice cells of Henle's layer, Huxley's layer, inner root sheath cuticle and hair cuticle. H. & E.

Medulla formation

FIGURE 17.1

Medulla in primary hair follicle. Notice the intracellular cavities. H. & E.

FIGURE 17.2

Medulla in white tipped hair of fawn birth coat. Notice the absence of intra-cellular cavities. H. & E.

For explanation of abbreviations used please see Appendix IV. Page 214.

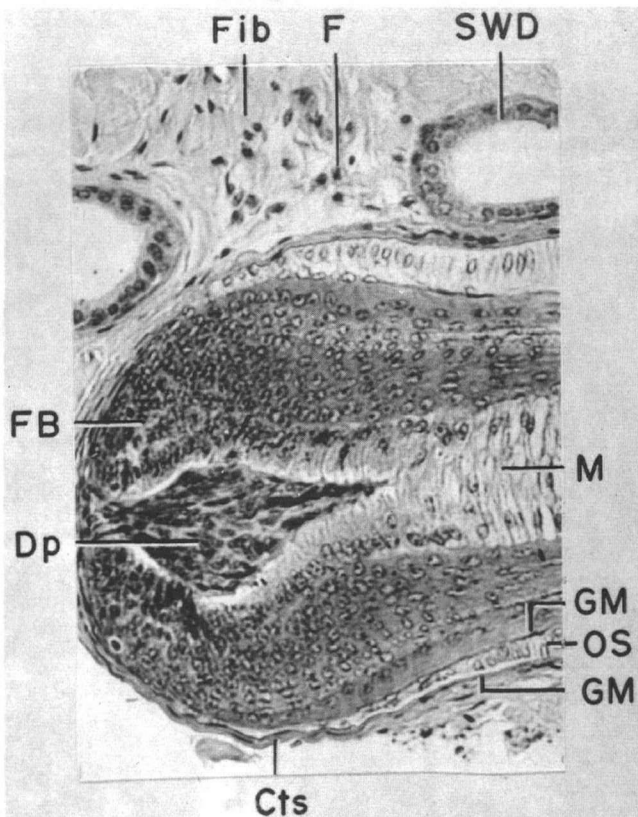


FIG 16.1

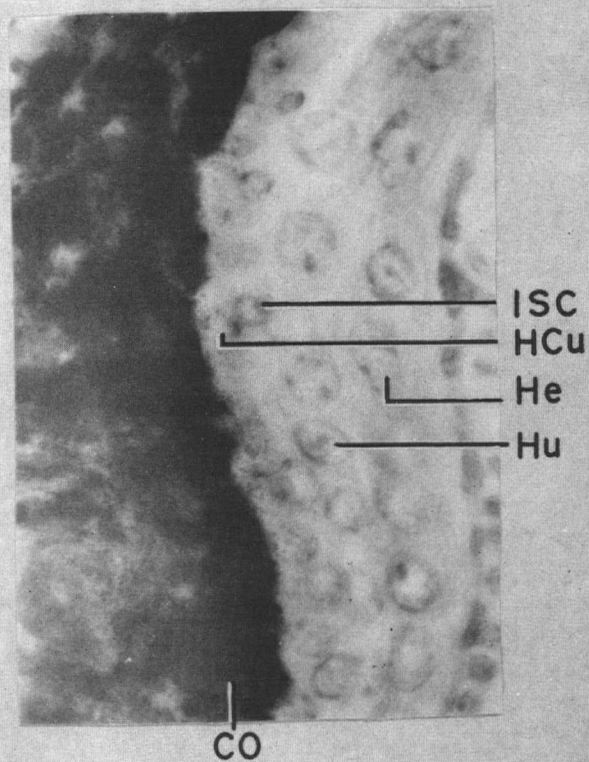


FIG 16.2

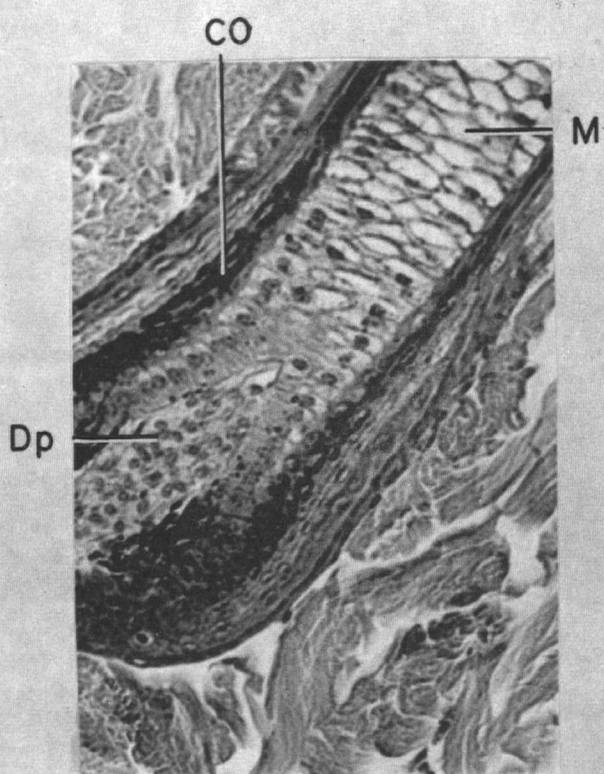


FIG 17.1

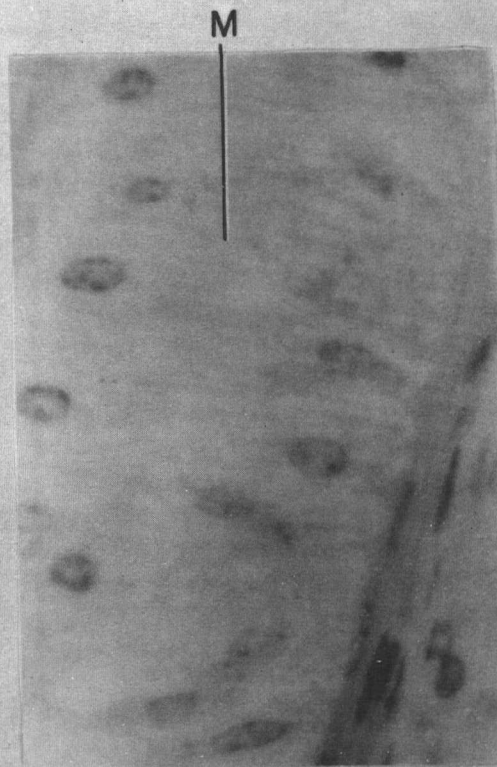


FIG 17.2

### Henle's layer

Most prominent of inner root sheath layers. Cells are large and rounded. It is bounded on the outer side by a glassy membrane, visible at places and then beyond that by the external root sheath. It is one celled in structure and is more darkly staining with eosin - haematoxylin than other inner root layers. The layer also has fibrous material whose percentage increases as one proceeds towards the follicle orifice.

### Huxley's layer

This also is one celled in thickness, but the cells are oval, a little smaller than Henle's layer cells, and compared to it are lightly staining.

### Inner root sheath cuticle

These cells are rounded in outline and the smallest of inner root sheath cells. As they rise upwards they elongate in the direction of the follicle axis, and form downward pointing scales which interlock with those of the hair cuticle. Thus the hair and the inner root sheath move upwards together in the follicle till they reach the vicinity of the sebaceous gland, where the inner root sheath breaks up. The Henle's and Huxley's layer fuse together in the upper reaches of the follicle, till they also break up in the vicinity of the sebaceous gland.

Straile (1965) suggests that the root sheath and the dermal papilla together affect the shape, size and movement of hair and therefore appear to be of great consequence.

## The fibre anatomy

The fibre can be divided into its three components, cuticle, cortex and medulla.

### The hair cuticle

In the upper regions of the bulb, the hair cuticle cells, which are rounded and larger than the adjoining cells of inner root sheath, cuticle, are easy to distinguish. As they rise upwards they elongate in the axis of the follicle and form the cuticular scales of the hair. These are pointing upwards and interlock with those of the inner root sheath.

### The cortex

Auber (1950) categorizes the differentiation of cortex within a fibre into four stages.

- a) The "preelongation region"
- b) The region of "cellular elongation"
- c) The cortical "prekeratinization region"
- d) The fully "keratinized region"

In Odocoileus the formation of the cortex has not been observed well. In hair fibres with prominent medulla, the cortex is reduced to a thin strip between the hair cuticle and the medulla. Most of the guard hairs are of this type. But in smaller fibres, e.g. later formed secondaries, the medulla is absent and the cortex with its sheath of cuticle constitutes the fibre.

In the other half of the bulb the cortical cells are characterized by their rounded appearance and large number of

melanocytes. In the higher regions of the bulb the cortical cells get elongated in the axis of the follicle and when fully keratinized form a compact homogeneous mass. No evidence of cortical fusi has been detected in Odocoileus. In the guard hairs the cortex of white tipped hairs is better developed and is two to three times thicker than that of other guard hairs.

### The medulla

In Odocoileus many of the guard hairs are heavily medullated. The medullary cells are noticed rising on each side of the dermal papilla in the upper half of the bulb. Externally on either side they are bounded by cortical cells. They are formed on the lower part of the bulb and have larger nuclei than the cortical cells. Initially their cell margins are not distinct but when observable are triangular or rhomboidal in form. The nuclei are large and melanin granules have been noticed in the cells. As the cells rise to the upper limits of the dermal papilla they are full of granular and fibrous material. As they extend further, vacuoles form in the cells and increase in size, subsequently occupying the whole cell and relegating the nuclei to the cell wall nearest to the dermal papilla. The medullary cell margins are strong and quite prominent and together with the central cavities present the characteristic medullar features.

Auber (1950) has elegantly discussed the formation of medulla and though Odocoileus follows the same general pattern many of the details as discussed by Auber have not been observed.

### The follicle bulb and dermal papilla

The base of the follicle which encloses the dermal papilla

is called the follicle bulb.

The follicle base first becomes bulbous in 181 mm foetus. The dermal elements later to constitute the dermal papilla are located adjoining the follicle base. In a 235 mm foetus the follicle base gets notched and the dermal papilla elements present a rounded more compact form. At 269 mm stage as much as three fourths of the dermal papilla is enclosed by the follicle base. In a 448 mm foetus the relationship between dermal papilla follicle bulb, and the covering connective tissue sheath becomes apparent. The dermal papilla is more or less fully enclosed by the follicle base and maintains contact with the connective tissue by means of a distinct stalk. This is characteristic of the adult material too.

The wall of the bulb is epidermal in origin and an extension of the external root sheath. It is responsible for giving rise to the cells which constitute the various follicles and fibre layers. These cells as they arise in the lower half of the bulb are undifferentiated but as they rise to upper regions of the bulb they get organized into the rudiments of different follicular and fibre layers.

The dermal papilla, as the name suggests, is dermal in origin and is believed to supply nutrients to the developing follicle. It consists of an agglomeration of well nucleated cells. It's exact role in the biology of the follicles is complicated and not well understood but has been discussed by Cohen (1965).

In Odocoileus it has been noticed that heavily medullated hair follicles have rounded bulbs and spatulate dermal papillae, whereas in non medullated hair follicles it is oval and the dermal

papilla has a narrow appearance and pointed apex. In the white tipped hair follicles, characterized by greater cortex a smaller non vacuolated medulla, the dermal papilla has a pointed apex. Thus papilla shape has direct relationship with the type of hair produced. What exactly this relationship is and how it operates is beyond the scope of the present work.

### Melanocytes

The growing hair follicles of Odocoileus are characterized by the presence of melanocytes.

In guard hair follicles they first appear in 202 mm foetus. The visible melanocytes are dark coloured, few, and scattered within the follicle. Some may be located in its external margin and an isolated few may occur even in basal layer of the epidermis. Subsequently they concentrate in the bulb. The melanocytes here are dendritic.

Of course the amount of melanocytes depends on the colouration and type of fibres being produced. The melanin deposited by melanocytes is confined to the hair fibre only and there too to the cortex, and the basal parts of the medulla. Variations in colour of summer and winter hairs in adult can be explained on the basis of the biochemical activity of melanocytes.

### Sweat gland

All follicles, except those of the woolly underhair, possess apocrine sweat glands. Initially they develop as bag like outgrowths from the neck of the follicle. The sweat gland at this stage is a solid outgrowth devoid of any lumen and the cells constituting it are similar to those of the follicle.

Sweat gland

FIGURE 18.1

Sweat gland forming at 202 mm stage.  
Longitudinal section. H. & E.

FIGURE 18.2

Sweat gland at 236 mm stage. Longitudinal section. Notice the position of sweat gland and arrector pili muscle. The hair is developing. H. & E.

FIGURE 18.3

Sweat gland at 269 mm stage. Longitudinal section. Notice its desposition in relation to sebaceous gland, and the gentle waviness which has begun. H. & E.

FIGURE 18.4

Sweat gland in adult material. Longitudinal section. Note the coils have been sectioned and possess a one cell thick lining. The inner root sheath and hair cuticle are also clear. H. & E.

For explanation of abbreviations used please see Appendix IV. Page 214.



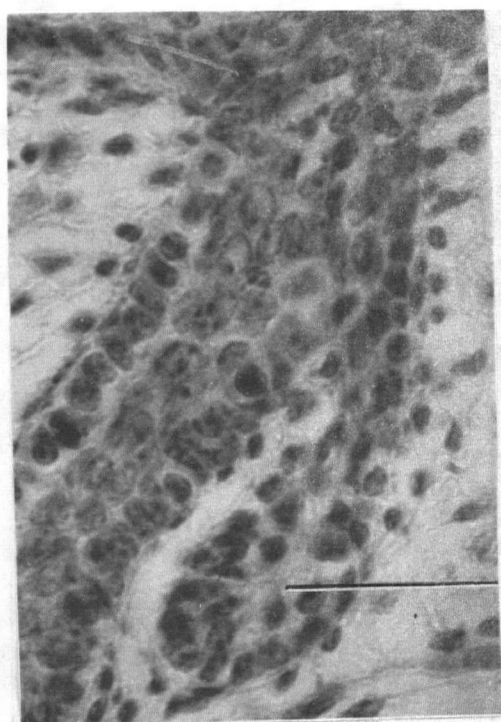


FIG 18.1

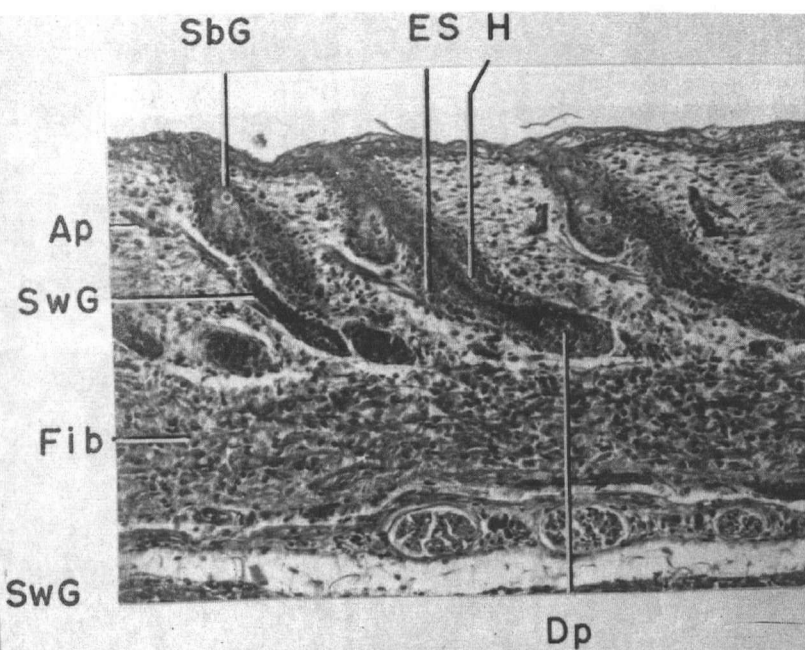


FIG 18.2

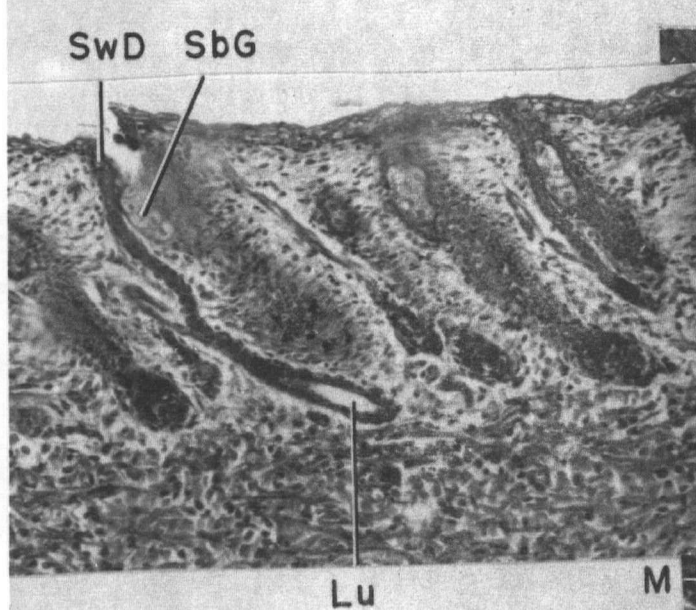


FIG 18.3

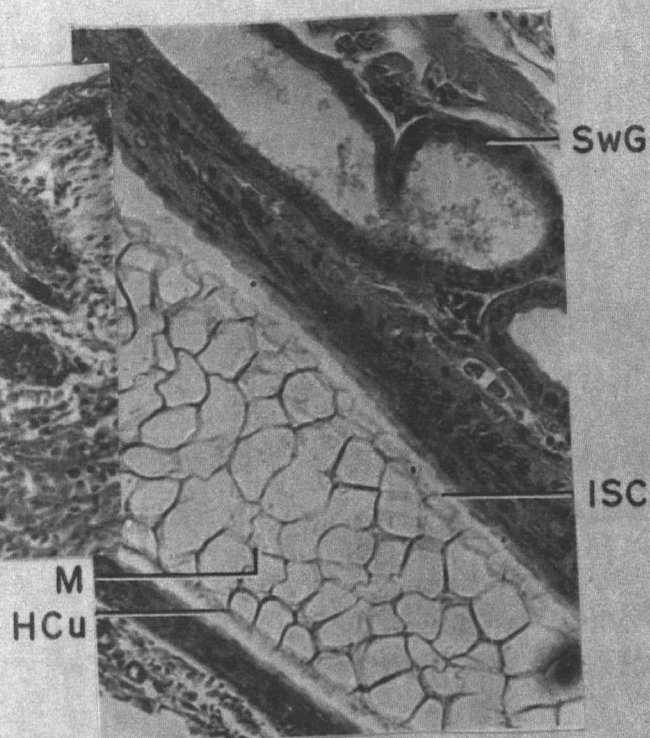


FIG 18.4

By the 211 mm stage the sweat gland has reached up to the top of follicle bulb, and differentiation begins to take place within the gland. The distal part develops a lumen, but the proximal part of the gland, where the sweat duct forms is at this stage still a solid mass of cells. The complete gland does not differ radically from the typical mammalian pattern in form or in constituent cells. The thickness of lumen wall is about  $33\mu$  and the lumen diameter (inner) is about  $184\mu$ . The wall of the duct is single celled and its thickness as well as the diameter of the duct is about  $42\mu$ . The sweat duct passes over the surface of the sebaceous gland in between its two lobes and opens by means of a funnel shaped opening into the hair follicle near the skin surface.

#### Sebaceous gland

All follicles except the smallest of the secondaries possess sebaceous glands. The primaries and first formed secondary follicles possess bilobed sebaceous glands, this is not so in smaller secondaries.

The sebaceous glands originate after the sweat glands, and their first traces are observed in 181 mm foetus. They are developed first in larger follicles. The sebaceous gland rudiments consist of few large rounded cells with clear cytoplasm and prominent nuclei. By 269 mm stage they resemble in appearance a grape bunch. By 335 mm the bulk of the gland is formed of large cells with clear cytoplasm a large centrally placed nucleus.

## Sebaceous gland

### FIGURE 19.1

Sebaceous gland rudiment. 235 mm stage. Longitudinal section. Notice its participation in hair canal formation. H. & E.

### FIGURE 19.2

Sebaceous gland at 269 mm stage. Longitudinal section. Notice the typical gland cell with prominent nuclei. The developing hair is lying next to it. H. & E.

### FIGURE 19.3

Sebaceous gland opening in adult material. Longitudinal section. Notice the lobed nature of the gland and its short duct which opens into the hair follicle. H. & E.

### FIGURE 19.4

Sebaceous gland and the follicular folds. Longitudinal section. The folds are caused by disintegration of inner root sheath near sebaceous gland. H. & E.

For explanation of abbreviations used please see Appendix IV. Page 214.

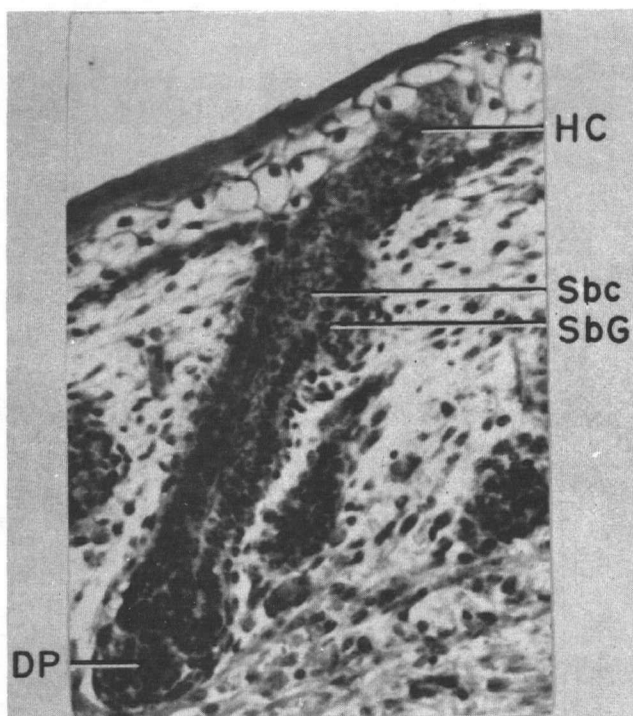


FIG 19.1

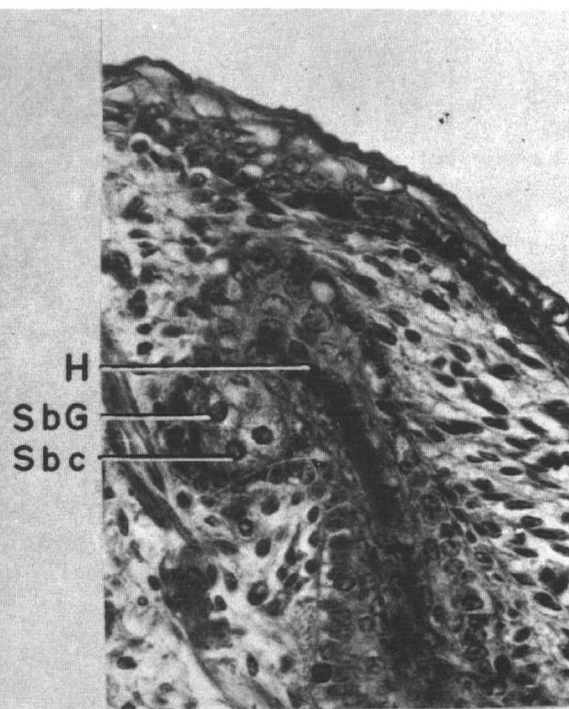


FIG 19.2

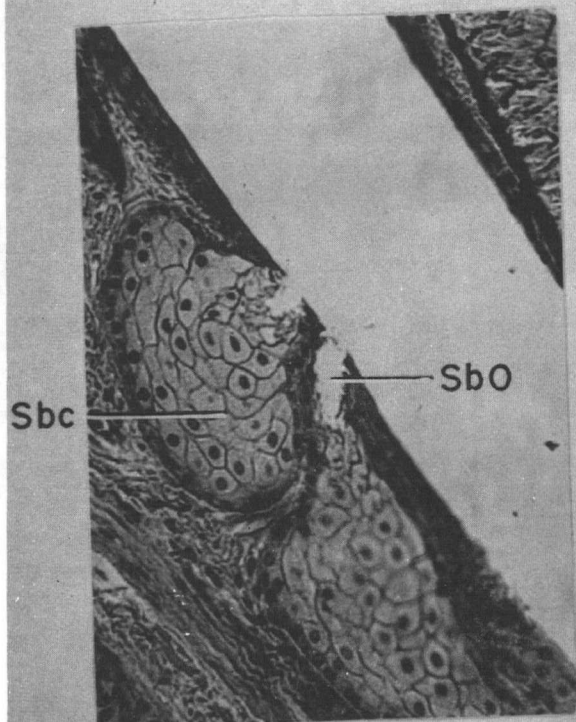


FIG 19.3

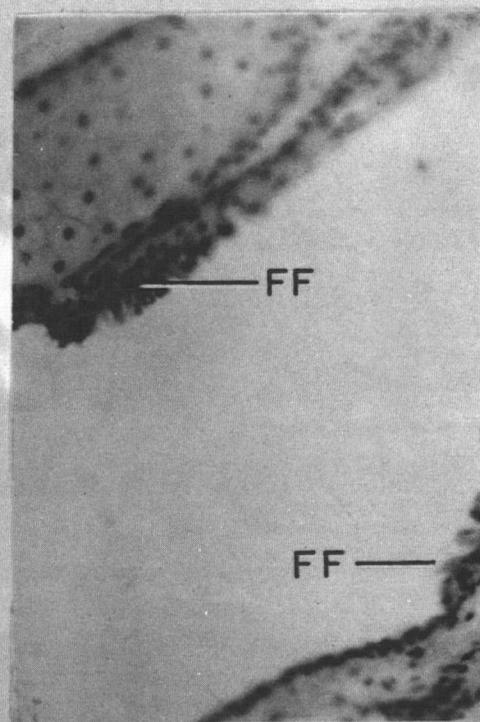


FIG 19.4

### Arrector pilii muscle

This is present in primary and first formed secondary follicles. It is formed from dermal fibrocytes and approaches the follicle on an oblique course, from a region just below the epidermis.

In a 211 mm foetus the fibrocytes in the dermis appear to be aligning to form the muscle. At this stage one distal end of the sweat gland is forming a lumen. The sweat gland passes between the strands of the developing muscle. As maturation proceeds the number of fibres increases within the muscle. They are elongated, and compactly arranged, and have flattened nuclei.

### Ental swelling

The hair follicle as well as the hair that it gives rise to are always inclined at an angle with respect to the skin surface. The side forming the acute and obtuse angles with the skin are referred to as ental and ectal respectively. The ental side of hair follicles have been noticed in many species to possess a swelling during the course of development — a swelling commonly referred to as the ental swelling. This constitutes the region where the arrector pilii muscle becomes attached to the follicle.

In Odocoileus, in a 211 mm foetus the ental swelling is just noticeable. It is more prominent by 235 mm stage, but from 287 mm stage onwards it diminishes. In actively growing follicles producing them it is not noticeable. I did not find any ental swelling in the secondary follicles.

Lyne and Heideman (1959) have reviewed theories regarding origin of the ental swelling and have concluded that it is not

formed by traction of arrector pili muscle, as it is present even when there is little or no muscle. This has also been corroborated by my observation on the Odocoileus material.

### The hair canal

Lyne (1957) has discussed at some length the process of hair canal formation in the merino foetus.

Observations on Odocoileus indicate that a process akin to that in merino takes place here. A 211 mm foetus shows within stratum spinosum granular material deposited obliquely with respect to the skin surface. This is just above the follicle and appears to represent the granulation stage referred by Lyne. Simultaneously sebaceous cells present in the neck of the follicle are in process of disintegration. In a 269 mm foetus the hair canal is distinct and leads obliquely from hair follicle towards skin surface. The hair canal formation starts by stages 3a, 3b, and is completed by stage 7. The sebaceous gland cells as well as those of the stratum spinosum take part in it.

### Paired follicles

Lyne and Heideman (1959) first described a case where two follicles develop separately but in close proximity of each other and open to the exterior by means of a common opening.

Only secondary follicles of Odocoileus sometimes exhibits this. The common hair canal has not been established for these follicles - but is likely since they have common opening and arise separately. Usually in paired follicles, one is smaller than its compatriot.

### Branched follicles

The latter formed secondaries in Odocoileus occur in groups of three or four, of which one follicle is large and the others successively smaller. The large follicle may possess a relatively large sebaceous gland and other assorted follicles appear in development to be derived from this large follicle and may lack sebaceous gland.

### Follicle density

The density of hair follicles varies with advancing foetal stages. The follicle number per  $\text{mm}^2$  is affected in two ways, either by formation of new follicles or by dispersal of follicles by stretching of skin, due to its growth.

The figures given here should only be taken as indicative of the trend, since corrections have not been made for tissue shrinkage during processing. In this tissue size comparisons are believed to be valid as all foetuses were fixed and preserved in the same manner.

At the 202 mm stage only primary follicles are forming but due to increase in foetal size resulting in stretching of skin, though the total number of follicles per  $\text{mm}^2$  is increasing the number of primaries per  $\text{mm}^2$  is decreasing. Follicle density at this stage is 90 per  $\text{mm}^2$  (58 primary and 32 secondary). By 287 mm stage follicle density is maximum i.e. 108/ $\text{mm}^2$ . (48 primary and 60 secondary). Hereafter the follicle density continues to decrease and at birth it is about 31/ $\text{mm}^2$  i.e. 11 primaries and 20 secondaries.

## Integumentary layers

These can be considered in the form of the two major components, the epidermis and the dermis.

Chase et al (1953), have made observations on this subject in mice and Lyne (1957) has described the development of epidermis in merino. These are interesting contributions shedding light on aspects of skin frequently ignored.

In respect of Odocoileus I have following observations to make:

### The epidermis

In an 89 mm stage the epidermis consists of small cells with prominent rounded nuclei. This corresponds to the basal layer of subsequent epidermal stages.

With increasing growth of the foetus the epidermis can be distinguished into the following layers: a stratum germinativum or basal layer and a stratum spinosum. The latter arises by proliferative activity of the basal layer over which it lies. In a 212 mm foetus it is of two layers. The cells are larger than those of the basal layer, have clear cytoplasm and prominent nuclei. The cells are irregular to oval and loosely arranged, those nearer the surface appear flattened.

### Periderm

It constitutes surface of the skin and is formed by stratum spinosum cells flattened and hyalinized. It is a continuous layer of uniform consistency with cellular components that cannot be distinguished.



FIGURE 20

Arrector pili muscle in adult material.  
Longitudinal section. H. & E.

FIGURE 21

Melanin in growing hair follicles. Notice  
its heavy deposition in cortical and medulla layer  
of follicle and hair. H. & E.

Dermis

FIGURE 22.1

Dermis in early developmental stage.  
Longitudinal section. H. & E.

FIGURE 22.2

Dermis in adult stage. Longitudinal section.  
Notice the heavy fibrous deposition near follicle  
base. H. & E.

For explanation of abbreviations used please  
see Appendix IV, Page 214.

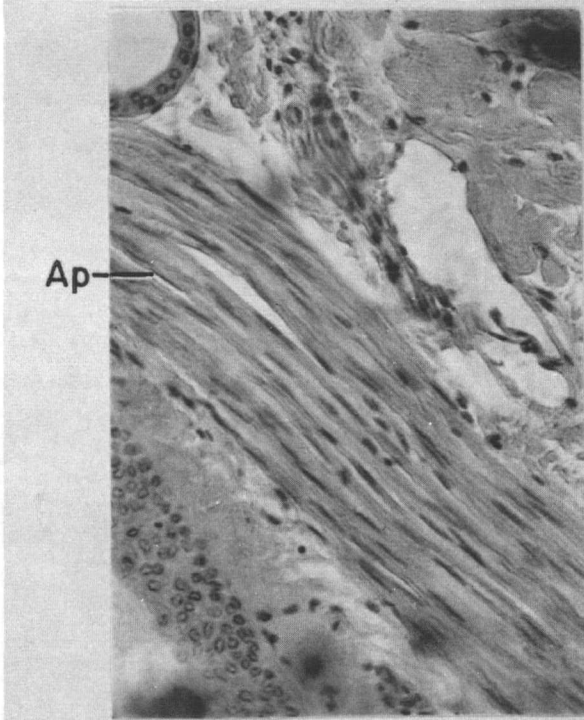


FIG 20

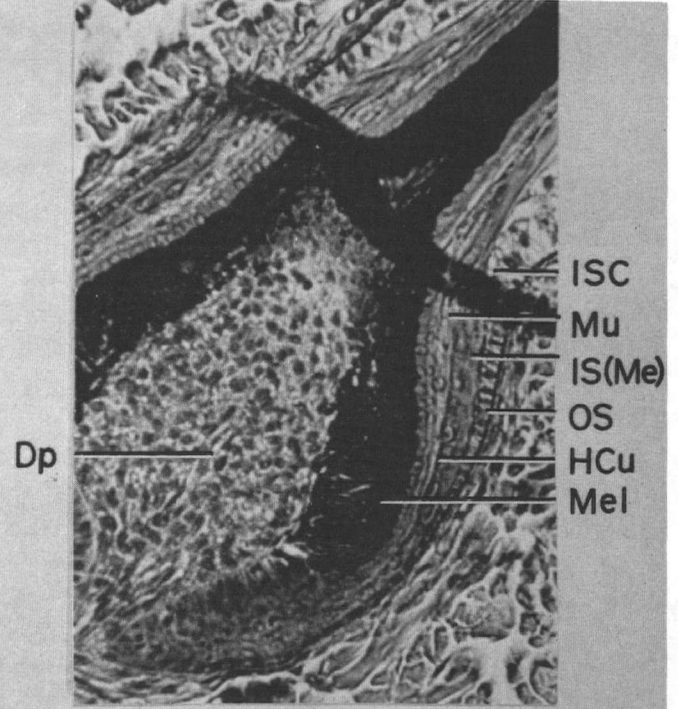


FIG 21

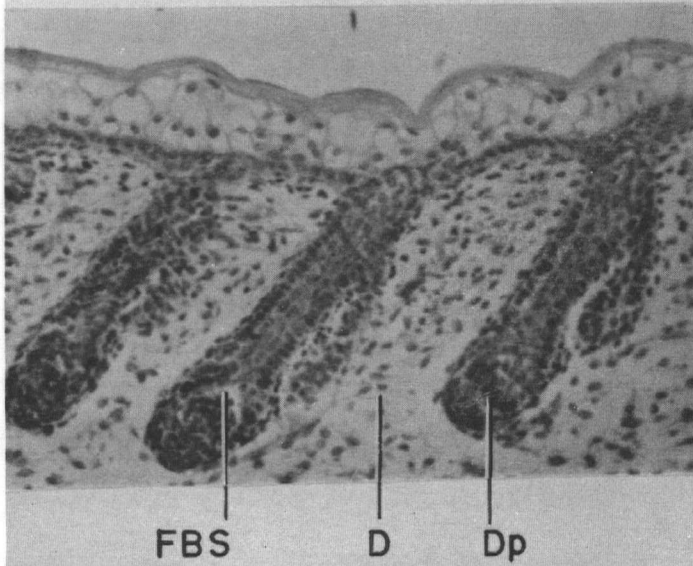


FIG 22.1

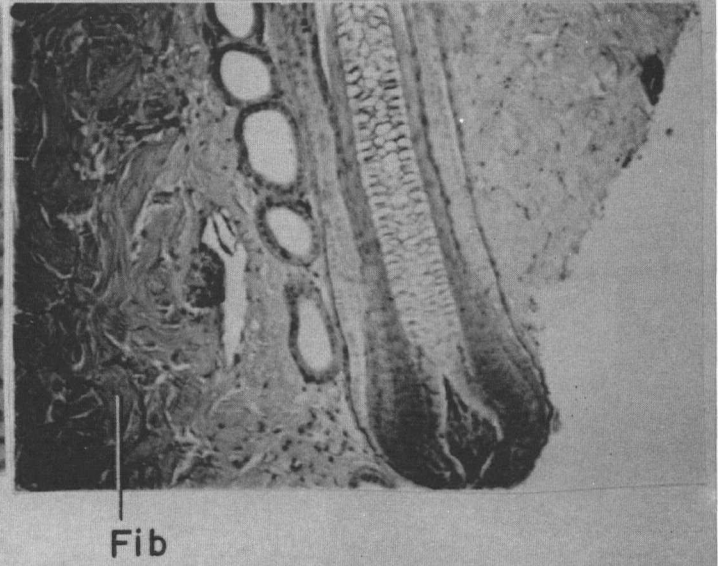


FIG 22.2

In keeping with the advancing stages of foetal and follicle development, changes also take place within the epidermis. In early stages of follicle development epidermis increases in thickness; but as hair development and maturation proceeds the thickness is reduced. At its maximum the epidermis is  $50\mu$  thick. The increase being most manifest in the stratum spinosum, which becomes three cells thick. In 235 mm foetus with stages of follicle development from 2b to 4, the epidermal cells show tendency towards compactness. At the same time the periderm is peeling off and being replaced by another layer of uniform consistency containing many granular deposits. This granular layer may be called the stratum granulosum.

In a 269 mm foetus some hairs have emerged, and the epidermis is greatly reduced in size being  $25\mu$  thick. The stratum corneum shows laminated structure and the stratum spinosum is two layered with flattened cells. In a 448 mm stage i.e. when fawn is about to be born, the stratum spinosum has lost its entity as a separate layer. Scattered cells may however be noticed between the stratum germinativum and the prominent stratum corneum. In a mature adult the epidermis is  $25\mu$  thick.

### The dermis

The preservation of my material was inadequate to permit detailed study of the various elements.

## Epidermis

FIGURE 23.1

Developing epidermis. Longitudinal section. 46.2 mm stage. Notice the stratum germinativum and the loosely arranged dermal elements. H. & E.

FIGURE 23.2

Developing epidermis at 112 mm stage. Longitudinal section. Note the distinctive stratum germinativum, follicle anlagen in it, two layered stratum spinosum and the periderm. H. & E.

FIGURE 23.3

Developing epidermis. Longitudinal section. Notice the enlarged nature of stratum spinosum. H. & E.

FIGURE 23.4

Epidermis in adult material. Longitudinal section. Notice the peeling stratum corneum and compact nature of epidermis and fibrous dermis. H. & E.

For explanation of abbreviations used please see Appendix IV. Page 214.

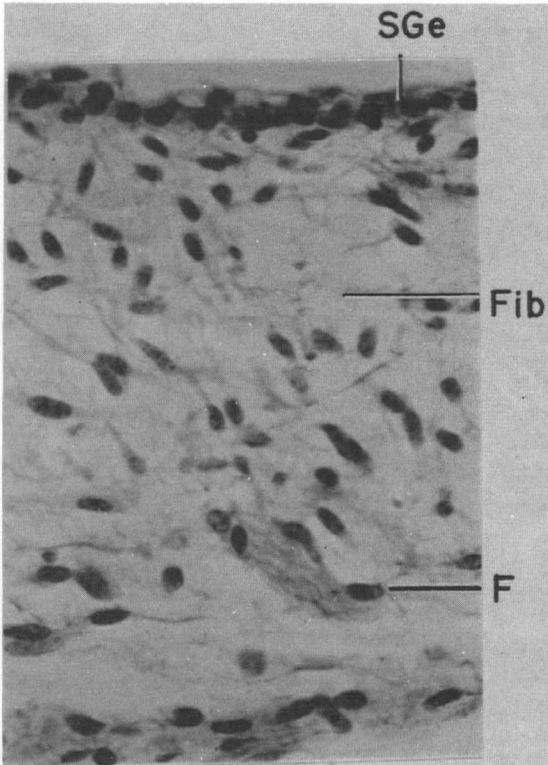


FIG 23.1

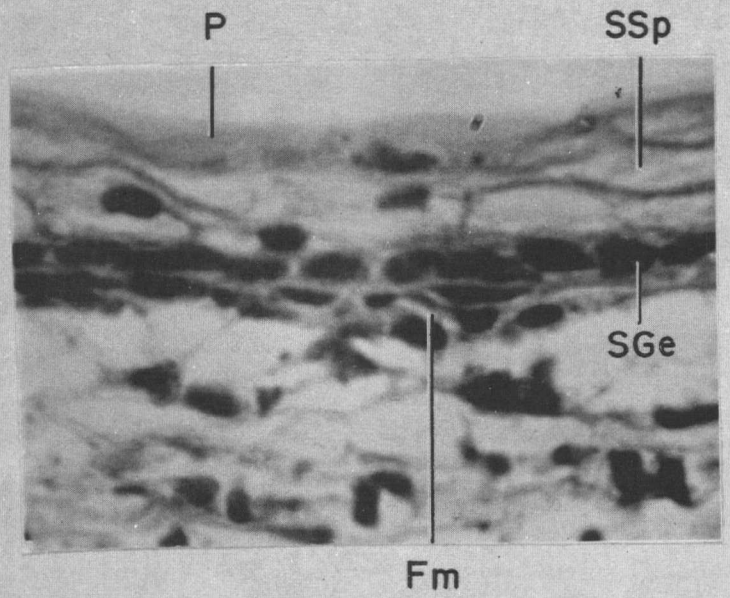


FIG 23.2

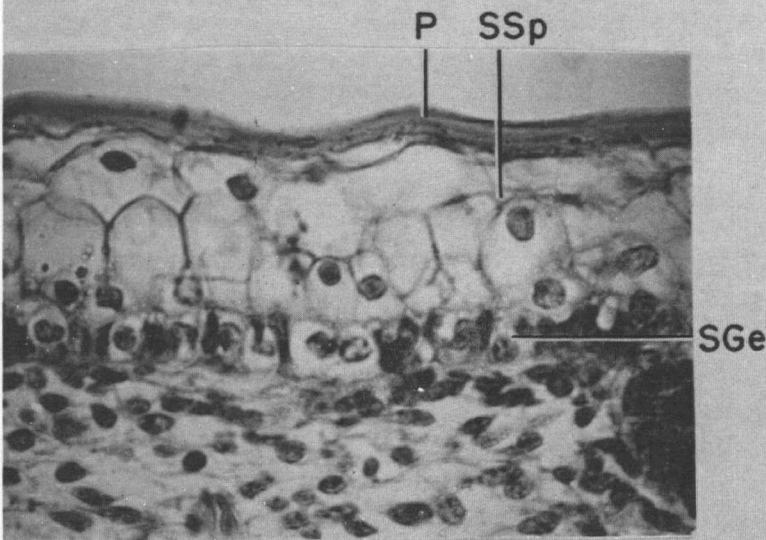


FIG 23.3

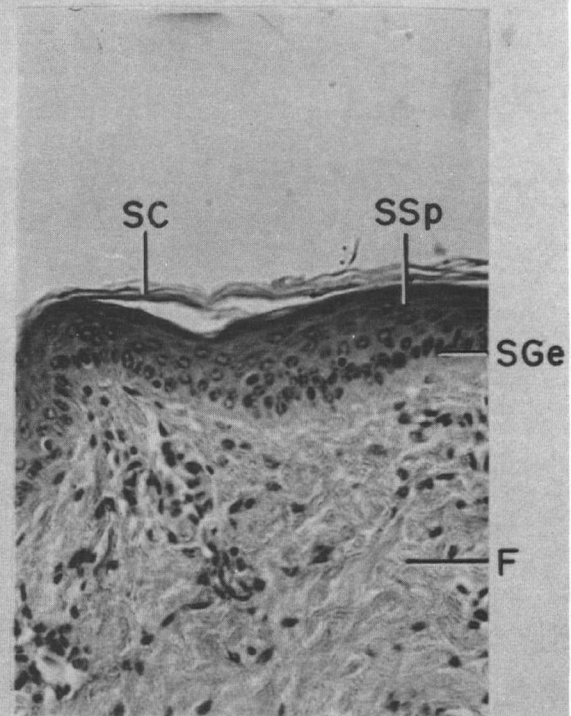


FIG 23.4

### Summary

The hair follicles of Odocoileus can be divided into primary and secondary types.

The primaries are first to originate, and develop in trios consisting of a larger central primary follicle and two smaller lateral primary follicles. This grouping is obvious during early developmental stages. All primaries possess sweat gland, sebaceous gland and pili muscle. The development of the follicles begins by 112 mm and by 448 mm stage they are actively producing hair.

The secondaries are smaller in size, arise later and are divided into first formed and later formed. The first formed secondaries are larger and possess a sweat gland, a sebaceous gland and arrector pili muscle. They start developing by 269 mm stage and by 448 are actively producing hair, some follicles do even reach resting stages. The later formed secondaries are smaller than the first formed, possess only sebaceous glands, and the smallest among them may even lack these; they may be single, paired or branched. When branched they are in clusters of 3 to 4 and are of gradually decreasing sizes. The later formed secondaries continue to form even postnatally and do not become fully functional until in the fawn winter coat.

Some of the central primaries grow and develop at a faster rate, dwarfing follicles adjacent to them. This is particularly noticeable at 287 mm stage, subsequently the size discrepancy gets reduced and is hardly noticeable postnatally. The neck of these follicles has been observed to assume occasionally a

bulbous form, but no definitive sinus has been detected. These follicles have most of the characteristics and also the function of the tylotrich follicles present in mammals.

The types of hair produced by the follicles are varied. The large guard hair follicles produce large guard hairs (tylotrichs ?) which are longer and tactile in function. The rest of the primary follicles produce the intermediate guard hairs, constituting the animal's overcoat. Some of the primaries in fawn birth coat produce white tipped hairs, responsible for the white spots in the birth coat. All primaries and first formed secondaries produce medullated hairs, while the later formed secondaries produce non medullated hairs.

Anatomically the follicles have basic mammalian features. The following amongst them are however characteristic and noteworthy.

- a) A glassy membrane between connective tissue sheath and the external root sheath is prominent at places, even on the follicle bulb.
- b) An additional glassy membrane is also noticed at places between external root sheath and the internal root sheath.
- c) The external root sheath is of uniform thickness around the follicle.
- d) Henle's layer is single celled and large, staining more deeply with Haematoxylin and Eosin than does Huxley's layer, which is also single celled but smaller.

The shape of the dermal papilla varies with the hair type being produced. In follicles producing heavily medullated hairs it is spatulated, while in those producing non medullated hairs it has a pointed apex; it is also pointed in the primary follicles, producing white tipped hairs.

In the early follicle development the observable melanocytes

are few and scattered. Some may occur even in the basal layer of the epidermis. By the time hair production commences, they assume dendritic form and are heavily concentrated in the follicle bulb. In general the pigmentation is confined to the hair cuticle, and to the cortical region. Some deposition may be noticed even in the basal region of the medulla.

The ental swelling in Odocoileus follicles was restricted to primaries and did not have any cause and effect relationship with the arrector pili muscle.

In the hairs produced in primary and first formed secondary follicles the medulla is better developed than the cortex. The hairs from later formed secondaries in contrast are non medullated and consist of cortex and hair cuticle. The bulk of the long tip of a large guard hair is made of cortex — as cortical tissue begins to form earlier than the medulla. The white tipped hairs. have in the region of the white tips greater proportional development of cortex than other medullated hairs.

The medulla in Odocoileus is very well developed and is characterized by presence of intracellular cavities. The white tipped hairs have however a medulla lacking in cavities; and the medullary cells are instead filled with porous and granular material, reminiscent of stages prior to cavity formation in normal medulla.

The sweat gland is prominent and its secretory part is sinuous. The sebaceous glands are well formed, generally bilobed in primary and first formed secondaries, and do not possess distinct acini. They have a short excretion duct and during development participate in hair canal formation.



The epidermis undergoes profound change of size during follicle development. The layer most affected is stratum spinosum, which is three layered at one stage and in adult animal almost disappears as an entity. Evidence of periderm being sloughed off during embryonic development is also present. The stratum corneum of adult material has also peeled appearance.

The dermis during development gets more and more compact and well organized. The collagen fibres in the reticular layer reach massive proportions in the adult.

## Chapter IV

### PELAGE MORPHOLOGY AND MOULT PATTERNS

#### INTRODUCTION

The present chapter deals with black tail pelage, that is the hairs produced by the follicles, their morphology and moult patterns.

It appears certain that morphological features of hair constituting the pelage contribute to its functional efficiency. The timing of the moult also normally bears an important relationship to prevailing environmental conditions and is oriented towards the animal's well-being.

During its life cycle a black tailed deer can be said to possess four different pelage types. These are:

- a) Fawn birth coat
- b) Fawn winter coat
- c) Adult summer coat
- d) Adult winter coat

I have studied the distinctive features of these different pelages and the pattern and timing of the moult.

#### MATERIAL AND METHODS

The study involved use of live deer as well as tanned hides. The hides were used for a general description of the summer and winter phases of the adult coat as well as the fawn birth coat. The winter coat of the fawn, as well as the moult pattern in animals has been discussed on the basis of observations on living animals. Hair samples for measurement and description were collected from specified regions on the body of the living animal.

The methods for the study of hair morphology were mostly those of Spence (1963) and gave good results. Hair samples were collected from specified regions, care being taken to see that they were not mutilated.

Hair length was measured to the nearest millimeter on a plastic measuring scale. The woolly under hairs were ignored for this purpose. The hair diameters were measured under a compound microscope with calibrated ocular micrometer.

To observe gross features of the medulla and the cortex of guard hairs the hairs were cleaned by immersion in carbon tetrachloride, transferred to xylene for 24 hrs and then placed directly into technicon mounting medium. The deer guard hairs had a large medulla which was clearly observable even without this treatment.

A technique suggested by Manby (1932) was used in the study of scale patterns.

Negative impressions of the individual hairs were made in a gelatin-glycerin mixture. The liquified medium is spread on a glass slide and allowed to solidify. After it solidifies the hair whose scale cast is to be prepared is placed on it. A glass slide is put on top of it and the two slides together, with the hair in between are warmed on a warming table. When the gelatinized mounting medium becomes soft pressure is uniformly applied to the upper side and subsequently both the slides are allowed to cool. When cold the upper slide is removed. The hair which is now fixed in the mounting medium is removed by means of a forcep, leaving the scale impression behind.

Satisfactory hair scale impressions were also obtained with a method suggested by Dr. J. Bendell of the Dept. of Zoology. This consisted of spreading a thin layer of quick-drying airplane glue (Lapage's airplane model cement) and pressing the hair on it. The mounting medium dries quickly, after which the hair is removed, leaving the scale impression behind.

The moult patterns were studied on the living animal. The moult progress was recorded on cyclostyled sheets having a cervid outline marked on it.

## Observations

### Hair characteristics

The characteristics as manifested by pelage are a sum total of the characteristics of individual hair types. It is therefore pertinent to discuss the major hair types present and their characteristics before discussing the different coats and hair patterns of moult.

### Hair types

#### Large guard hairs

These are long hairs up to 80 mm in length and uniformly scattered over the body — about 2 cms apart. They possess black tips 15 to 20 mm long and have a slightly crimped shape. They are heavily medullated and morphologically are akin to kemp of sheep and goats.

FIGURE 24

Skin surface view at 269 mm stage. Notice emerging large guard hairs.

FIGURE 25

Skin surface view at 287 mm stage. Notice intermediate guard hairs are also emerging along with large guard hairs.

FIGURE 26

Fawn birth coat hair array. Notice the hair types.

FIGURE 27

Fawn winter coat guard hair array. Notice the hair types.

For explanation of abbreviations used please see Appendix IV, Page 214.

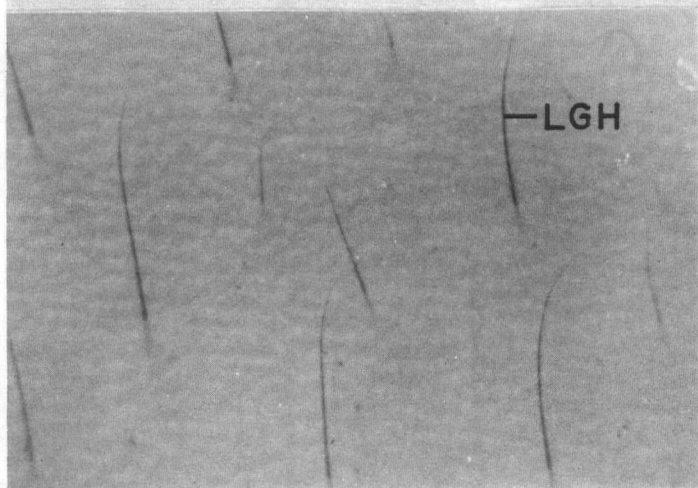


FIG 24

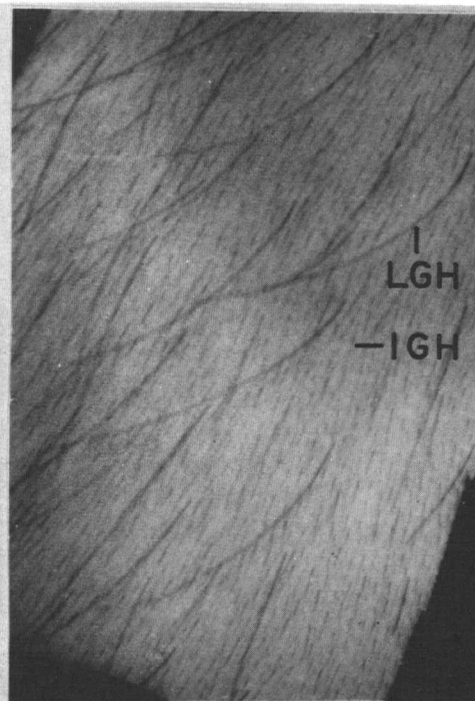


FIG 25

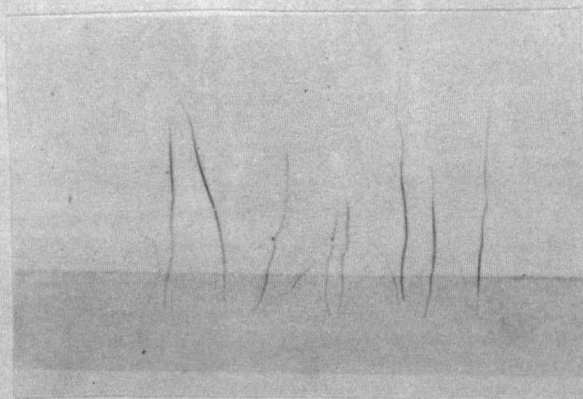


FIG 26

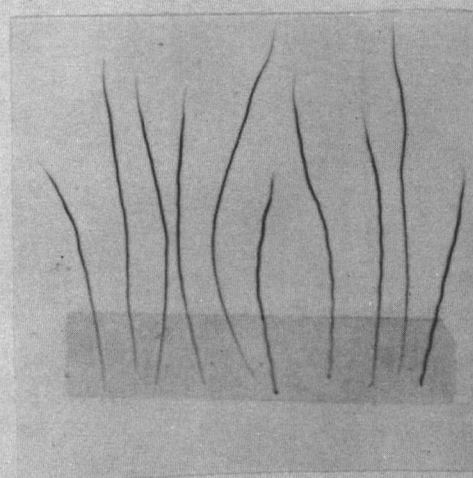


FIG 27

### Intermediate guard hairs

These hairs are abundantly present in the pelage and compose the bulk of it. They give the pelage its characteristic colouration. They vary from 18 to 44 mm in length and bear a black tip 3 to 5 mm in extent. Their form is kemp like — particularly the longer hairs. Hairs of varying lengths and thickness occur but all are larger than the hairs produced in secondary follicles. The smaller among them however may conceivably arise in first formed secondaries. These hair types are not 'crimpy' kemp types — and can be called "Transitional" hair types. In fawn birth coat this type constitutes the bulk of the undercoat.

### Woolly under hairs

These are woolly hairs which constitute the under coat of the animal. They are thin and curly — diameter varying from 18 $\mu$  to 16 $\mu$ . They are non medullated.

### Beard type

These are long hairs which differ from kemps in not being crimpy. They are soft and of variable length. In Odocoileus these hairs are restricted chiefly to black patch on the tail, axillae, inguinal region, posterior margin of rump.

### White tipped hairs

In addition to these hair types the fawn birth coat possesses white tipped hairs. These are of the same length and type as intermediate guard hairs, but possess white distal extremities 5 to 8 mm in length. These hairs are responsible

Adult summer coat

FIGURE 28.1

Adult summer coat hair array. Notice the hair types.

FIGURE 28.2

Close up of summer coat.

Adult winter coat

FIGURE 29.1

Adult winter coat hair array. Notice the hair types.

FIGURE 29.2

Close up of winter coat. Notice its thick nature.

For explanation of abbreviations used please see Appendix IV, Page 214.



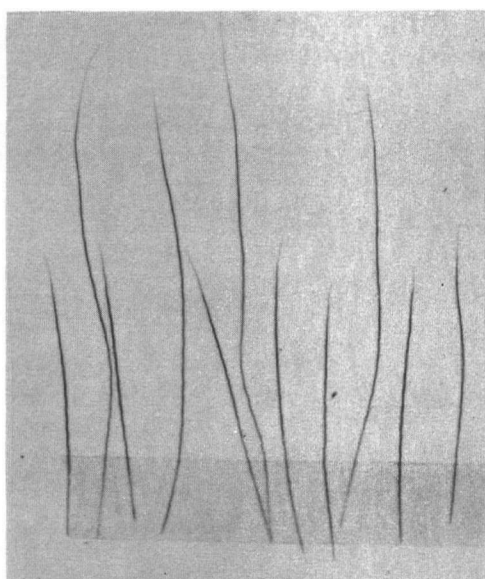


FIG 28.1

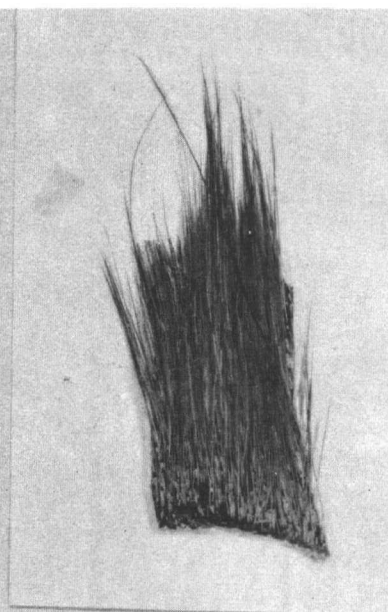


FIG 28.2

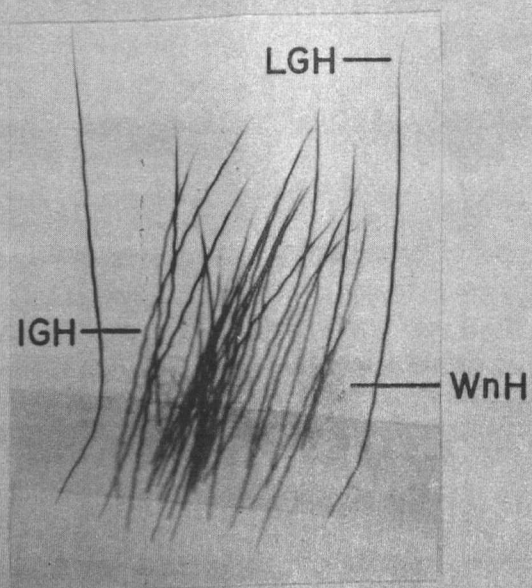


FIG 29.1

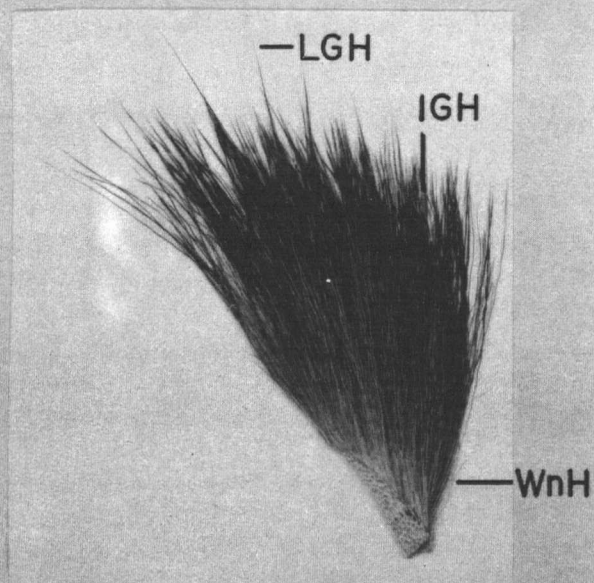


FIG 29.2

for white spots on fawn birth coat.

The extreme tip of all types of hairs is pointed and devoid of any pigment.

### Cortex, medulla and scutellation

Observations were also made on the cuticular scale patterns medulla and cortex features of these hair types.

In fawn birth coat all guard hairs presented scale pattern of irregular waved mosaic nature with margins smooth and intermediate. (Terminology as per Spence (1963), Wildman (1937) ). The medulla was wide and of unbroken lattice type. Cortex was reduced on the shaft and could only be distinctly seen as a translucent homogeneous mass at the tip and base of the hair. The white tipped hairs had a greater development of cortex and the medulla, though wide, lacks intracellular cavities, The undercoat hairs are mostly medullated and possess fragmental medulla. The scale pattern present is a variation of the coronal scales - involving two scales that envelop the hair shaft and not one as in the case of true coronal scale pattern.

In fawn winter coat the scales on guard hairs are of irregular mosaic and not irregular waved mosaic. The features of cortex and medulla are the same as before.

In adult summer coat the features of cortex and medulla are same. The guard scale patterns are the same except that at distal extremities the margin changes from "intermediate" to close. Woolly under hairs are missing in this coat.

In the adult winter coat there is greater diversity. The features of cortex and medulla are same but scutellation varies.

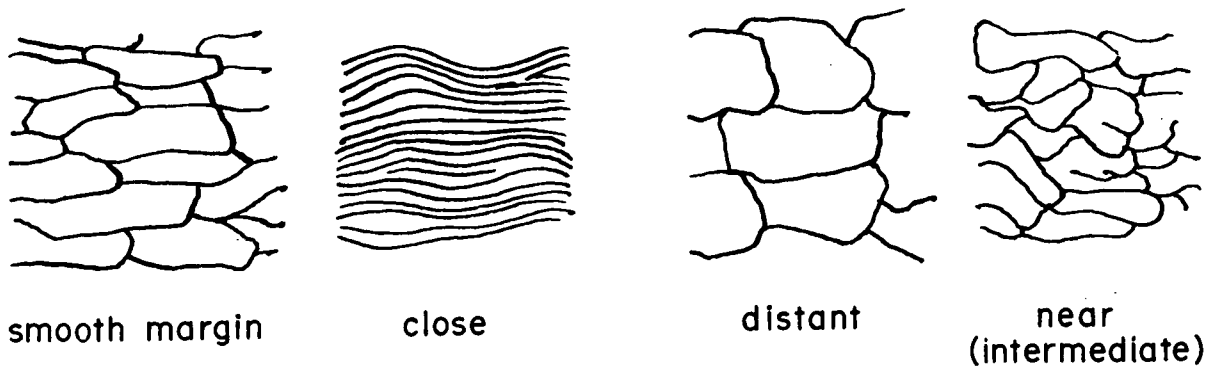


FIG. 30 ANTERO POSTERIOR DISTANCE  
BETWEEN SCALE MARGINS  
*AFTER SPENCE (1963)*

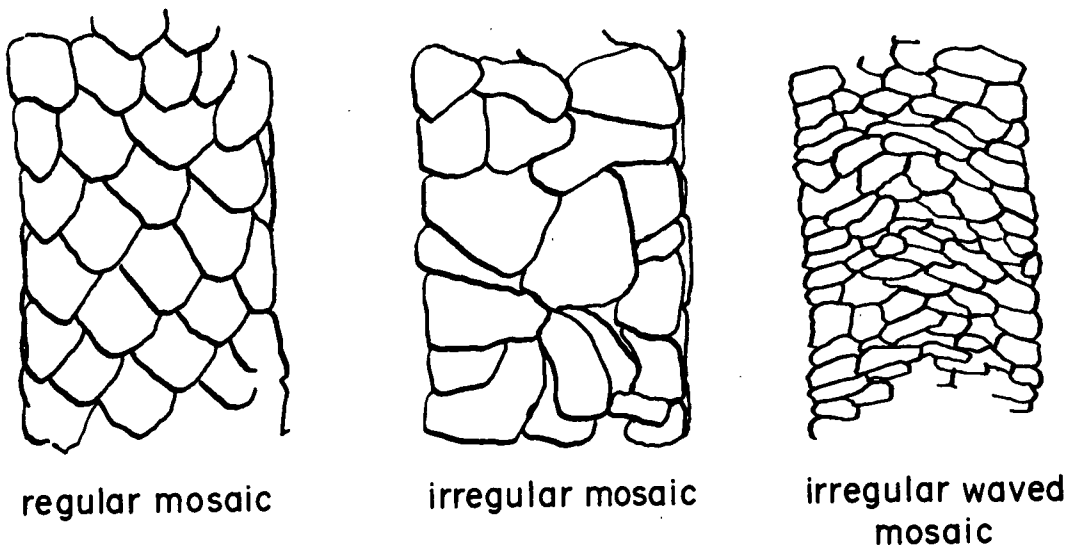


FIG. 31 ARRANGEMENT OF HAIR SCALES  
*AFTER SPENCE (1963)*

Large guard hairs basically have irregular mosaic scales, margin smooth, intermediate to distant - in rest of the hair margin is smooth - intermediate to near. The intermediate guard hair scales are regular mosaic, margin smooth and distant but in distal end margin becomes smooth, intermediate to near.

The beard type have irregular waved mosaic scales with margins smooth and intermediate, in the mid part of the hair shaft as well as distal part margin may be intermediate to close. The woolly hairs have scales as before and are non medullated.

In fawn birth coat the hairs are softer and of smaller diameter. The number of non medullated fibres is very low. The smaller hair types bear a fragmental type of medulla as opposed to the wide latticed type present in guard hairs. Most of the fawn undercoat is made up of transitional hair types which are all medullated.

In fawn winter coat the hairs have attained larger diameter and length. The true non medullated woolly hairs are present in large numbers and consist only of cortex and cuticle.

In adult summer coat in contrast to adult winter coat the hairs are of smaller diameter and greater length. The woolly undercoat is missing.

In adult winter coat the hairs are shorter but of greater diameter, than those in adult summer coat. The medulla is wide and of larger diameter, The scale pattern is greatly variable. A well developed woolly undercoat is present.

Generally in medullated hairs it can be said that areas with larger diameter have a regular mosaic scale pattern with margins smooth and distant, whereas in hairs with smaller diameter the

scales become irregular mosaic to irregular waved mosaic with smooth margins and distance between margins varying from intermediate to near. In woolly under hairs there is no change of diameter in the main hair shaft consequently scale pattern remains uniform.

Hausman (1930), Mahal et al (1951) have made some observations on scale pattern in animals. The general conclusion being that there is no relationship of any of the attributes i.e. number of scales per unit length, average visible scale height etc. to breed or wool type.

### Colouration

The other important aspect of hair is its colouration. That of the distal half of the total hair length is important in determining the pelage colouration.

The extreme tip of most hairs is generally colourless. This is followed by a black coloured zone, which really constitutes the visible part of the hair tip. This region is followed by zones of whitish yellow, reddish yellow or grey depending on the nature of hair coat. The colour variation in different coats or over different body regions of the same coat as they exist are caused by presence or absence of these coloured zones, or changes in their extent in the distal end of the hair. These are discussed in a subsequent chapter in detail.

The birth coat of fawns and the summer coat of adults show resemblances to each other. The visible part of hairs in the pelage consist of a black tip, followed by a reddish yellow hair shaft. The basal part of each hair is light coloured ending in a pigmentless area of the bulb. The large guard hairs have

proportionately longer black tips. The beard type hairs are of uniform colouration either black or white.

In the winter coat of fawns and adults the black tipped zone is followed by a yellowish white zone. This in turn is followed by greyish colouration fading towards the base. In the large guard hairs the 'yellowish' zone is replaced by a 'reddish yellow' zone of greater length. Thus the colouration here is more reminiscent of the summer coat and indicates that even in winter coat the melanocyte activity in large guard hair follicles is different from the adjoining hair follicles. The fawn winter coat hairs may be completely black coloured over the entire length. As before the beard type hairs are either completely black or white.

The woolly under hairs which occur in bulk in the winter coat are not visible externally. When actively growing they are greyish but when resting are virtually colourless.

In the course of this study observations were made on hair length, diameter and the extent of the different colour zones, in the large and intermediate guard hairs, in different body regions of the animal and in different coats. This is in an attempt to put in quantitative terms, what their interrelations are and how they affect the pelage colouration in different body regions and in different coats.

The colouration of the pelage as a whole does not remain static during the course of the year. The winter coat in its early phases presents a steely grey appearance but with continued hair growth and environmental effect this fades to a yellowish grey colouration, which is retained most of the time. Just prior to shedding the coat has a well worn look and a faded appearance.

The summer coat of adults is reddish brown when in prime but fades to paler shades before moult. The upcoming greyish woolly undercoat in the later parts of the summer also contributes to changing in colour to a greyish shade.

Hayman and Nay (1960) have classified stages in a cattle coat during the course of the year, on the basis of "appearance of the coat, the number of loose fibres, their degree of looseness, and the progress of shedding". Each stage is given a score, there being twelve stages and the score of the last one being twelve.

These stages cannot be applied "in toto" to deer. Whereas in cattle a percentage of hairs is being shed all the time, this is not so in deer. In contrast to the cattle, passage of a hand over the deer body when hairs are in resting stages hardly brings about any loss of hairs even though the hairs can be plucked easily.

#### Coat description and pattern of moult

We have already referred earlier to the fact that the black tail deer in course of its life cycle has four types of coats. The characteristics of hair types constituting these coats have also been referred to.

Now I shall endeavour to describe the features of these coats as they occur on the animals and the moult processes by which one coat type gives way to another.

#### Fawn birth coat

The black tail fawns are born in summer mostly in May and June. The coat with which they are born and which is retained

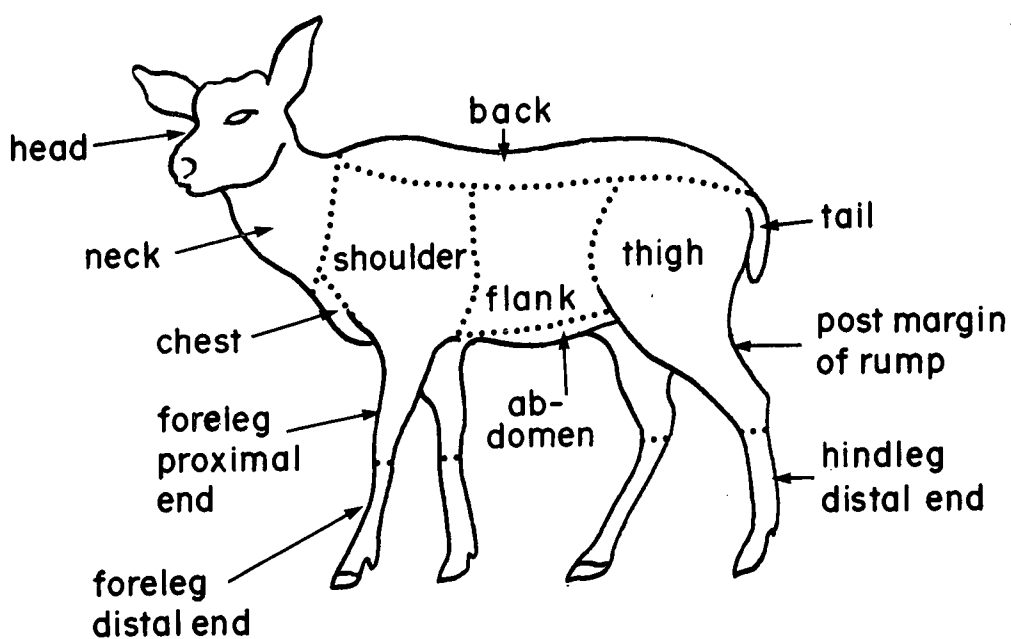


FIG. 32.1 DIFFERENT BODY REGIONS OF THE BLACK TAIL DEER. SIDE VIEW

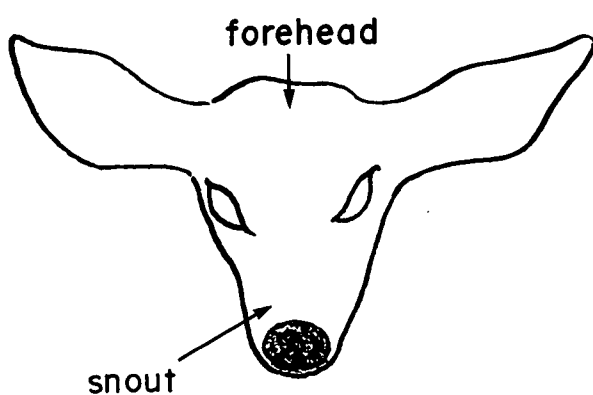


FIG. 32.2 HEAD, FRONT VIEW

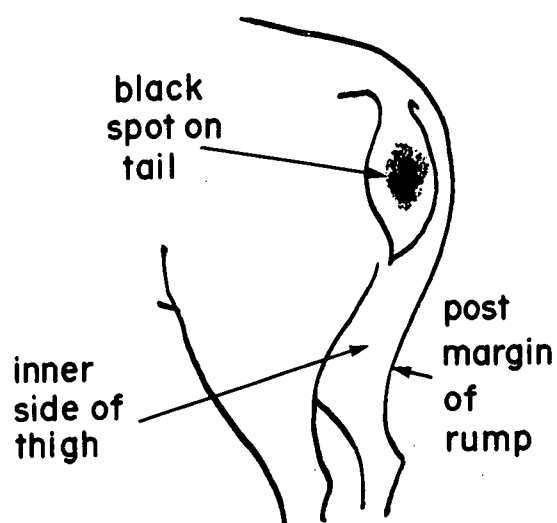


FIG. 32.3 POSTERIOR VIEW



till its moult in late summer or autumn is very soft and gives the young a fluffy appearance. The softness of the coat is related to fineness of the hair types constituting the coat, whereas the fluffiness may be correlated with the greater follicular density and the disparity in the lengths of large guard hairs vis a vis others in the pelage.

The coat is brownish in colour, darker dorsally, fading laterally to lighter shades. There are two parallel rows of white spots on the back, the others being scattered along the flanks and thighs. The hairs on the face and the distal ends of the limbs are shorter than those over the rest of the body. The hairs occurring in the axillar, inguinal, rump and tail regions are in the same relationship longer. In the axilla and inguinum their density appears less. The tail characteristically bears a black tip.

In contrast to the brownish shade present dorsally the hairs occurring in the neck, chest, and abdomen are lighter in colour. Those occurring in the axilla, inguinal region, ventral side of the tail and posterior margin of the rump are white.

Hairs in the vicinity of the tarsal and metatarsal glands are longer, coarser, and erectile.

#### Moult in the fawn birth coat

There was some variation in the initiation and completion of the moult of the fawn leading to its shedding of the birth coat and aquisition of the winter coat. This generally begins in the late summer and is completed in October, by which time the adults also have assumed the winter coat.

Moult in the fawn can be best described in terms of four stages which follow each other in a time sequence and are easy to distinguish. These stages have been categorized on the basis of the fawn's appearance as modified by the moult in progress.

#### Stage I (July)

The hairs covering the ear pinnae are shed first, giving the ears a naked appearance for a while. Simultaneously the hairs surrounding the eyes are shed and replaced by cream-coloured hairs which distinctly demarcate this area. Hairs are then replaced on cheeks, front part of the face and forehead. The last parts of the head to moult are the inner sides of the ears and here the dark coloured margins lose the hairs first.

At the end of this stage the head has completely moulted into the winter pelage. Initially it has a glossy appearance and is in distinct contrast to the birth coat still prevalent on the body.

#### Stage II (August)

Moult then proceeds on the under side of the neck and chest, while the hairs on the body are relatively intact.

This phase is followed by the general loss of the spotted nature of the coat as the white tipped hairs are lost. Thus these hairs shed earlier than many others in the pelage. This is interesting because none of the other intermediate guard hairs are being shed at this stage. The mechanism of control over such apparently precise local moulting is not known.

Towards the end of this phase there is considerable loss of

Moult stages fawn birth to fawn winter coat

FIGURE 33.1

Fawn in birth coat.

FIGURE 33.2

Moult stage I. Head has moulted.

FIGURE 33.3

Moult stage II. The neck is moulting but birth coat is intact on most of the body.

FIGURE 33.4

Moult stage III. The white spots have all disappeared but birth coat is loosely present over the body.

FIGURE 34

Fawn in winter coat.



FIG 33.1

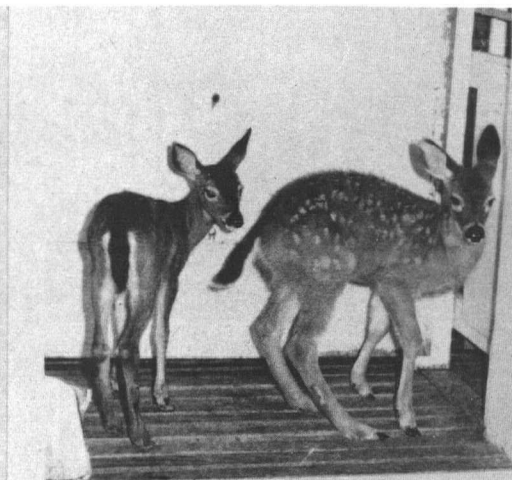


FIG 33.2



FIG 33.3



FIG 33.4



FIG 34

hair over the body. It has no pattern but is general. The hairs most affected are the transitional types forming the bulk of the under coat. At the end of this stage the fawn shows a thinned out appearance with only larger and intermediate guard hairs remaining.

### Stage III (September)

The upcoming winter coat is seen through the thinned out birth coat. The remaining birth coat hairs are now shed directionally in a caudal wave.

### Stage IV (October)

The fawn is now in full winter coat, except that the old birth coat hairs are still present in the vicinity of tarsal and metatarsal glands, these are progressively replaced.

### Fawn winter coat

By October end the fawns are in their full winter coat. This grey coat greatly resembles the winter coat of the adult. The hairs have smaller diameter and length, and are softer than those of adult winter coat. A woolly undercoat is present here.

Other details of hair and their topographical variation are the same as in the adult.

### Moult from fawn winter coat to adult summer coat

The yearling animal on moulting from fawn winter coat -- assumes a summer coat identical to that of the adult. The process of moult could not be documented as the experimental animals had

bitten off their coat to a great extent and no meaningful observation could be made.

Linsdale and Tomich (1953) state that in mule deer yearlings the spring moult starts later than in the adults and extends for a longer period. The moult is said to have no pattern but is manifested by gradual replacement of old hairs by the new coat growing underneath. This is in contrast to adult spring moult in which a pattern can be discerned.

#### Adult summer coat

This coat is very different from the adult winter coat. The standard hair types, their morphology and colouration have already been referred to.

In general the summer coat hairs are longer and straighter than their winter counterparts. The kemps possess much less wavy form. The percentage of hairs below 30 mm length is much less than in the winter coat. The hair diameter is also smaller and less variable in relation to hair length than in the winter coat. The summer pelage is yellowish red in contrast to yellowish grey of the winter coat. The parts of the hair responsible for it are the visible distal half of the hair consisting of the black tip and the reddish yellow hair shaft.

The summer coat is also characterized by the lack of the woolly undercoat. Thus there is opportunity for greater air circulation over body, and presumably greater opportunity for dissipation of body heat.

Hairs on the lower legs are longer on the forward surface than elsewhere. In the vicinity of the tarsal and metatarsal gland

the hairs are rougher and coarser. The hairs occurring on the underside of the tail, posterior side or the rump and in periphery of the urogenital area as well as in axilla and inguinum, are long and white. The tail carries a black spot dorsally.

#### Moult from adult summer to adult winter-coat

This takes place during late summer to early autumn and lasts from August to October. The general direction is from head towards tail i.e. cauded.

The moult is first noticed in the ears, which dorsally bear a very thin coat of hair. A thicker coat grows in its place and the pinnae are fully covered.

The next region to moult is head. The loss of hairs on the face is diffuse, but where the hairs are longer on the head the moult tracts appear. One of these moves upwards through the region between the eyes and the ear pinnae and touches the dorsal side of the neck. The other tract moves sideways along the cheek till it meets the neck. The loss of hairs on the lower jaw also takes place about this time but is diffuse.

On the neck the shedding continues along the side, and undersurface. The summer hairs present dorsally in the neck region undergo a gradual thinning and are amongst the last summer hairs to be shed.

While the neck is losing hairs the shoulders and the anterior region of the back also begin to shed. On shoulders the thinning begins in the central region and gradually spreads out to meet the neck, back, flanks and chest region. The hair shedding on the shoulder area continues onto the flank region in a diagonal manner and proceeds towards the abdomen. Simultaneously hair loss

FIGURE 35

Adult in summer coat.

Moult from adult summer coat to adult winter coat

FIGURE 36.1

Moult stage I. The ears have moulted.

FIGURE 36.2

Moult stage II. Moult progressing cauded.  
The body is moulting.

FIGURE 36.3

Moult stage III. Only the distal end of legs  
remain to be moulted.





FIG. 35

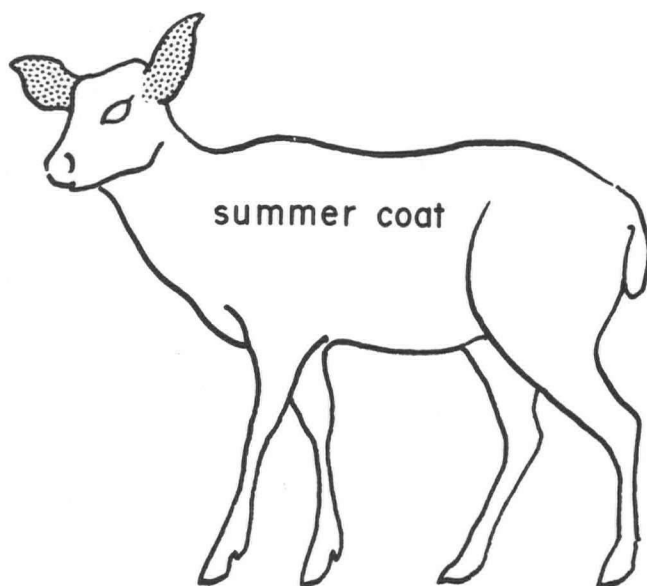


FIG. 36.1 STAGE 1

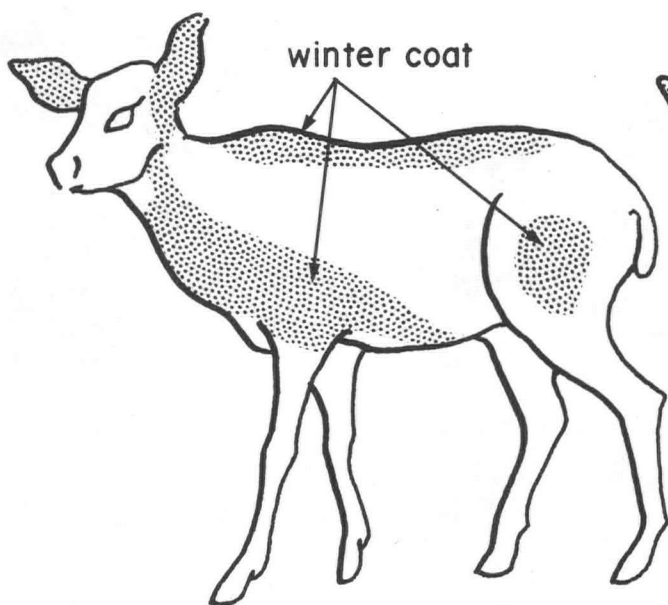


FIG. 36.2 STAGE 2

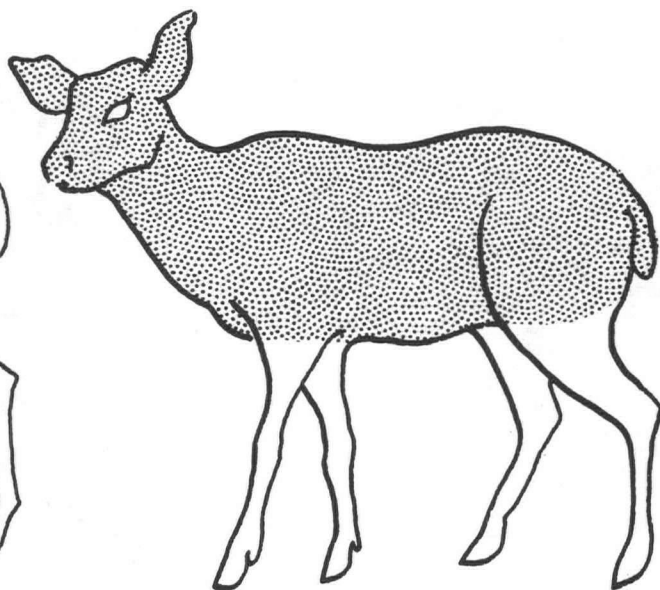


FIG. 36.3 STAGE 3

FIG. 36 ADULT SUMMER TO ADULT WINTER MOULT STAGES

on the back is progressing steadily caudad. The summer hairs on the upper side of the flanks are also shed about this time (late August) and a stage is reached when the summer hairs on the body remain in the region of the chest, abdomen, the limbs and posterior part of the back.

The wave of moult now proceeds from the shoulders, first along the front of the foreleg, then to the posterior face and toward the hoof where it is diffuse and gradual. This takes place in September.

The loss of summer hairs in the chest region takes place in late August. The shedding proceeds between the forelegs towards the abdomen where again moult becomes diffuse.

In early August the central part of thighs begin to shed hairs. This patch enlarges to meet dorsally the back and laterally the flanks. The posterior margin of this patch is demarcated by the elongated hairs in the rump region, which are amongst the last to be shed.

Distally in the hind leg moult differs from that of the fore legs as it proceeds along the sides leaving the summer hairs more or less intact in the front part and also in the posterior margin and in the area surrounding tarsal and metatarsal glands and around hooves. The loss of hair in these places is very gradual and diffuse and may continue even into early October.

The long white hairs on the rump are shed gradually from the vicinity of the tail downwards in early September. The white hairs bordering the anal and urogenital area are shed earlier than those of the posterior margin of rump and here the trend of shedding is ventrad.

The shedding of the hairs on tail is diffuse and appears to take place during summer. By fall the tail has new hairs.

#### Adult winter coat

The winter coat of the black tail is much denser than the summer coat because there is well developed woolly undercoat. In contrast to the reddish yellow tinge of the summer coat in its early stages presents a sleek metallic grey appearance (October), but soon fades to a paler shade.

The forehead region is demarcated on its sides by two dark lines which descend and meet in between the eyes. The presence of greyish hairs around the eyes and in front of the snout give a distinct mask like appearance present only in the winter coat. The hair colouration varies but the hair types except for the wool fibres and their distribution on the body are as in summer.

The individual hairs however have large diameter and a length relatively shorter (refer to later tables) than that in the summer coat. The kemps are more wavy in form. The percentage of short hairs is greater than in summer coat. The wavy nature of kemps assists in accommodating the woolly undercoat properly — both together constituting a good insulating layer on the body in winter.

#### Moult from adult winter coat to adult summer coat

At our latitude this moult begins in mid-April and ends by late June and follows a pattern different from that of the fall moult.

Generally the flanks are the first to shed, and patches having new summer coat are formed on both sides. This culminates

Adult winter to adult summer coat moult

FIGURE 37

Adult in winter coat.

FIGURE 38.1

Moult stage I. The moult starts on the body.

FIGURE 38.2

Moult stage II. Moult spreads cephalad and caudad.

FIGURE 38.3

Moult stage III. Moult complete except for a patch under the throat, and some hairs on hind leg distal end.



FIG. 37

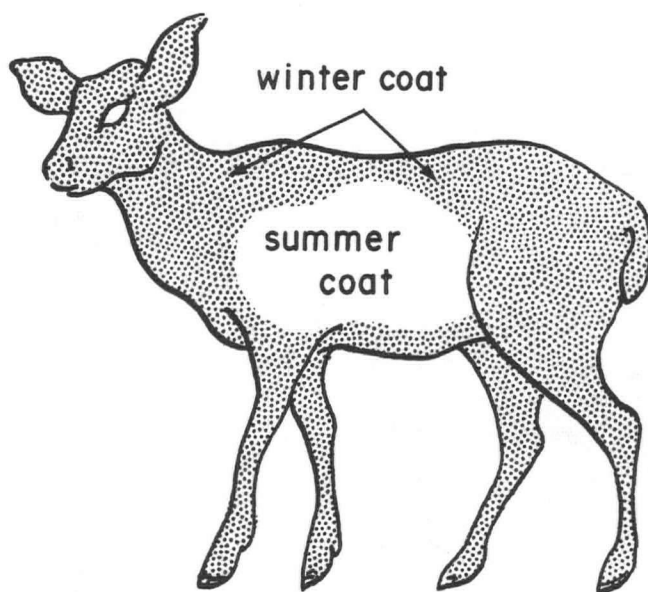


FIG. 38.1 STAGE I

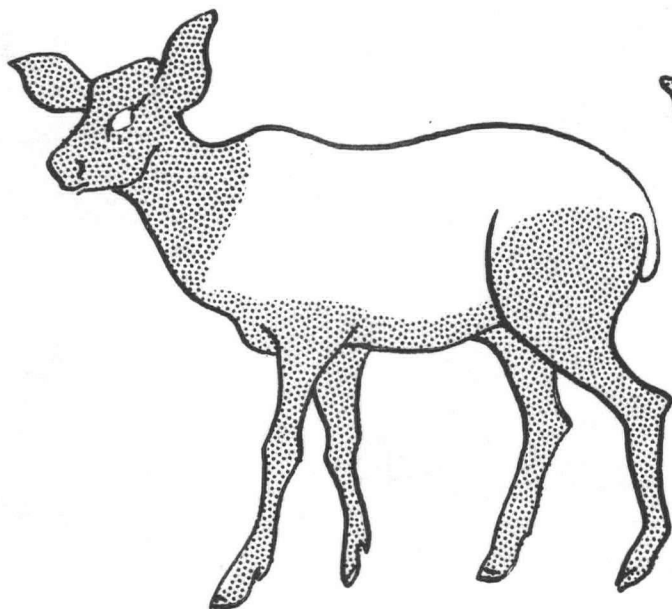


FIG. 38.2 STAGE 2

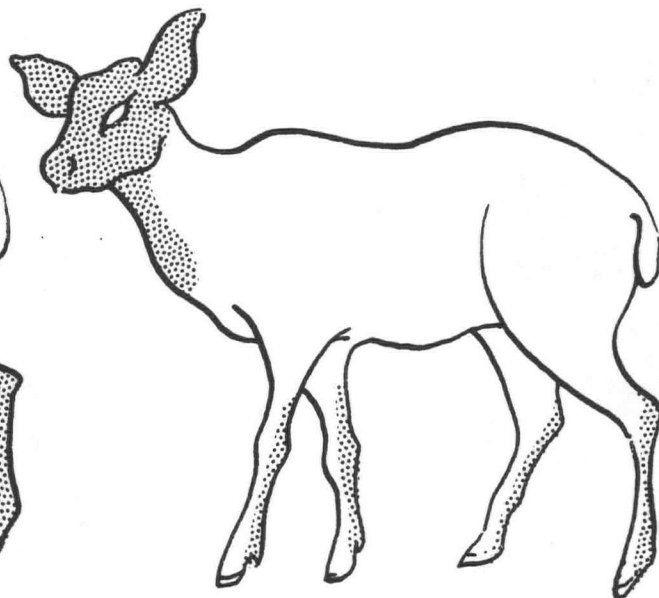


FIG. 38.3 STAGE 3

FIG. 38 ADULT WINTER TO ADULT SUMMER MOULT STAGES

in a stage when the animals appear to have moulted centrally along the flanks and to some extent dorsally. The shedding of short hairs on the face as well as on the distal ends of legs is taking place diffusely. The new hairs are of the same colour as the old hairs and have already grown to some length before the old hairs are shed. The flank moult is completed by early June.

On the body the moulting now proceeds in two directions — cephalad along the neck and caudad along the rump. Along the neck the hairs are first lost on the dorsal and lateral sides and those on the lower side are amongst last to be shed. This occurs in June. Posteriorly on the thighs the hairs are shed and moulting proceeds downwards. The winter hairs on the posterior margin of the rump are among the last to shed and are moulted ventrad. The hairs around the anal and urogenital region moult earlier than this (mid-June). The abdomen moults diffusely in May. Hairs on the posterior margin of the hind limbs and across the tarsal and metatarsal glands are again the last to be shed.

In early June the ears also shed their hairs and during the rest of summer coat they are covered sparsely by small hairs giving the pinnae a bare appearance. Gross inspection of the ears reveal a rich blood supply and it is tempting to suggest that they are important in thermoregulation. If this is so the almost naked condition in summer and heavily furred state in winter has adaptive significance.

### Summary

The major pelage types in the life history of the black tail deer have been investigated and the process of moulting from one type into another has been documented.

The hairs of this species can be distinguished as follows: large guard hairs, intermediate guard hairs, and beard type (long and soft guard hairs in Odocoileus restricted only to tail). These arise in primary follicles. The first formed secondary follicles give rise to small but medullated hairs i.e. of transitional type and the later formed secondaries to the non medullated woolly under hairs — forming the animals undercoat. The first formed secondaries and some primaries produce special medullated hairs; with well developed proximal end but thin and wavy distal end. These have been called transitional types. They in fact constitute the undercoat in fawn birth coat. In addition primary follicles in the fawn birth coat at places give rise to white tipped hairs. Thus the primary follicles are capable of giving rise to many hair types.

The hair scale characteristics depend on hair dimension and not on hair type. They seem to be vary closely with the hair diameter. The woolly under hair present a variation of coronal scale type; and are of uniform diameter. The guard hair diameter is however greatly variable. Their scale pattern varies from irregular mosaic to irregular waved mosaic with smooth margins and the intermarginal distance varying from distant, intermediate (close), to near. The adult winter coat hairs present greater variability in scale pattern.

The hairs of fawn birth coat resemble those of adult summer coat in colouration. The fawn winter coat possesses true woolly undercoat, and resembles adult winter coat. The adult summer coat hairs are longer, straighter and less crimped than the winter coat hairs. It lacks woolly undercoat and has a characteristic colouration. The adult winter coat hairs are shorter, thicker and darker. There is also greater variability in their length.

The pelage colouration depends on the colouration of the visible extremities of guard hairs. These as well as other morphometric details of hairs have been covered in a separate chapter.

The black tail deer moults twice a year i.e. in spring and again in late summer to early autumn. The fawn birth coat begins to be shed by July and the fawn winter coat is assumed by October. The birth coat moult takes place in distinctive stages and the trend is caudad. White spots are lost early. The spring moult of yearlings (i.e. fawn winter to adult summer coat) could not be observed. The adult winter moult begins on the flanks and spreads both cephalad and caudad. The shedding of the summer coat is caudad. The woolly undercoat of non medullated hair moults in diffuse fashion only once a year i.e. in May.



## Chapter V

THE HAIR CYCLE OF THE BLACK TAIL DEERINTRODUCTION

The moult is only a terminal stage of the hair cycle and to appreciate the phenomenon of hair replacement properly the annual hair cycle in itself has to be clearly understood. The significance of this has been adequately stressed by Ling (1965), and by Ryder (1964). The best way to do this is to sample the skin at regular intervals and record the changes in the hair follicle in the course of the year. Nothing is known of this phase of the seasonally cyclical biology of any cervid.

MATERIAL AND METHODS

Two animals were used for this study and skin biopsy samples were collected every fortnight by means of trephine. The details of the trephine have been discussed by Ling (1965).

The animals were immobilized by using Succinylcholine chloride (ANECTINE). The dosage for deer was worked out by Zoology Dept. in course of earlier research and was .0013 cc/lb of animal weight. As the animals were weighed every week correct dosage could be administered while sampling. The dosage was administered by tuberculin syringe, using disposable needles.

The response in the animal was variable. W9 in particular often had difficulty breathing after collapsing on the ground and often required artificial respiration. Subsequent manipulation of the dosage revealed that even 50% of prescribed dosage

FIGURE 39

The trephine used for taking skin biopsy sampling.

FIGURE 40

Fortnightly sampling sites. The number denotes the "sample" number as well as its location on the animal's body.

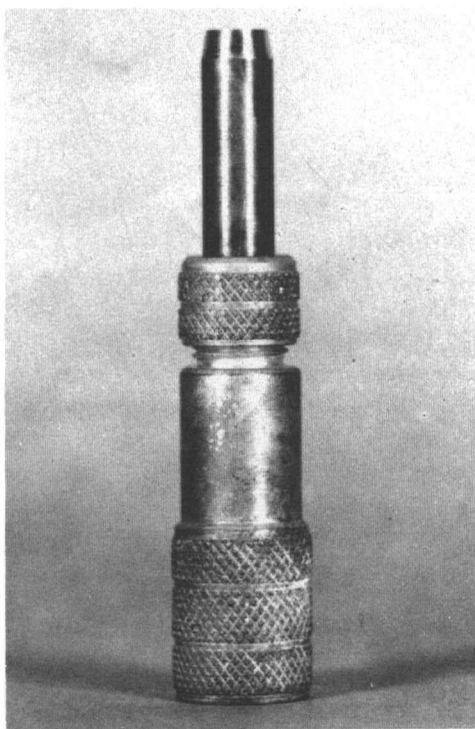


FIG 39

1	5	9	13	17	4
15	19	23	27	22	8
11	25	30	29	26	12
7	21	28	24	20	16
3	18	14	10	6	2

FIG 40

was sufficient to immobilize this individual and the dosage was modified accordingly. For the other animal regular dosage did not create problems.

A sampling programme was also drawn up to ensure that successive sampling sites were not adjoining each other. Samples were taken from the thigh, and fixed in BOUIN'S fluid, and stored in 70% alcohol. Subsequently each sample was divided into two equal parts. One part was sectioned longitudinally i.e. perpendicular to the surface, along the plane of the hairs and the other part was sectioned across the surface. The sections cut at  $8^{\mu}$  were stained with haematoxylin and eosin.

#### OBSERVATIONS

On the thigh the main body pelage consists of three types of hairs. The large and intermediate guard hairs and the woolly under hairs. In adult animals all growing central primary follicles are of approximately the same length and there is less length variation than in these hairs in the natal pelage.

The follicles in all species studied assume the following stages during the hair cycle. The phase during which the follicle is formed and the new hair is produced has been termed the anagen. This involves transformation of the resting follicle into an active follicle. The follicle base is clavate and encloses the dermal papilla while the rest of the newly forming follicles can be distinguished into an external root sheath and a central mass of undifferentiated cells. Subsequently all the normal layers are differentiated and the follicle starts producing new hair. When the follicle has reached its full period of

growth it enters into catagen stage. This is a transitional short lived period, leading to the resting stage of the follicle, namely telogen. In catagen the bulb becomes collapsed and the dermal papilla is not tightly held by the follicle base. The hair base forms a club enclosed in a sac of external root sheath and the portion of the follicle below it degenerates into a strand of cells. The hair and the follicle part remaining migrate upwards till they reach sebaceous gland level, where they remain. This is the telogen or resting stage. During subsequent hair cycle the follicle will be reactivated, old hair shed and by a repetition of process already described new hair will be produced. All the follicles discussed here undergo these stages but due to the very short nature of its duration catagen has not been observed fully here.

To understand the events involved in the hair cycle of my animals let us begin with the winter coat in the resting stage. The winter coat attains full growth by early November and reaches resting stage then.

The histological examination of the material reveals that by early March the guard hair follicles have started growing, the large guard hair follicles presumably starting first, and possess the first emergent summer coat hairs. These are scattered all over the body, reaching lengths which makes them protrude in April over the existing winter coat.

The summer coat guard hairs emerge in mass first on the flanks and then continue emerging towards neck and the posterior end. The large guard hairs of winter coat are shed in April and the pelage at this stage consists of resting winter coat intermediate guard hairs and woolly under hairs, plus actively growing

## Guard hairs

FIGURE 41.1

Deer follicle. Notice the shape of dermal papilla and the inner root sheath cell layers and melanin deposition in cortex. H. & E.

FIGURE 41.2

Deer secondary follicle. Notice the external root sheath, cell orientation as well as the membrane. H. & E.

FIGURE 42

Guard hair follicles in catagen. Growth has ceased and the follicle is withdrawing. H. & E.

FIGURE 43.1

Base of follicle in telogen. Notice the withdrawn follicle base and rounded dermal papilla and the resting hair. Notice position of sweat gland and the resting follicle. H. & E.

FIGURE 43.2

Close up of resting follicle. Notice the partially enclosed rounded dermal papilla. H. & E.

For explanation of abbreviations used please see Appendix, Page 214.

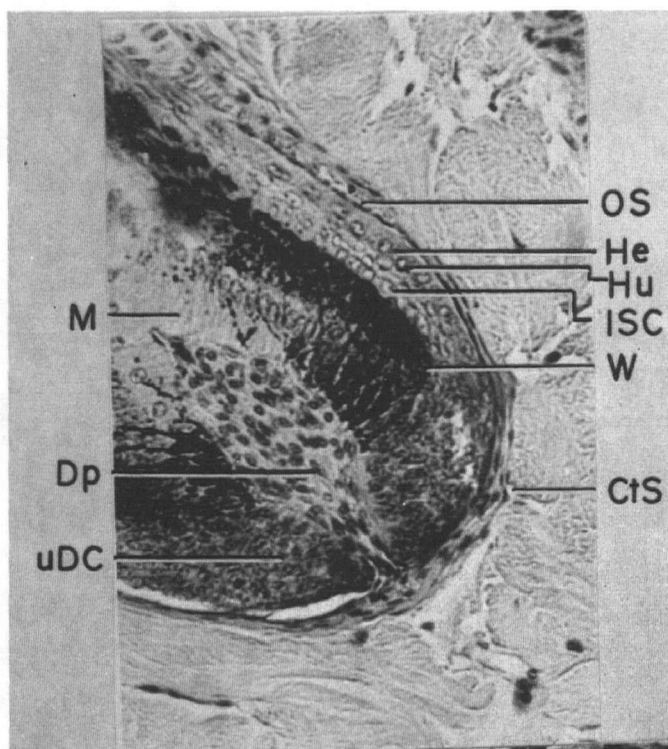


FIG 41.1

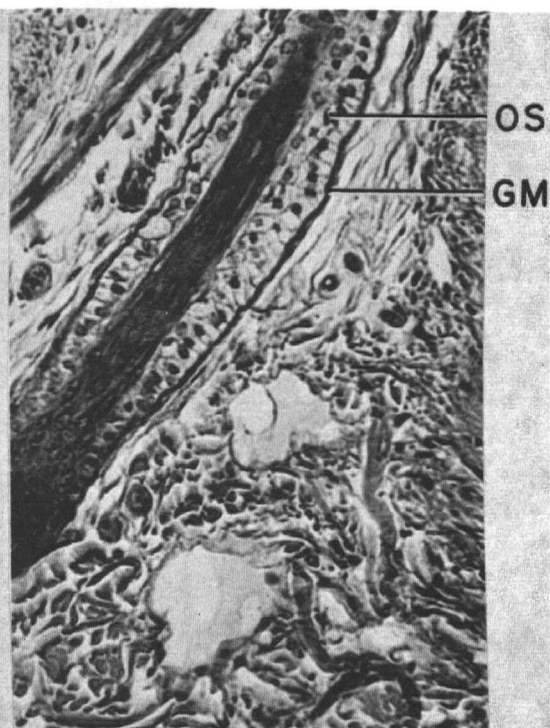


FIG 41.2

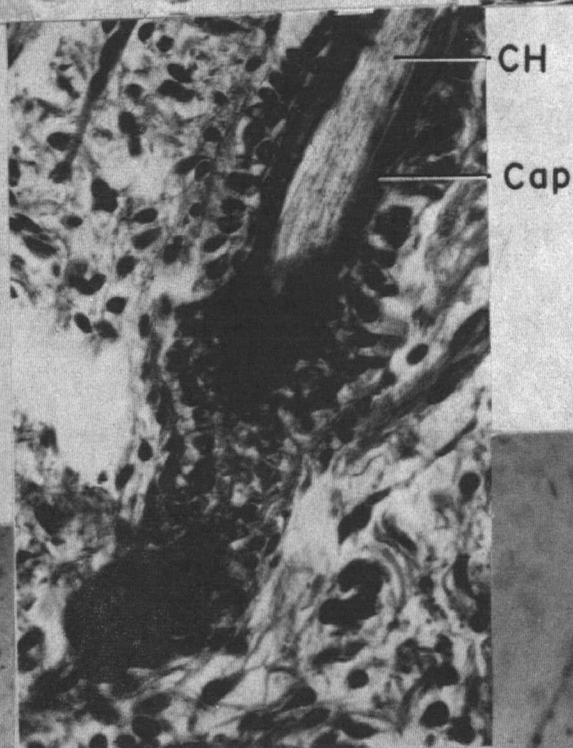


FIG 42

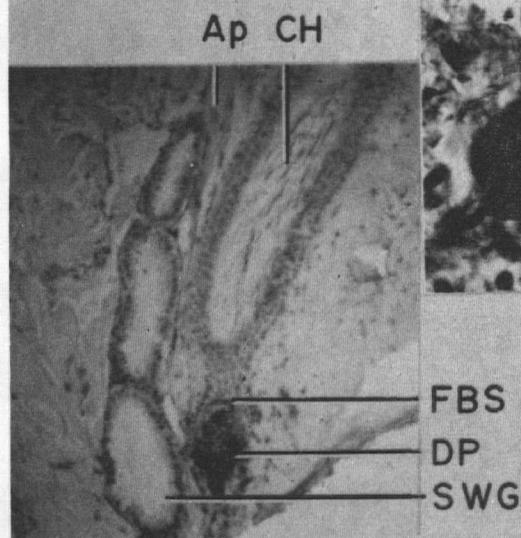


FIG 43.1

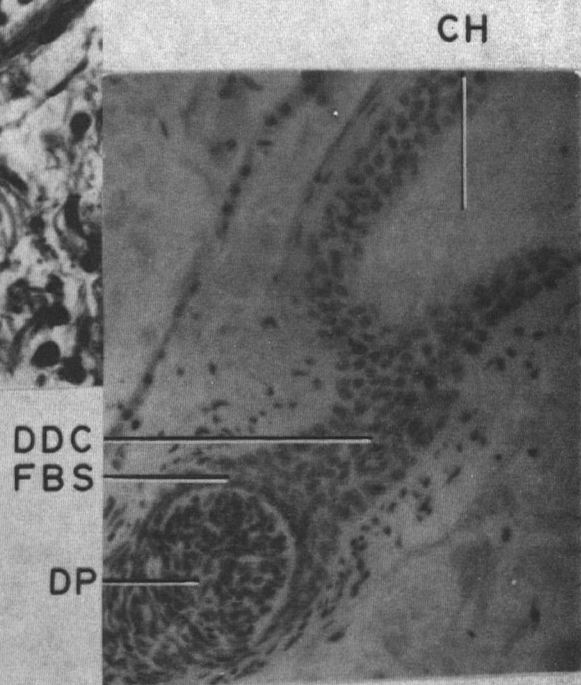


FIG 43.2

summer coat guard hairs. Intermediate guard hairs first emerge by mid-March and large guard hairs by early March. By late March all guard hair follicles are vigorously growing and winter coat intermediate guard hairs are still resting.

The first formed secondary follicles which give rise to medullated hairs were also noticed growing in March. These follicles have emergent hairs in April. The follicle at this time contains an emergent hair plus the old resting hairs.

By mid-May some of the smaller intermediate guard hairs are reaching resting stages and by late June all hairs are in resting stage. The larger guard hair follicles coming to rest last. The first formed secondaries are also in resting stage now and animal is in fully formed summer coat.

By mid-July the first formed secondaries start growing again. By the end of July all secondaries are actively growing woolly hairs. The previous year's woolly hairs had been lost in May without any regenerative activity in their follicles. The guard hair follicles are also starting to grow and by early August the winter coat hairs have emerged on the surface. They make their way through the growing woolly hairs and overtake them in growth rate. By October end all winter coat guard hairs are resting. The intermediate guard hairs come to rest and then the last guard hairs.

The first formed secondary follicles are also resting by October. By December all woolly under coat hairs are resting. Thus later formed secondary follicles have a longer growing period.

The guard hair follicles and woolly under hair follicles continue to rest till March and July respectively when they start growing again.



FIGURE 43.3

Dermal papilla in telogen close up.  
Longitudinal section. H. & E.

FIGURE 43.4

Close up of spatulate dermal papilla of guard  
hair. Longitudinal section. H. & E.

FIGURE 43.5

New hair growing beside old resting hair.  
Notice the position of arrector pili muscle.  
Longitudinal section. H. & E.

FIGURE 43.6

Transverse section of 43.5 above. H. & E.

For explanation of abbreviations used please  
see Appendix IV, Page 214.

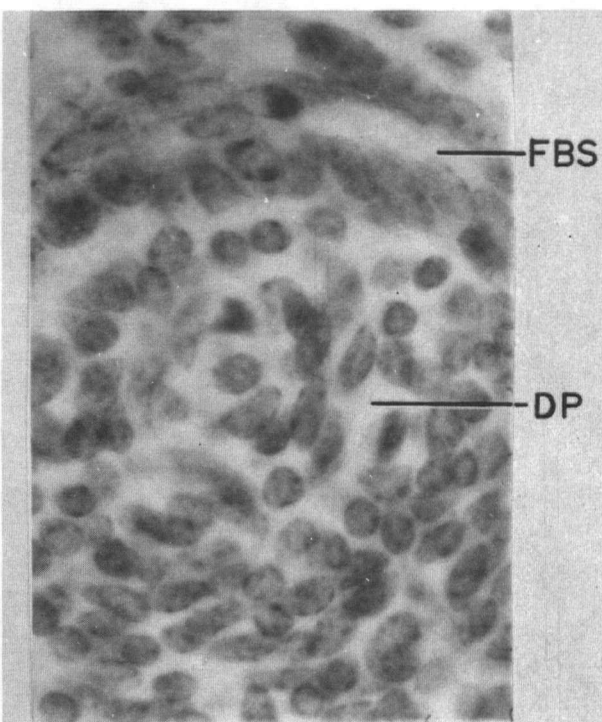


FIG 43.3

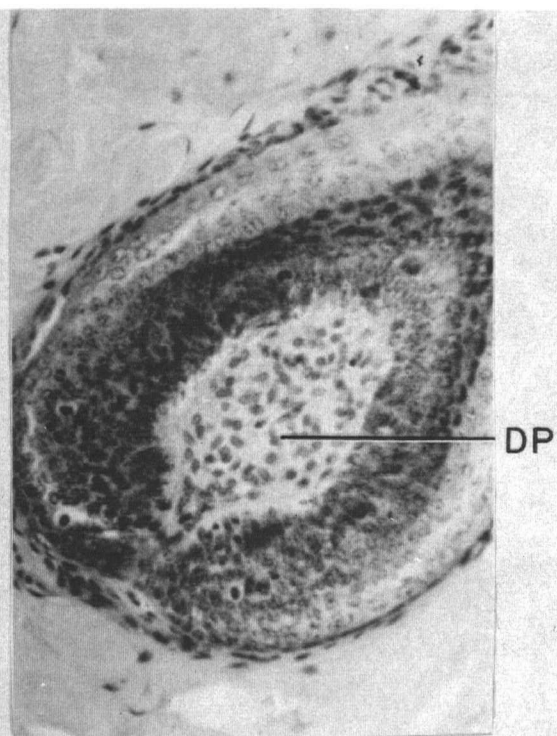


FIG 43.4

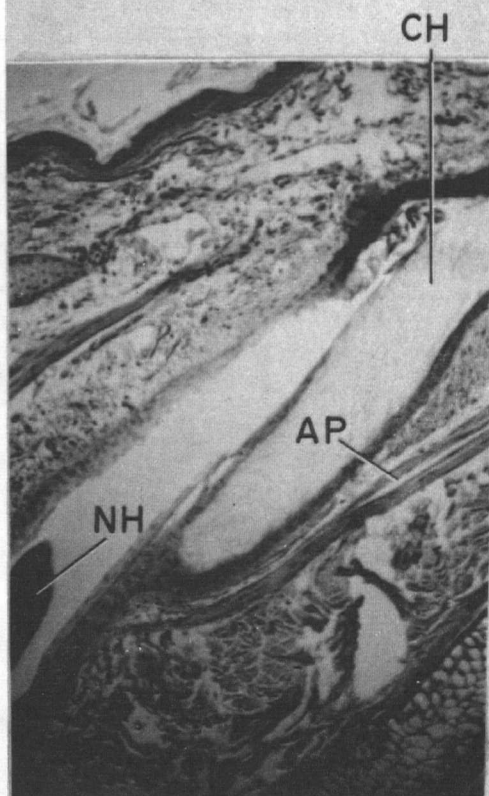


FIG 43.5

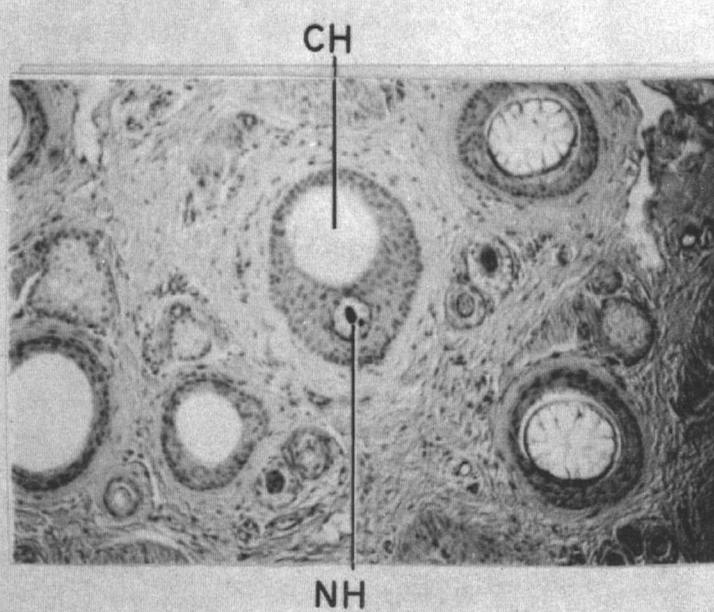


FIG 43.6

Summary

Guard hairs of both coats of the adults have a  $3\frac{1}{2}$ -month growth period. However summer pelage is in a resting state on the body for two months and the winter pelage for five months. The large guard hairs start growth early but come to rest last.

The first formed secondaries also appear to shed their hairs twice, and thus behave like primaries. The later formed secondaries have a  $5\frac{1}{2}$ -month growing period and a  $6\frac{1}{2}$ -month resting period. They are lost in May by being broken off at the surface of the skin. Thus though absent from the functional summer coat, their stubs are present in the follicles. These are shed in mid-July when these follicles start growing and producing new hair again.

TABLE 3Annual Cycle of the Black Tail Deer

Activity	Duration	
	From	To
Summer coat grows	First March	Mid-June
Summer coat rests	Mid-June	Mid-August
Follicle rests	Mid-June	Mid-July
Summer coat sheds	Mid-August	October
Winter coat grows	Mid-July	October
Winter coat rests	November	April
Winter coat sheds	May	June
Woolly under coat grows	Mid-July	December
Woolly under coat rests	January	Mid-July
Woolly under coat sheds	May	Mid-June

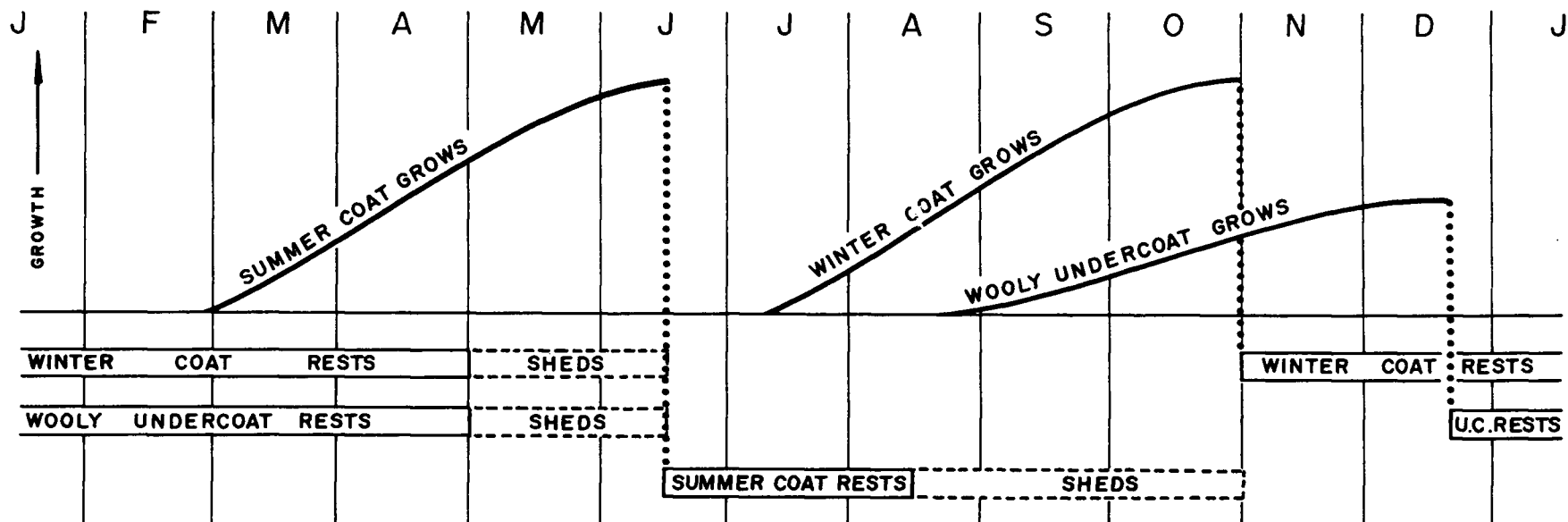


FIG.44 DIAGRAMATIC REPRESENTATION OF THE ANNUAL HAIR CYCLE

## Chapter VI

### THE MORPHOMETRY OF BLACK TAIL HAIRS

#### INTRODUCTION

As shown in Chapter IV, the deer alters its pelage characteristics between youth and maturity and also between summer and winter, each year of its life. It is assumed that the succession of pelage and also the details of the hairs themselves develop in response to genetic instructions that are essential components of the entire catalogue of such that govern the form and function of the animal.

I have described the follicles from which the several types of hairs arise and given a general description of each type, the features of the coat of which they constitute a part and the moult patterns that these coats follow. It is important however to establish in more detail the differences that distinguish the hair types and the seasonal changes they undergo amidst conditions close to the optimum. Only with such details in hand can alterations arising from environmental impact or alterations associated with species or geographic areas be studied.

#### MATERIAL AND METHODS

To establish the variation in the different coat types, in regions within these coat types and in hair types within these regions, guard hair samples were selected on random basis from five selected regions. These were:

- 1) Back
- 2) Flank
- 3) Abdomen
- 4) Thigh
- 5) Hind leg. Distal end.

The samples were sorted out into large and intermediate guard hairs and were measured for length and diameter. The different coloured bands present on the hairs were also measured. The data so collected was statistically analysed in an I.B.M. 7040 computer with the help of programmes available from the Faculty of Forestry.

These analyses were of two kinds.

A) For the study of variation in length, diameter and colour zone in different coats, regions and type of hair.

B) For the study of correlation between the length and diameter in the hair under different circumstances.

For the first kind of study a nested (within) analysis of variance of lengths of hair was done. Similar analysis was undertaken for the measurements of diameter of the hairs. In addition the proportion of the total length of the hair under each of the four colour zones was computed and a similar separate analysis of variance done for each zone. The results are summarized below.

### OBSERVATIONS

#### Length

The length measurements taken are given in Table 5.

The results of analysis of variance are given in Table 4.

TABLE 4  
Nested Analysis of Variance Hair Length

Source	Degree of freedom	Sum square	Mean square	F
Coat	3	31431.00	10477.00	318.73**
Region within coat	16	109130.00	6820.70	207.56**
Type within region within coat	20	71055.00	3552.80	108.08**
Error	660	21694.00	32.87	
Total	699	233310.00		

As the 'F' values are highly significant Duncan's multiple range test L1, (1964) was performed for the coat means, regions within coat means and type within region within coat means. The results are tabulated in Table 6, where two or more means are underscored by the same line it denotes that they are not significantly different from each other at 5%, significance level. Other apparent differences are significant.

To understand whether the hair types /region/ coat are or are not significantly different from each other in respect of the particular parameter under consideration, refer to Table 5. The underscoring of figures where present implies that the hair types are not significantly different in respect of the parameter in question, as tested by Duncan's multiple range test.

On perusal of the data in relation to the hair length the following points emerge.

The large guard hairs and the intermediate guard hairs are consistently different in length. Only in region five of the



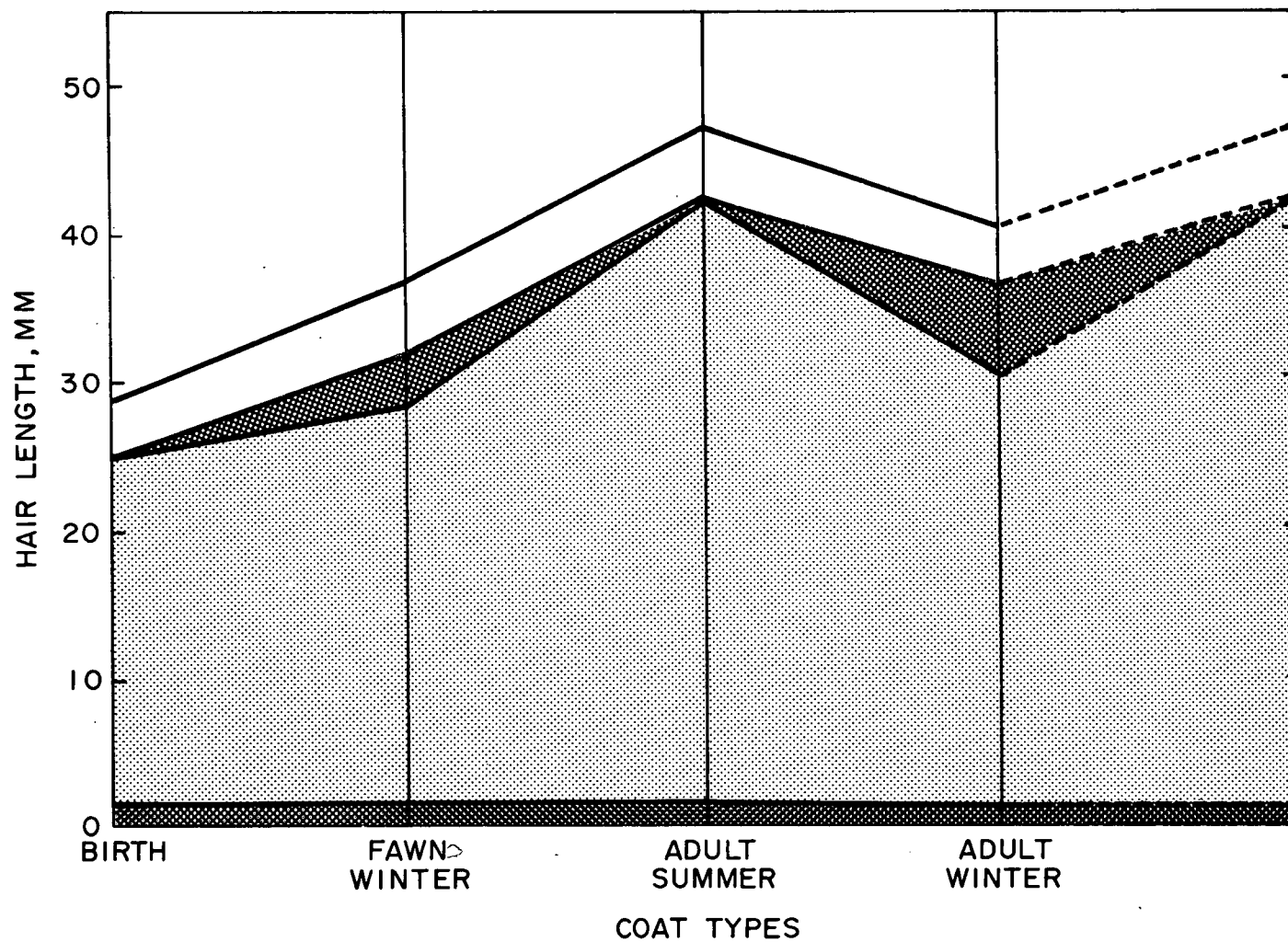


FIG. 45 GUARD HAIR LENGTH RELATIONSHIP IN DIFFERENT COATS OF BLACK TAIL DEER; WITH THEIR MAJOR HAIR COLOUR ZONES

TABLE 5

## Lengths of Hair Samples in mm

Coat type	Region	Hair type 1 (Large guard)		Hair type 2 (Intermediate guard)		Mean length & No. of Observations
		Length (mm)	No. of Observation	Length in mm	No. of Observation	
Coat I (Birth coat)	1	46.1875	16	21.8696	23	31.8462(39)
	2	58.2308	13	30.8824	17	42.7333(30)
	3	44.0000	11	18.7200	25	26.4444(36)
	4	41.9333	15	23.8400	25	30.6250(40)
	5	15.8000	10	11.9545	22	13.1563(32)
					Average	28.9379(177)
Coat II Fawn winter coat	1	56.0000	11	39.2000	25	44.3333(36)
	2	59.0000	6	37.0000	26	41.5313(32)
	3	51.6364	11	32.0417	24	38.2000(35)
	4	55.8750	16	34.9630	27	42.7442(43)
	5	13.7143	14	11.3125	16	12.4333(30)
					Average	36.7784(176)
Coat III Adult summer coat	1	76.6923	13	43.0000	25	54.5263(38)
	2	79.0769	13	46.9583	24	58.2432(37)
	3	70.1429	14	38.7600	25	50.0256(39)
	4	73.0000	13	47.0000	25	55.5947(38)
	5	23.3077	13	12.7917	24	16.4865(37)
					Average	47.1536(189)
Coat IV Adult winter coat	1	58.1818	11	43.2083	24	47.9143(35)
	2	58.3333	12	44.8400	25	49.2162(37)
	3	49.5556	9	43.3636	11	46.1500(20)
	4	58.1111	9	39.4400	25	44.3824(34)
	5	21.3750	8	11.8333	24	14.2188(32)
					Average	40.4114(158)

TABLE 6

Duncan's Multiple Range Test

---

Hair Length in millimeters					
A <u>Within coats</u>					
Coat	III	IV	II	I	
Mean length	47.15	40.41	36.78	28.94	

---

B <u>Regions within coats</u>					
<u>Coat I</u>					
Region	2	1	4	3	5
Mean length	42.73	<u>31.55</u>	<u>30.63</u>	26.44	13.16
<u>Coat II</u>					
Region	1	4	2	3	5
Mean length	<u>44.33</u>	<u>42.74</u>	<u>41.53</u>	38.20	12.43
<u>Coat III</u>					
Region	2	4	1	3	5
Mean length	<u>58.24</u>	<u>55.89</u>	<u>54.52</u>	50.03	16.49
<u>Coat IV</u>					
Region	2	1	3	4	5
Mean length	<u>49.22</u>	<u>47.91</u>	<u>46.15</u>	<u>44.30</u>	12.22

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C - The hair types within regions see Table 5

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fawn birth coat and fawn winter coat are these differences statistically not significant. The hairs in region five of all the coats were considerably smaller in length than those in the other regions sampled.

Amongst the regions sampled for length, the hairs on flanks (region two) were observed to be the longest. The increases in hair length can be attributed either to faster rate of growth or to longer duration of growth or both. No observations in this respect are available in relation to the different body regions of the black tail deer. It may be of interest to investigate hair growth over different body regions of the same animal over a period of time and establish presence of growth gradients if any.

The hair length also increases from fawn birth coat onward to adult summer coat but decreases again in the adult winter coat.

### Diameter

The diameter measurements taken are shown in Table 8 and the results of the analysis of variance are given in Table 7.

TABLE 7

Nested Analysis of Variance Hair Diameter

Source	Degree of freedom	Sum square	Mean square	F
Coat	3	1977300.00	659100.00	819.88**
Region within coat	16	1065400.00	66587.00	82.83**
Type within region within coat	20	358400.00	17920.00	22.29**
Error	660	530570.00	803.90	
Total	699	393700.00		

As the 'F' values are highly significant Duncan's multiple range test L1 (1964) was performed for the coat means, regions within coat means, and the hair type within region within coat means. The results are tabulated in Table 9. Where two or more means are underscored by the same line it denotes that they are not significantly different from each other at 5% significance level.

To understand whether hair types /region/ coat are or are not significantly different from each other in respect to diameter refer to Table 8. Figures underscored indicate that the hair type in question are not significantly different in respect of this parameter (diameter), as tested with Duncan's multiple range test.

In respect to hair diameters the following can be said. In the fawn birth coat the diameters of large guard hairs and intermediate guard hairs are not significantly different but in subsequent coats generally the large guard hairs, though of greater length, possess smaller diameters than the comparable intermediate guard hairs. The consistent exceptions to this have been in region five of all the four coats and also regions one and two of three and region one of coat four.

In the fawn birth coat and fawn winter coat the greater diameter is attained by hairs in the flank region. But in the adult summer and winter coats it was the abdominal hairs which characteristically attained the largest diameters.

The average diameter for the pelage continues to increase from fawn birth coat onwards till the adult winter coat stage is reached. Thus winter hairs are of larger diameter than the summer hairs.

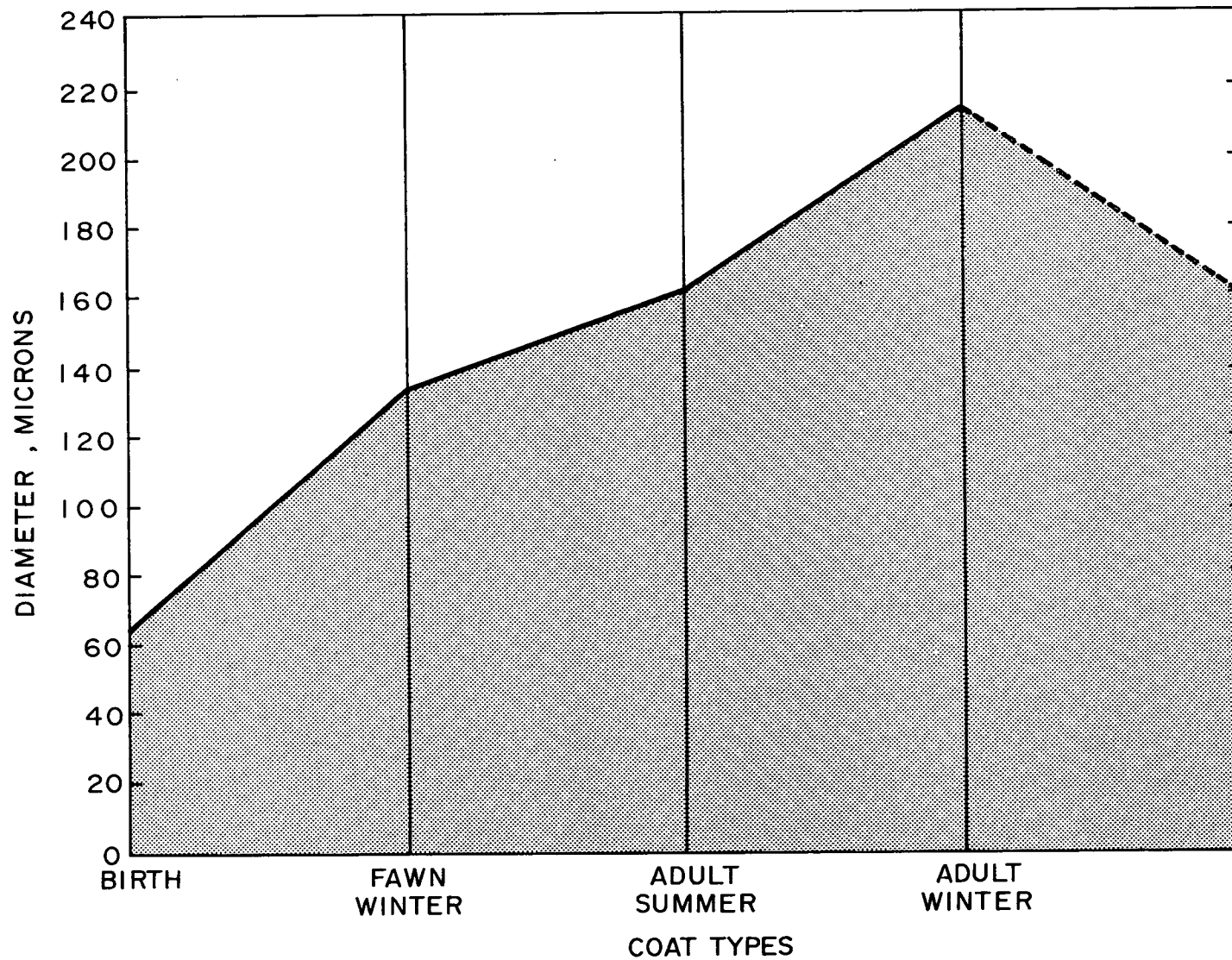


FIG.46 GUARD HAIR DIAMETER RELATIONSHIP IN DIFFERENT BLACK TAIL COATS

TABLE 8

## Diameter of Hair Samples in Microns

Coat type	Body Region	Type 1 Primary Guard Hairs		Type 2 Secondary Guard Hairs		Mean Diameter
		Diameter	No. of Observations	Diameter	No. of Observations	
Coat I Birth coat	1	<u>60.3750</u>	16	<u>57.3478</u>	23	58.5897(39)
	2	<u>62.9231</u>	13	<u>72.8824</u>	17	68.5667(30)
	3	<u>50.8182</u>	11	<u>56.4400</u>	25	54.7220(36)
	4	<u>73.1333</u>	15	<u>75.7200</u>	25	74.7500(40)
	5	<u>65.9000</u>	10	<u>62.9545</u>	22	63.8750(32)
					Average	64.1017(177)
Coat II Fawn winter coat	1	99.6364	11	152.6400	25	136.4444(36)
	2	108.0000	6	177.6538	26	164.2188(32)
	3	117.3636	11	142.1250	24	134.3429(35)
	4	116.3125	16	156.0741	27	141.2791(43)
	5	<u>84.3571</u>	14	<u>85.8125</u>	16	85.1333(30)
					Average	133.5114(176)
Coat III Adult summer coat	1	<u>150.3077</u>	13	<u>143.8400</u>	25	146.0526(38)
	2	<u>174.2308</u>	13	<u>170.1667</u>	24	171.5946(37)
	3	153.4286	14	227.8800	25	201.1538(39)
	4	155.3077	13	187.8800	25	176.7368(38)
	5	<u>99.0769</u>	13	<u>113.0000</u>	24	108.1081(37)
					Average	161.1640(189)
Coat IV Adult winter coat	1	<u>200.4545</u>	11	213.4167	24	209.3429(35)
	2	<u>194.8333</u>	12	261.4400	25	239.8378(37)
	3	238.6667	9	387.0909	11	320.3000(20)
	4	163.0000	9	273.2800	25	244.0882(34)
	5	<u>76.0000</u>	8	<u>96.3750</u>	24	91.2813(32)
					Average	214.0949(158)

TABLE 9Duncan's Multiple Range TestHair Diameter in micronsA Within coats

Coat	IV	III	II	I
Mean diameter	214.09	161.16	133.51	64.10

B Regions within coatsCoat I

Region	4	2	5	1	3
Mean diameter	<u>74.75</u>	<u>68.56</u>	<u>63.57</u>	58.58	54.72

Coat II

Region	2	4	1	3	5
Mean diameter	164.21	<u>141.27</u>	<u>136.44</u>	<u>134.34</u>	85.13

Coat III

Region	3	4	2	1	5
Mean diameter	201.15	<u>176.73</u>	<u>171.59</u>	146.05	108.10

Coat IV

Region	3	4	2	1	5
Mean diameter	320.30	<u>244.08</u>	<u>239.83</u>	209.34	91.28

C Hair type within region refer to Table 8



## Colouration

The colouration of the coats differ greatly, particularly between the summer and winter pelages. The summer coats are reddish-yellow while the winter coats are greyish. The fawn birth coat and adult summer coat have similar general colouration of hairs but subtle differences do exist. The yellow coloured zone which follows the black tip is short, but present in the adult summer coat while it is totally absent in the fawn birth coat. The presence of white spots on the fawn birth coat is also very characteristic. The fawn winter coat is also a little darker than the adult winter coat, as some of the guard hairs in it are completely black, particularly on the back and sides. The different colour bands on an agouti pattern hair represent pulses of activity in pigment production by the follicle. Superficial study of hairs present in the different pelages of this deer led us to the impression that these pulses, and the results as seen in the pigmentation of the hair, differed within the different pelages, as well as between body regions. To explore this in more detail appropriate samples of hair were subjected to detailed measurement of the lengths of each of four colour segments, black, yellow, grey (or reddish-yellow), and white (colourless).

## Black coloured zone

In the regions sampled the tip of the hair is black. This is also true for abdominal hairs. This zone was longer in the back region of the fawn birth coat but attained its maximum extent in some hairs of the back in fawn winter coat. Generally the large guard hairs have greater proportion of this black

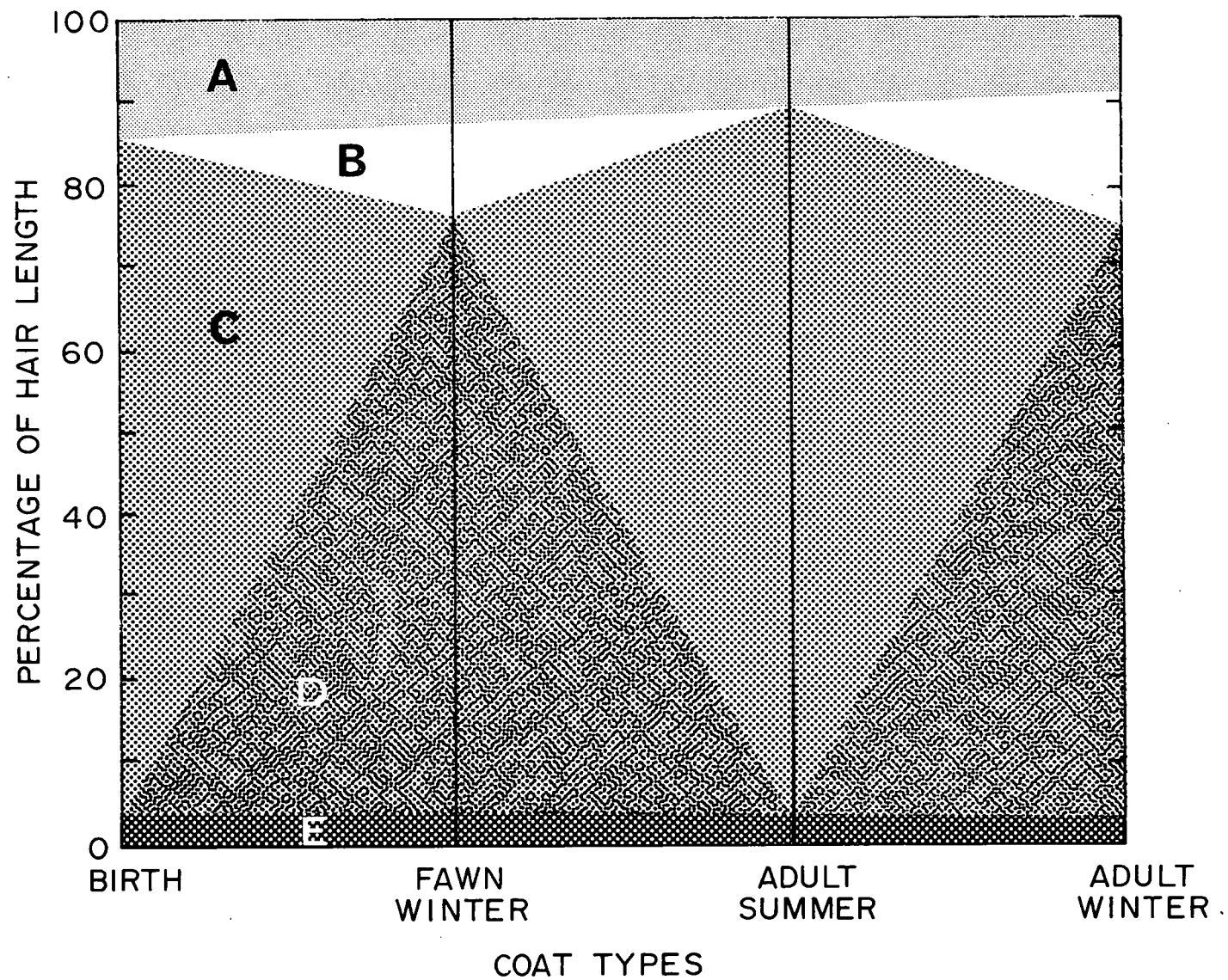


FIG.47 PERCENTAGES OF DIFFERENT COLOURED ZONES IN COAT TYPES IN RELATION TO TOTAL HAIR LENGTH, A = BLACK, B=YELLOW, C= REDDISH YELLOW, D=GREY, E = WHITE.

TABLE 10

## Black Coloured Zone

Coat type	Region	Hair type I		Hair type II		Mean & No. of Observations
		Black colour zone	No. of Observations	Black colour zone	No. of Observations	
Coat I	1	0.3993	16	0.2167	23	0.2916(39)
	2	0.1385	13	0.1260	17	0.1314(30)
	3	0.2307	11	0.0450	25	0.1017(36)
	4	0.1711	15	0.1044	25	0.1294(40)
	5	0.0941	10	0.0874	22	0.0895(32)
					Average	0.1526(177)
Coat II	1	0.6751	11	0.1258	25	0.2936(36)
	2	0.1182	6	0.0964	26	0.1005(32)
	3	0.0384	11	0.0721	24	0.0615(35)
	4	0.1286	16	0.0812	27	0.0989(43)
	5	0.0828	14	0.0889	16	0.0861(30)
					Average	0.1294(176)
Coat III	1	0.1522	13	0.1269	25	0.1355(38)
	2	0.0924	13	0.0798	24	0.0843(37)
	3	0.0575	14	0.0878	25	0.0770(39)
	4	0.1114	13	0.1021	25	0.1053(38)
	5	0.0732	13	0.1037	24	0.0930(37)
					Average	0.0990(189)
Coat IV	1	0.0303	11	0.0969	24	0.1074(35)
	2	0.1432	12	0.0656	25	0.0908(37)
	3	0.1633	9	0.0604	11	0.1067(20)
	4	0.1538	9	0.0706	25	0.0926(34)
	5	0.0853	8	0.0851	24	0.0851(32)
					Average	0.0957(158)

coloured zone, than the intermediate guard hair types. Table 10 depicts the extent of this region amongst the samples studied and also identifies those not significantly different from each other (underlined figures). Taking the average for the coats, it is found that the black coloured region has maximum extent (15% of total hair length) in fawn birth coat and decreases consistently till it attains a level of 9% in adult winter coat.

TABLE 11

Nested Analysis of Variance. Black Coloured Region

Source	Degree of freedom	Sum square	Mean square	F
Coat	3	0.38033	0.12678	66.38**
Region within coat	16	2.3570	0.14731	77.13**
Type within region within coat	20	3.1390	0.15695	82.18**
Error	660	1.2605	.0019098	
Total	699	7.1368		

As the 'F' values are highly significant Duncan's multiple range test was performed for the coat means, region within coat means and type within region within coat means. The results are tabulated in Table 12. Where two or more means are underscored by the same line it denotes that they are not significantly different from each other at 5% significance level.

Table 12

## Duncan's Multiple Range Test

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Black coloured region (ratio of hair lengths)					
<u>A Within coats</u>					
Coat	I	II	III	IV	
Black colouration	.1526	.1294	<u>0.0990</u>	<u>0.0957</u>	

---

<u>B Regions within coats</u>					
<u>Coat I</u>					
Region	1	2	4	3	5
Black colouration	0.291600	<u>0.131400</u>	<u>0.129400</u>	0.101700	0.89500
<u>Coat II</u>					
Region	1	2	4	5	3
Black colouration	0.293600	<u>0.100500</u>	<u>0.098900</u>	<u>0.086100</u>	0.061500
<u>Coat III</u>					
Region	1	4	5	2	3
Black colouration	0.135500	<u>0.105300</u>	<u>0.093000</u>	<u>0.084300</u>	0.077000
<u>Coat IV</u>					
Region	1	3	4	2	5
Black colouration	<u>0.107400</u>	0.106700	<u>0.092600</u>	<u>0.908000</u>	<u>0.085100</u>

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C - Hair types within regions refer to Table 10

---

Yellow coloured zone

In all winter coats and to a small extent in the intermediate guard hairs from back of adult summer coat, a zone of yellow colouration lies below the black tip. This zone is completely missing in the fawn birth coat. It reaches its maximum extent in adult winter coat. Regionally it reaches its greatest extent in region five of the fawn winter coat. Table 14.

TABLE 13Nested Analysis of Variance. Yellow Coloured Zone

Source	Degree of freedom	Sum square	Mean square	F
Coat	3	2.8983	0.96611	710.10**
Region within coat	16	4.9296	0.30810	226.46**
Type within region within coat	20	1.5374	0.076869	56.50**
Error	660	0.89794	0.013605	
Total	669	10.263		

As the 'F' values are highly significant Duncan's multiple range test L1 (1964) was performed for the coat means, region within coat means and type within region within coat means. The results are tabulated in Table 14. Where two or more means are underscored by the same line it denotes that they are not significantly different, from each other at 5% level of significance. To understand if any of the hair type /region/ coat are not significantly different in respect of the parameter in question (yellow colouration) see Table 14. If underscored the figures are not significantly different as per Duncan's multiple range test at 5% significance level.

TABLE 14

## Yellow coloured Zone Extent

Coat type	Region	Hair Type I		Hair Type II		Mean & No. of Observations
		Yellow coloured Zone	No. of Observations	Yellow coloured Zone	No. of Observations	
Coat I	1	0.0000	11	0.0000	23	0.0000(39)
	2	0.0000	13	0.0000	17	0.0000(30)
	3	0.0000	11	0.0000	25	0.0000(36)
	4	0.0000	15	0.0000	25	0.0000(40)
	5	0.0000	10	0.0000	22	0.0000(32)
					Average	0.0000(177)
Coat II	1	0.0212	11	0.0556	25	0.0451(36)
	2	0.0000	6	0.0961	26	0.0781(32)
	3	0.0197	11	0.0000	24	0.0062(35)
	4	0.0000	16	0.0378	27	0.0238(43)
	5	0.4542	14	0.4348	16	0.4438(30)
					Average	0.1061(176)
Coat III	1	0.0000	13	0.0357	25	0.0235(38)
	2	0.0000	13	0.0000	24	0.0000(37)
	3	0.0000	14	0.0000	25	0.0000(39)
	4	0.0000	13	0.0000	25	0.0000(38)
	5	0.0000	13	0.0000	25	0.0000(37)
					Average	0.0047(189)
Coat IV	1	0.3126	11	0.1052	24	0.1702(35)
	2	0.3761	12	0.0588	25	0.1617(37)
	3	0.0000	9	0.0000	11	0.0000(26)
	4	0.2440	9	0.0934	25	0.1333(34)
	5	0.1080	8	0.2727	24	0.2315(32)
					Average	0.1511(158)

TABLE 15Duncan's Multiple Range TestYellow coloured zoneA Within coats

Coat	I	III	II	IV
Yellow zone	0.000000	0.004700	0.106100	0.151100

B Regions within coatsCoat I

All figures are zero no significant difference

Coat II

Region	3	4	1	2	5
Yellow coloured zone	0.006200	<u>0.028300</u>	<u>0.045100</u>	0.078100	0.443800

Coat III

Region	2	3	4	5	1
Yellow coloured zone	<u>0.000000</u>	<u>0.000000</u>	<u>0.000000</u>	<u>0.000000</u>	0.023500

Coat IV

Region	3	4	2	1	5
Yellow coloured zone	0.000000	0.133300	<u>0.161700</u>	<u>0.170200</u>	0.231500

C Hair types within regions see Table 14



Grey or reddish-yellow coloured zone

This is the next colour zone on the hair shaft. In winter coat it is grey and in summer coat it is reddish-yellow. It is characteristically of greater extent in the abdominal region. This zone is larger in the fawn birth coats and adult summer coats than in the other pelages.

The quantitative details of this region are given in Table 17.

TABLE 16

Nested Analysis of Variance of Grey/-Reddish-Yellow Zone

Source	Degree of freedom	Sum square	Mean square	F
Coat	3	2.6347	0.87825	104.57**
Region within coat	16	7.6320	0.47700	56.79**
Type within region within coat	20	4.9701	0.24851	29.59**
Error	660	5.5431	0.0083986	
Total	699	2.0780		

As the 'F' values are highly significant Duncan's multiple range test L1 (1964) was performed for the coat means, region within coat means, and type within region within coat means. The results are tabulated in Table 18. Where figures have been underscored by a line it means that they are not significantly different at 5% level of significance. To find out if hair types within region within coat are significantly not different in respect of parameter in question (grey/-reddish-yellow zone) see Table 17 underscored figures imply that they are not significantly different.

TABLE 17

## Grey or Reddish-yellow Zone Extent

		Hair Type 1		Hair Type 2		Mean & No. of Observations
Coat type	Region	Grey coloured zone or Reddish-yellow	No. of Observations	Grey coloured zone or Reddish-yellow	No. of Observations	
Coat	1	0.5787	16	0.7477	23	0.6184 (39)
	2	0.8442	13	0.8484	17	0.8466 (30)
	3	0.7453	11	0.9720	25	0.9027 (36)
	4	0.8043	15	0.8537	25	0.8352 (40)
	5	0.8365	10	0.8206	22	0.8256 (32)
					Average	0.8146 (177)
Coat II	1	0.2874	11	0.7815	25	0.6305 (36)
	2	0.8390	6	0.7726	26	0.1850 (32)
	3	0.9223	11	0.8959	24	0.9042 (35)
	4	0.8572	16	0.8551	27	0.8559 (43)
	5	0.3893	14	0.3879	16	0.3885 (30)
					Average	0.7269 (176)
Coat III	1	0.8347	13	0.8123	25	0.8200 (38)
	2	0.8949	13	0.8986	24	0.8973 (37)
	3	0.9278	14	0.8717	25	0.8918 (39)
	4	0.8747	13	0.8760	25	0.8756 (38)
	5	0.8803	13	0.8168	24	0.8391 (37)
					Average	0.8649 (189)
Coat IV	1	0.5368	11	0.7742	24	0.6996 (35)
	2	0.4362	12	0.8528	25	0.7265 (37)
	3	0.8002	9	0.8849	11	0.8468 (20)
	4	0.5675	9	0.8204	25	0.7534 (34)
	5	0.7578	8	0.5707	24	0.6175 (32)
					Average	0.7125 (158)

TABLE 18

## Duncan's Multiple Range Test

Grey/Reddish-yellow ZoneA Within coats

Coat	IV	II	I	III
Grey/reddish yellow zone	0.719500	0.726900	0.814600	0.846900

B Region within coatsCoat I

Region	1	5	4	2	3
Grey/reddish yellow zone	0.678400	0.825600	0.835200	0.846600	0.902700

Coat II

Region	5	1	2	4	3
Grey/reddish yellow zone	0.388500	0.630500	0.785000	0.855900	0.904200

Coat III

Region	1	5	4	3	2
Grey/reddish yellow zone	0.820000	0.839100	0.875600	0.891800	0.897300

Coat IV

Region	5	1	2	4	3
Grey/reddish yellow zone	0.617500	0.699600	0.726500	0.753400	0.846800

C Hair types within region see Table 17

White coloured zone (Translucent)

This zone constitutes the basal stalk of the hair. The medulla is missing in this region and the cuticle and cortex are translucent.

This region is characteristically longer in the abdominal hairs. Considering the coats it reaches its greater development in the fawn birth coat. The significance of it's reaching greater extent in abdominal hairs is not clear. It is likely that medulla formation stops early in this area and consequently a greater proportion of non medullated basal region is formed. The explanation of early stoppage of medulla formation here is locked in the complex biochemical activity taking place within the hair follicles and needs further study.

Where two or more means are underscored it denotes that for the parameter in question they are not significantly different from each other at 5% level. To find out if any of the types within regions within coats are not significantly different refer to Table 19. Figures underlined here are tested by Duncan's multiple range test and found to be not significantly different.

TABLE 19

## White Coloured Zone

Coat type	Region	Hair Type I		Hair Type II		Mean & No. of Observations
		White coloured zone	No. of Observations	White coloured zone	No. of Observations	
Coat I	1	0.0220	16	0.0467	23	.0366(34)
	2	0.0173	13	0.0328	17	.0261(30)
	3	0.0240	11	0.0550	25	.0455(36)
	4	0.0246	15	0.0444	25	.0370(40)
	5	0.0753	10	0.0920	22	.0808(32)
Average						.0458(177)
Coat II	1	0.0181	11	0.0261	25	.0236(36)
	2	0.0171	6	0.0276	26	.0256(32)
	3	0.0197	11	0.0319	24	.0281(35)
	4	0.0214	16	0.0219	27	.0262(43)
	5	0.0753	14	0.0920	16	.0818(30)
Average						.0354(176)
Coat III	1	0.0131	13	0.0236	25	0.0200(38)
	2	0.0127	13	0.0216	24	0.0185(37)
	3	0.0147	14	0.0522	25	0.0387(39)
	4	0.0138	13	0.0219	25	0.0191(38)
	5	0.0465	13	0.0795	24	0.0679(37)
Average						0.0328(189)
Coat IV	1	0.0173	11	0.0238	24	0.0217(35)
	2	0.0174	12	0.0228	25	0.0211(37)
	3	0.0405	9	0.0473	11	0.0442(26)
	4	0.0173	9	0.0259	25	0.0236(34)
	5	0.0490	8	0.0851	24	0.0761(32)
Average						0.0358(158)

TABLE 20

Nested Analysis of Variance. White Coloured Zone

Source	Degree of freedom	Sum square	Mean square	F
Coat	3	0.017580	.0058599	80.74**
Region within coat	16	0.29121	.018201	250.76**
Type within region within coat	20	0.057962	.002898	39.93**
Error	660	0.047903	.000072581	
Total	699	0.41466		

As the 'F' values are highly significant Duncan's multiple range test L1 (1964) was performed for the coat means, regions within coat means and type within region within coat means. The results are tabulated in Table 21.

TABLE 21

Duncan's Multiple Range Test

<u>White coloured zone</u>				
<u>A Within coats</u>				
Coat	III	II	IV	I
White coloured zone	0.032800	0.035400	0.035800	0.045800

---

<u>B Regions within coats</u>					
<u>Coat I</u>					
Region	2	1	4	3	5
White coloured zone	0.026100	<u>0.036600</u>	<u>0.037000</u>	0.045500	0.086800

<u>Coat II</u>					
Region	1	2	4	3	5
White coloured zone	<u>0.023600</u>	<u>0.025600</u>	<u>0.026200</u>	<u>0.028100</u>	0.081000

<u>Coat III</u>					
Region	2	4	1	3	5
White coloured zone	<u>0.018500</u>	<u>0.019100</u>	<u>0.020000</u>	0.035700	0.067900

<u>Coat IV</u>					
Region	2	1	4	3	5
White coloured zone	0.021100	0.021700	0.023600	0.044200	0.076100

C hair types within region see Table 19

### Summary

This chapter deals with morphometric observations on hairs in respect of their length, diameter and colouration (i.e. proportion of the total hair length occupied by each of the colour zones). The data are based on observations on random samples of two hair types (large guard hair and intermediate guard hair). These hairs were studied in the four coats (i.e. each coat being treated as a whole). Comparative variation was also studied in respect of five standard selected regions within each of the coats. Finally, the hair types within each region were investigated and compared.

Nested (within) analysis of variance was done on data obtained on hair length, hair diameter, and the different colour zones present on the hair shaft. The 'F' values obtained were highly significant, indicating that there was statistically significant variation between some of the aspects compared. To find out the statistical significance of the individual values, Duncan's multiple range test was also done.

The large guard hairs and the intermediate guard hairs are consistently different in length. Only in region five of the fawn birth coat and fawn winter coat are these differences not significant. The hairs in region five of all the coats were considerably shorter than those in the other regions sampled. Amongst regions sampled hairs were found to be longest on the flanks. The hair length increases from fawn birth coat onward to adult summer coat but decreases in the adult winter coat.

In fawn birth coat the diameters of large guard hairs and intermediate guard hairs are not significantly different, but



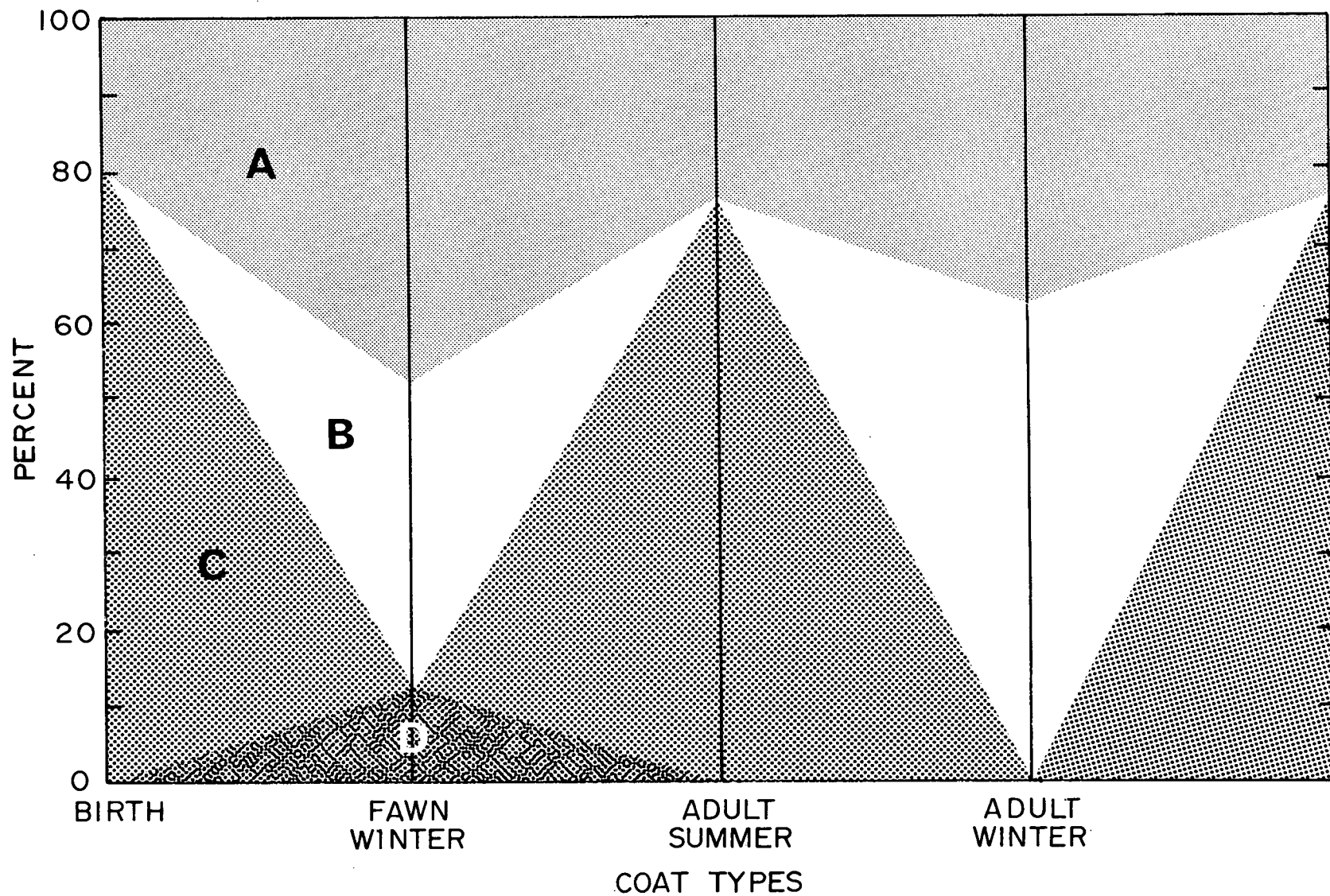


FIG.48 PERCENTAGES OF DIFFERENT COLOURED ZONES IN VISIBLE PORTION OF PELAGE HAIR (ASSUMED TO BE 10 MM IN WINTER COAT AND 20MM IN SUMMER COAT) A=BLACK, B=YELLOW, C=GREY, D=REDDISH YELLOW

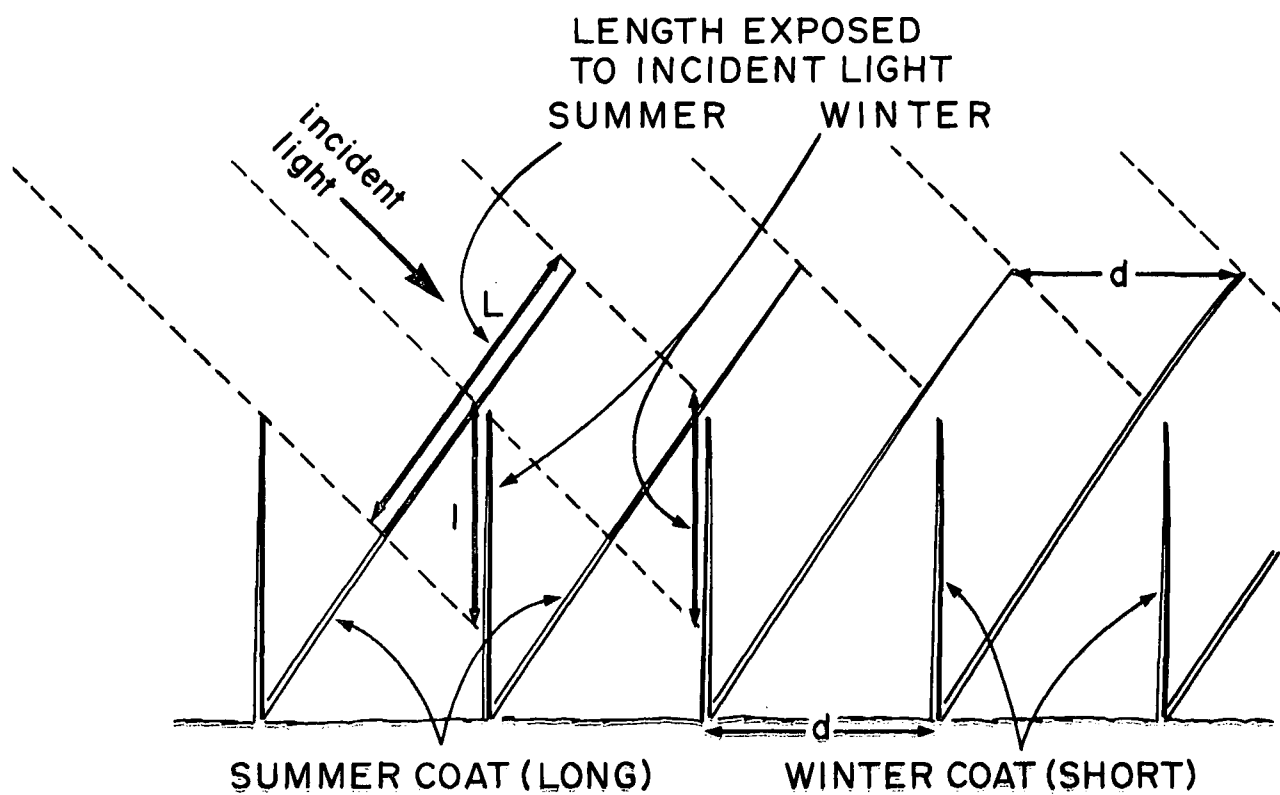


FIG. 49 DIAGRAM REPRESENTING POSITION OF OF GUARD HAIRS IN SUMMER COAT AND WINTER COAT

subsequently large guard hairs, though of greater length, possess smaller diameters than comparable intermediate guard hairs. The average diameter for the pelage continues to increase from fawn birth coat onwards until adult winter coat stage is reached. The winter hairs are of larger diameter than the summer hairs.

In fawn birth coat and fawn winter coat the greater diameter was noticed to be attained by hairs in flank region. In adult summer and winter coats it was the abdominal hairs which attained greater diameter.

The black coloured zone has maximum extent in the fawn birth coat and decreases consistently till it reaches adult winter coat. The large guard hairs have greater proportion of this than the intermediate guard hairs. Even abdominal hairs have dark tips.

The yellow coloured zone is completely missing in fawn birth coat. It is present to a very small extent in the longer hairs of the adult summer coat. It is well developed in fawn winter coat, but reaches its maximum extent in the adult winter coat.

The grey-reddish yellow zone constitutes the bulk of the shaft — except in distal extremities of limbs. It is reddish yellow in summer and grey in winter coats. It reaches its greatest proportion in abdominal hairs where it is always pale grey in colour.

A white coloured (translucent) zone constituting the basal stalk of the hairs is characteristically longer in abdominal hairs. It consists only of cortex and hair cuticle. The medulla being absent here. Pigmentation of any kind is lacking in this zone.

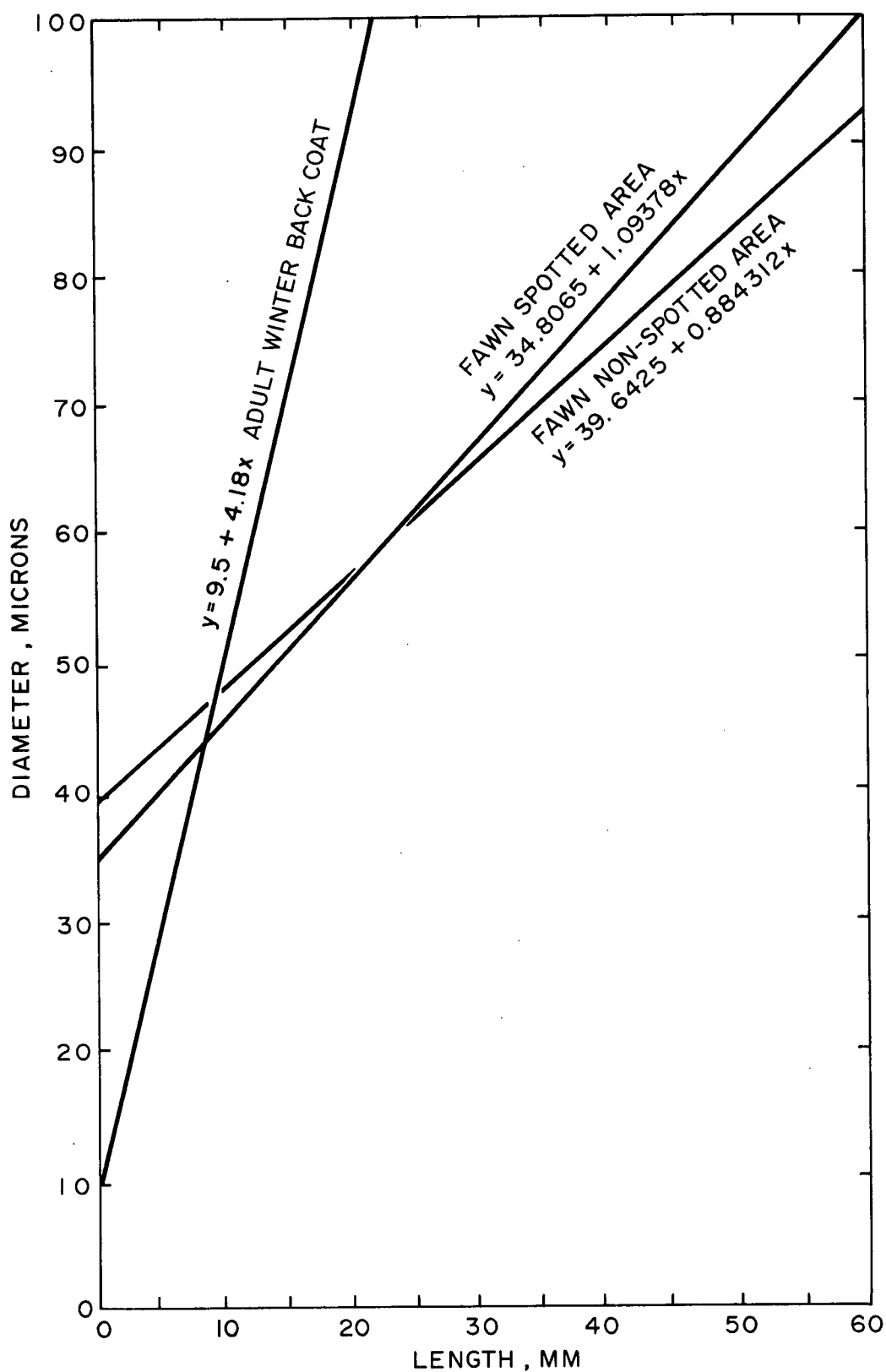
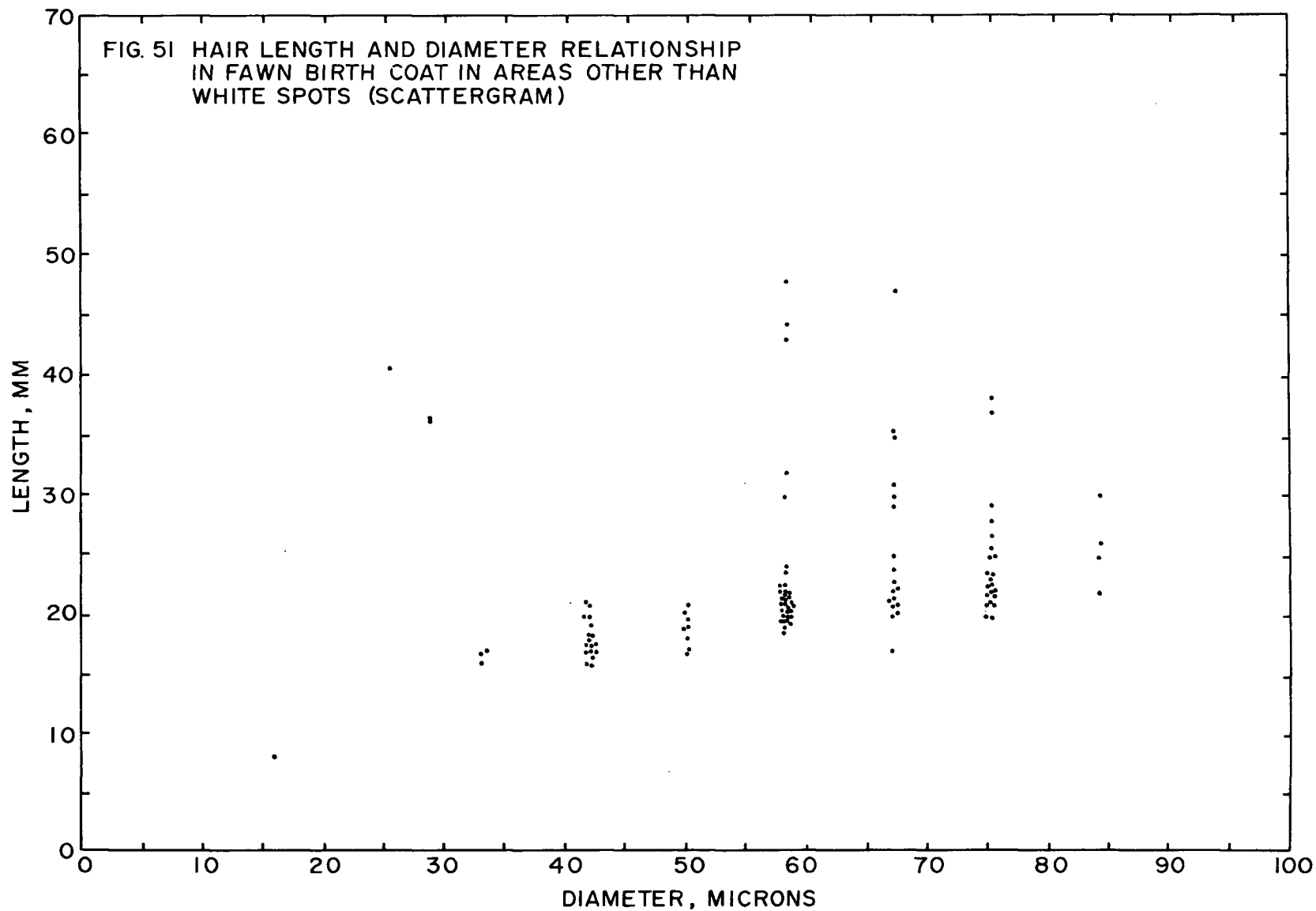
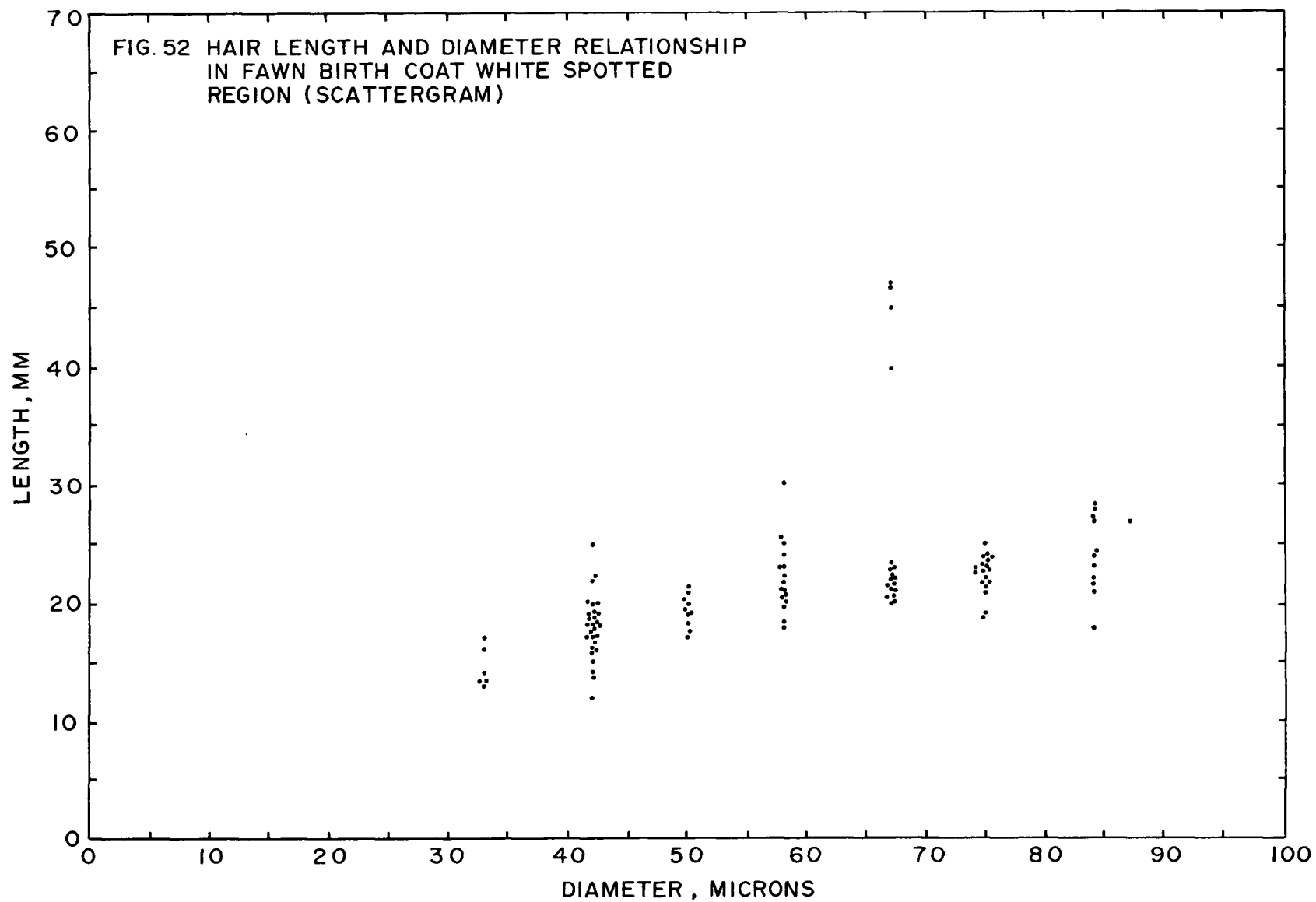
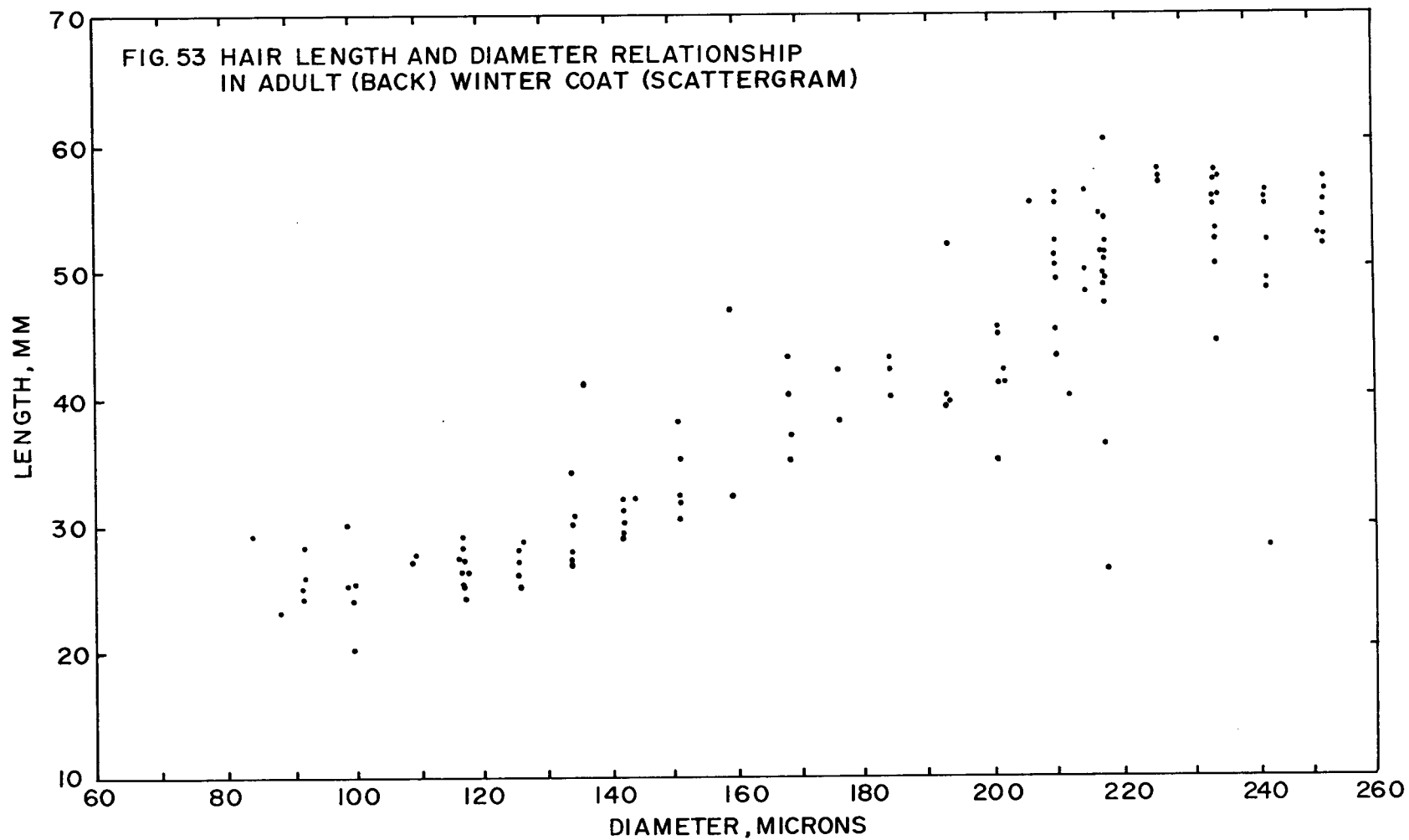
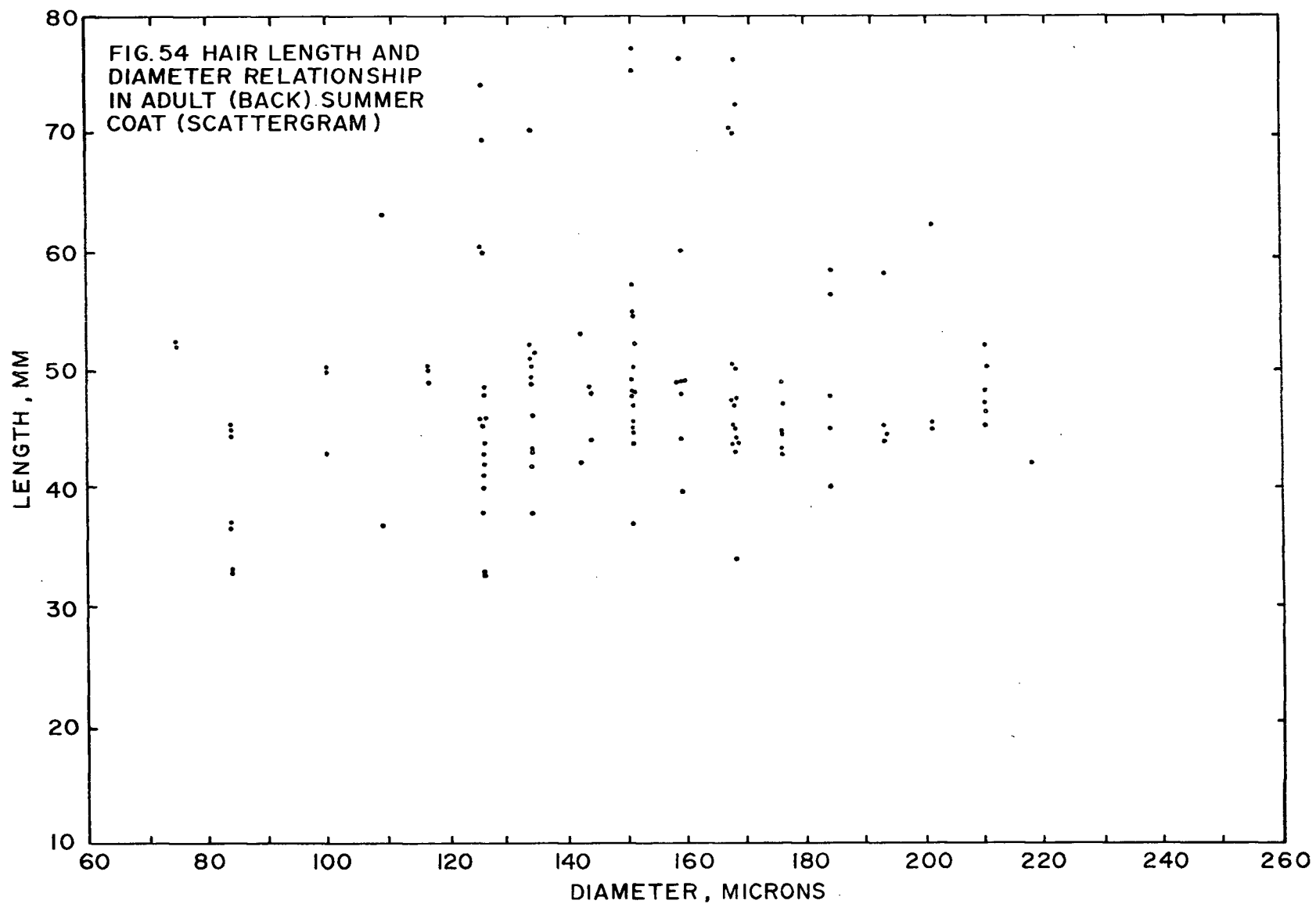


FIG. 50 REGRESSION LINES COMPARING LENGTH AND DIAMETER RELATIONSHIP IN FAWN SPOTTED AREA AGAINST FAWN NON-SPOTTED AREA AND ALSO IN ADULT WINTER COAT











Chapter VII  
EFFECT OF ADVERSE NUTRITION AND VARIATION  
OF HABITAT ON CERVID PELAGE

INTRODUCTION

Black tail deer are often short of food in winter, and where populations are high many animals die. The adverse nutrition affects the general biology of the animal is a truism. However there is no information upon the influence of impaired nutrition upon the pilary system and whether or not any imposed changes in the pelage may contribute to the winter mortality of deer living under adverse circumstances.

The effect of nutrition on animal pelage has attracted some attention. Flesch (1954) touches on this. Ryder (1958) has adequately reviewed the nutritional factors affecting hair growth and takes into account among others the contribution of Fraser (1934), Krishnan (1939), Coop (1954), Van Koetsveld (1954) and Ryder (1954). Bandy (1965) refers to condition and behaviour of the black tailed deer as affected by the plane of nutrition.

Chiefly the role of nutrition has been studied with respect to its effect on the rate of fibre production and upon the characteristics of fibres produced, mechanism of hair loss and the period of follicle development.

To document the effect of adverse nutrition on the cervid pilary system an experiment was designed and the resulting data were studied.

## MATERIAL AND METHODS

Four male black tail deer raised under identical conditions were selected. These were U16, TR, U26 and W4. They were housed under identical conditions in the animal unit of the Department of Zoology at the University of British Columbia. All the animals were maintained on U.B.C. ration 36-57. (Table 22,23). Addison (1965) has worked out the digestibility of this ration (Table 23) and has determined the calorific value of the ration per gramme, as 3.136. Animals U26 and W4 were put on an ad libitum diet and served as controls. U16 and TR were used as experimental animals and were put on a restricted diet. Originally this was planned as 60% of that consumed by the control animals, but this did not have any early effects on the experimental animals, perhaps due to nutritional reserves in the animals. The diet of the experimental animals was therefore reduced until the fat reserves were exhausted and the animals evinced the sluggish behaviour accompanying malnutrition. Details of daily caloric intake and weight at weekly intervals are given in Appendix 1 and 2.

The effect of adverse nutrition on black tail pelage was studied on a comparative basis between control and experimental animals.

TABLE 22

COMPOSITION OF ADULT RATION -- U.B.C. 36-57  
Addison (1965)

<u>Ingredient</u>	<u>Amount</u>
Corn meal	600 lbs.
Ground wheat	250 lbs.
bran	275 lbs.
Molasses	150 lbs.
Beet pulp	200 lbs
Vita grass	200 lbs.
Soya bean meal	175 lbs.
Herring meal	110 lbs.
Bone meal	20 lbs
Iodised salt	20 lbs.
	<hr/>
	2000 lbs.

TABLE 23

## NUTRIENT COMPOSITION OF RATION

U.B.C. 36 - 57 Compared with N.R.C.

REQUIREMENTS FOR GROWING SHEEP - Addison  
(1965)

Nutrient	Units	N.R.C. Requirements <sup>1</sup>	U.B.C. 36 - 57
Digestible protein <sup>2</sup>	mgm/cal <sup>3</sup>	36.3	32
Ca	mgm/cal	0.97	1.01
p	mgm/cal	0.87	1.63
Vitamin A	Iu./cal	1.84	44
Vitamin D	I./cal	0.5	44

1 - Calculated from total daily requirements for  
a 60 lb. lamb.

2 - Crude protein x 60%

3 - Calories of apparent digestible energy

4 - Total contribution from all ration ingredient  
not known but a partial total exceeds the  
N.R.C. requirement.

TABLE 24

DIGESTIBLE ENERGY CONTENT OF THE ADULT RATION  
Addison (1965)

---

TATION	Gross energy <sup>1</sup>		Digestible % <sup>2</sup>	Digestible <sup>3</sup>	Digestible <sup>4</sup>
				energy (Dry)	energy (Air dry)
	Feed	faeces			
ADULT	4363	4136	42 - 63%	171 to 2873	1518 to 2543

---

1 - Gross energy in calories /mg.

2 - % digestibility

3 - Digestible energy in calories/mgm of oven dry feed

4 - Digestible energy in calories per mg of air dry  
feed (10% moisture)

---

Once the normally growing winter coat reached its resting stage, an artificial hair cycle was induced by plucking resting hairs from selected body sites on control (W<sup>4</sup>) and experimental (U<sup>16</sup>) animals. Using the technique of immobilization and skin biopsy sampling described in earlier chapters, I took samples earlier from these sites. Their histological examination enabled me to attempt a comparative record of hair growth in well fed and underfed animals.

The observations of physical characteristics of hair (length diameter, colouration) were made as per techniques described in earlier chapters. Weight measurements were made on "Mettler" balance. The textile chemistry section of the National Research Council, kindly made some observations on tensile strength of hairs grown by well fed and underfed animals. The fibres were conditioned and tested at  $70 \pm 20^{\circ}\text{F}$  and  $65 \pm 2\%$  R.H. The machine used was CRE (Instron) tester — 1.0 inch/min constant rate of specimen extension, giving a breaking time of roughly 20 - 25 seconds. Machine capacity used = 0 - 1.00 lb. Initial clamp separations = 2 cms. Root end of fibres placed in the clamp.

#### OBSERVATIONS

- a) Normally grown winter pelage on control and experimental animals.

As soon as the effect of malnutrition was felt the experimental animals began chewing off large patches of hair on their sides and by mid-winter they had bare patches on flanks and thighs. These animals lacked insulation on large areas of body in winter and on particularly cold days appeared visibly affected as

manifest by their stiff gait and the fluffed appearance of the remaining body hairs. In contrast the control animals had normal pelage and behaved normally. Towards early spring the bare patches on the body of the experimental animals were covered by newly growing winter hairs, but before they could attain any degree of length they were chewed off again. This tendency to chew off the coat in undernourished animals was also noticed by Bandy (1965), who detected it in fall and winter. My animals exhibited the tendency throughout the year. It can impose an added stress on animals living under conditions of winter chill and malnutrition. It should not be assumed, however that this behaviour occurs in the wild where "roughage" in the form of plant material, even if of poor quality may substitute for the eating of the animal's own hair.

In the body area where the pelage remained intact the winter coat of control animals differed from that of the experimental animals in the following respects. The coat of control animals was long and sleek. The experimental animals had shed the large guard hairs and the overcoat consisted mostly of intermediate guard hairs and presented a rough appearance. The hairs in the experimental animal were shorter and narrower than those of control animals, but appeared stiffer than those in control animals. This stiffness can be attributed to greater amount of cortical tissue vis a vis medulla in experimental animals, suggesting that undernourishment affects more medullary mass within the hairs. Krishnan (1939) has suggested that changes in hair diameter due to adverse nutrition are results from changes in dimensions of medulla. Ryder (1956), Coop (1954) however feel that both cortex and

medulla are affected by undernourishment. My study suggests that in deer medulla has the crucial role to play in determining hair diameters and thus corroborates Krishnan (1939). Field observation of undernourished deer during severe winters on Vancouver Island (Cowan verbatim) suggested that the hairs of these animals broke off close to the body leaving the animal ill covered. This led to the postulate that malnutrition might be responsible for reducing the physical properties of the hair and rendering it more vulnerable to normal abrasion. Ryder (1958) has given some study to this in sheep and states that malnutrition reduces the breaking strength per unit cross-section and makes the wool fibres thinner.

In order to explore this possibility arrangements were made with the Textile Chemistry Section of the Division of Applied Chemistry of the National Research Council of Canada. Mr. A.S. Tweedie and Mr. P. Sturgeon kindly made some trial tests of tensile strength on individual hairs taken from our experimental animals.

Other evidences of imposed changes in hair structure was sought in length, weight, diameter to length and in the relative development of the cortex and medulla in the hairs of the two groups of animals.

The results were inconclusive. The large guard hairs gave results indicating that control hairs are a little stronger than experimental hairs, thus supporting Ryder (1958) but observations on intermediate guard hairs gave reverse results (Tables 25, 26).

Thus contradictory results were obtained. To obtain meaningful results very large number of hairs would have to be tested



TABLE 25

## BREAKING STRENGTH (lb)

Fibres Conditioned and Tested at

 $70 \pm 2^{\circ}\text{F}$  and  $65 \pm 2\%$  R.H.Large Guard Hairs

U26 Full Diet

U16 Reduced Diet

0.188	0.207
0.225	0.257
0.227	0.321*
0.281*	0.271
0.304	0.274*

0.259	0.249
0.249*	0.199
0.246	0.280*
0.263	0.180
0.250	0.243

Av = 0.256

Av = 0.242

Average for 7 fibres  
(i.e. excluding fibres = 0.240  
which slipped)

Av = 0.232

Range for 10 fibres 0.188 - 0.321

0.180 - 0.263

\*Fibres slipped in one clamp before reaching breaking  
load was released fibre reclamped and extended till breaking.  
load was reached.

TABLE 26Intermediate Guard Hairs

U26 Full Diet

U16 Reduced Diet

0.133	0.136
0.139	0.119
0.153	0.184
0.163	0.129
0.140	0.133

0.199	0.182
0.209	0.195
0.202	0.208
0.202	0.183
0.218	0.169

Av = 0.144 lb.

Av = 0.197 lb.

Range 0.119 - 0.184 lb.

Range 0.169 - 0.209 lb.

\*Observations were also made to evaluate effect of adverse  
nutrition on fibre weight.

TABLE 27Intermediate Guard Hairs

U26		U16	
10 I guard hairs		15 I guard hairs	
(Av. weight per fibre calculated from total weight of sample)		0.000314	
0.000457			
Fibre length	Av - 52 mm	Av - 39 mm	
(approx) Range	- 46-58 mm	Range - 36-41 mm	
Fibre	10	Fibre	15

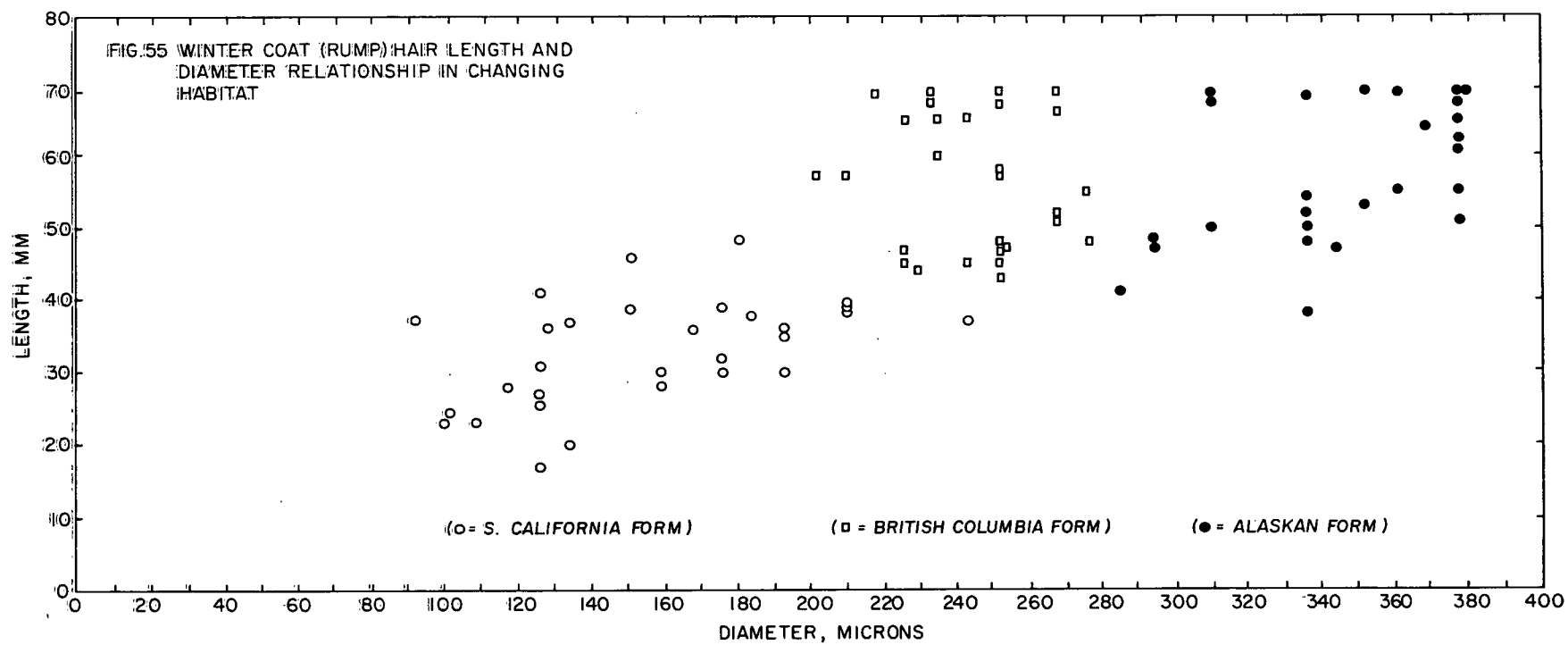
\*Thus weight of hairs as well as length is greater in well fed animals than in starved animal.

and this was not possible.

Hair samples collected from the rump region of well fed and underfed animals were collected when they were in their winter coat. Regression analysis was done on the length and diameter data collected. In the well fed animals the hair length varied from 28.00 mm to 75.00 mm as against 23 mm to 52 mm in the underfed. The diameter variation was 117 microns to 277 microns. In the underfed animals the diameter varied from 92 to 235 microns.

Regression analysis however revealed that in underfed animals though the actual mean diameter was less there was a relative increase in diameter for any given length. It would thus appear that with limited nutrients growth in hair diameter enjoys a higher priority than growth in length. This is in consonance with the belief that hairs with greater diameter not only provide cover but also better insulation (as they proportionately possess greater medulla).

At this stage the possibility of variation in hair length and diameter in the black tail deer forms, occupying different climate areas was also investigated. For this purpose black tail pelage samples were obtained from Southern California and Alaska. Hairs from identical regions were compared with British Columbian forms as regards hair length and diameter. The Southern Californian form inhabiting warm and dry areas was found to possess hairs which were considerably smaller in diameter, and shorter. The form in Alaska (sitkensis) presented the greatest diameter. The hair length was however not appreciably greater than that found in the British Columbian variety. The consistent increase in hair diameter from Southern California to Alaska again underscores its



importance in providing adequate insulation to the animal.

b) The artificially induced hair cycles.

The artificial hair cycle was started by plucking resting hairs from the thigh region of the control (W<sup>4</sup>) and experimental (U16) animals. Most of the guard hairs were easy to pluck. The woolly hairs were difficult to pluck — in the sense that most of them broke at the surface, leaving part embedded in the follicle. The new hair cycle study was thus confined to guard hairs.

Fortnightly observations on the plucked sites on control and experimental animals did reveal that nutrition had an effect on emergence of new hairs on plucked sites. Although hairs were plucked on control and experimental animals on the same day i.e. 1st November 1966, the time at which the new hairs emerged on the surface were different. In the control animal they emerged in 60 days while in experimental animal they emerged in 90 days. The resting stages were reached in W<sup>4</sup> by mid-March and that in U16 by mid-April, in the plucked sites. Thus the duration of the growth period (artificially induced) is similar to that in normal hair cycle and did not differ between the experimental control animals. Lowenthal and Montagna (1955) found that in mice "when the hairs are plucked at the time when the animals are placed on reduced diet the follicles remain quiescent for as long as two months but they become active on the very day the animals are given ad libitum food".

My experimental animals were placed on reduced diet for some time before the artificial hair cycle was actually started and during the experiment at no time were they given ad libitum

## Artificially induced hair cycle

FIGURE 56.1

Plucked follicles regrowing in underfed animal (U16) first week. Notice the rounded dermal papilla, enveloping follicle base and cord of undifferentiated cells above it. Longitudinal section. H. & E.

FIGURE 56.2

Plucked follicles regrowing in well fed animal (W4) first week. Note the appearance of plucked follicle. Longitudinal section. H. & E.

FIGURE 57

Hairs emerging after four weeks in well fed animal (W4). Transverse section. H. & E.

FIGURE 58

Hairs actively growing two months after plucking in underfed animal (U16). Longitudinal section. H. & E.

For explanation of abbreviations used please see Appendix IV, Page 214.

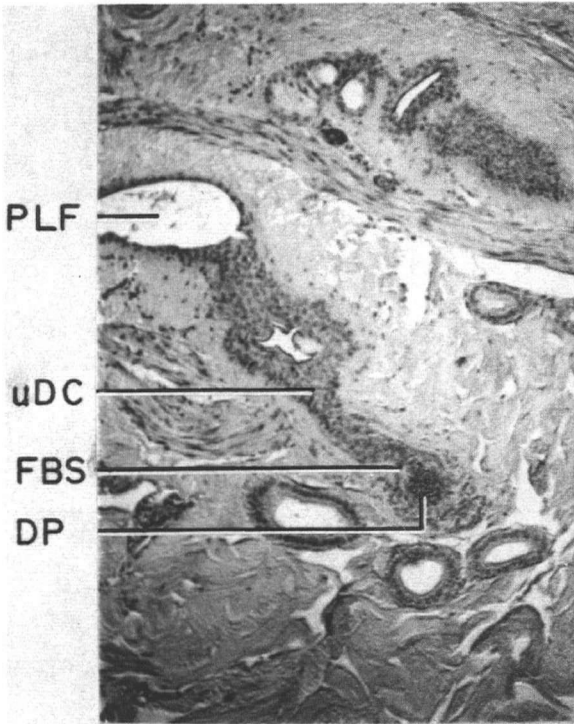


FIG 56.1

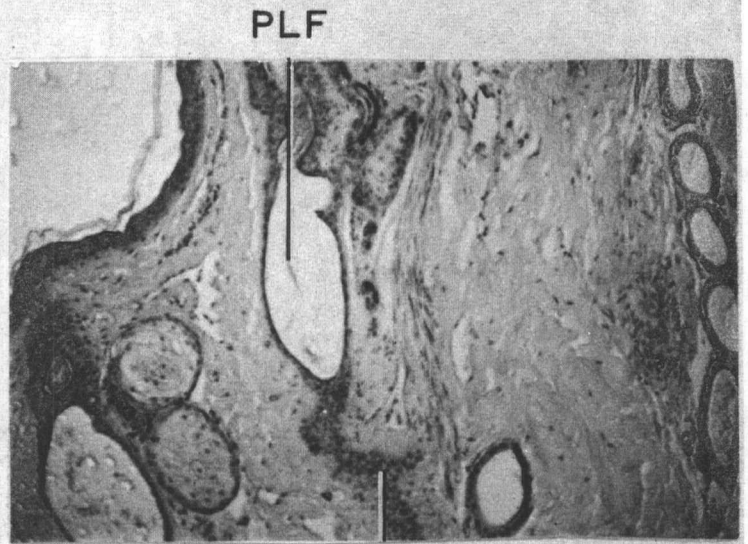


FIG 56.2

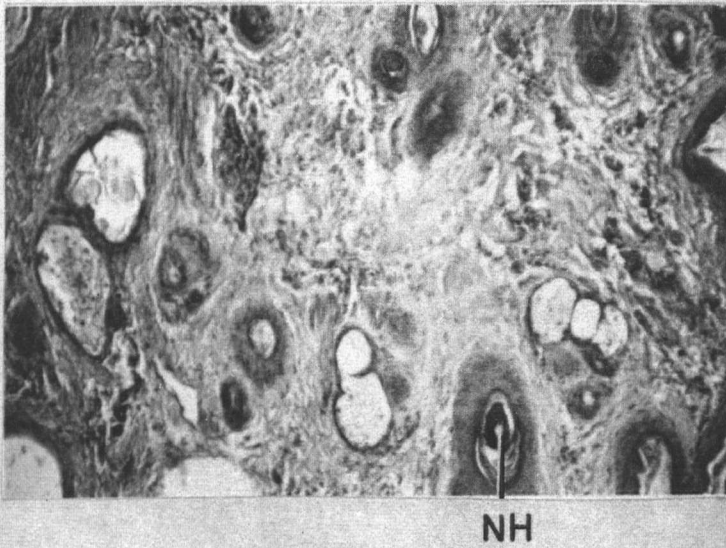


FIG 57

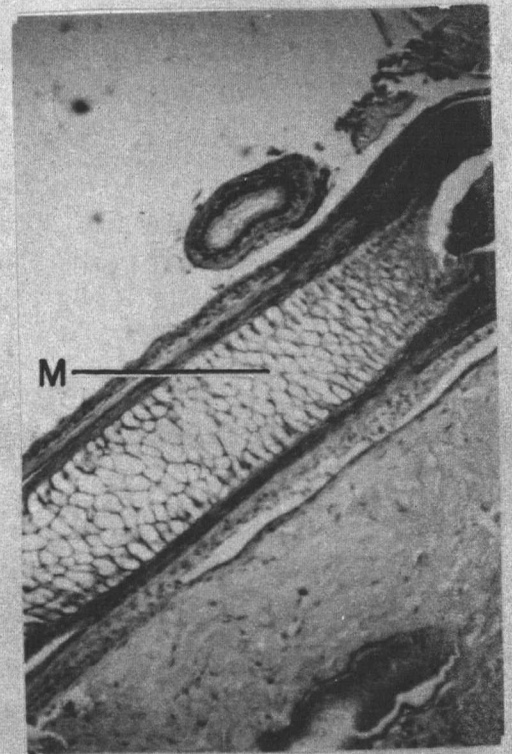


FIG 58

diet. At one stage (mid-Dec. 1966) owing to considerably weakened condition of U16, his diet was increased. It is conceivable that this increase in diet may have triggered the hair growth cycle earlier than it would have otherwise started.

In both the animals hairs grew considerably longer in the vicinity of the biopsy sites than elsewhere on the plucked area. Ebling (1964) first reported that hairs attain greater lengths at the site of wounds and sutures during his work on hair growth. This can now be confirmed also for deer.

The hairs growing in the plucked areas were of winter type but did not exhibit the metallic grey colouration in early stages of growth so characteristic of the early stages of a normally grown winter coat, instead they were light-brown in colour. Here too the hairs in experimental animals were of smaller length and diameter than those of the control animals. The difference in colouration of the early phases of artificially induced hairs (growing in Nov. - Dec.) and normally growing winter hairs (August to Sept.) could be attributed to subtle biochemical changes within the hair follicle as it prepares itself for the production of normal summer hairs.

#### c) Histological changes during the artificial hair cycle

When the experiment was started on November 1, 1966, the winter coat had finished growing and all the primary follicles were in telogen.

In the black tailed deer this stage is similar to that found in the mouflon, Ryder (1966). The follicle ceases production of medulla and the basal hair part is consequently devoid of it. The resting hair follicle is pulled towards the skin surface



FIGURE 59

Well fed animal in winter coat.

FIGURE 60

Underfed animal in winter coat. Notice coat chewed off on sides resulting in bare patches and rough appearance of the coat.

FIGURE 61

Hairs growing faster in the vicinity of skin biopsy areas. Notice the sampling sites.



FIG 59



FIG 60

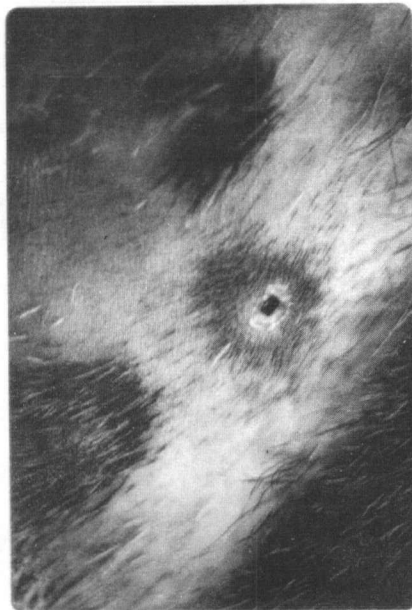
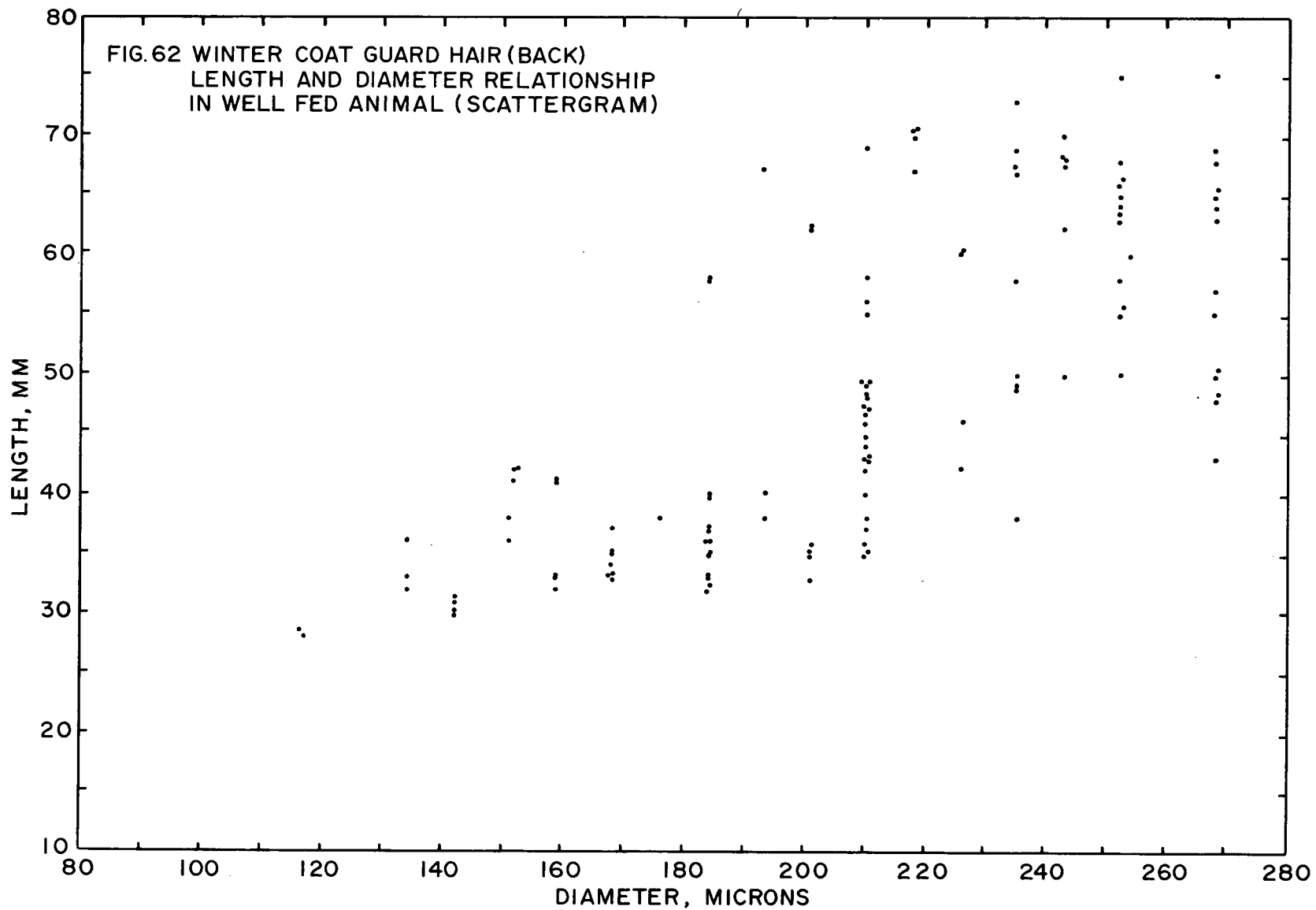
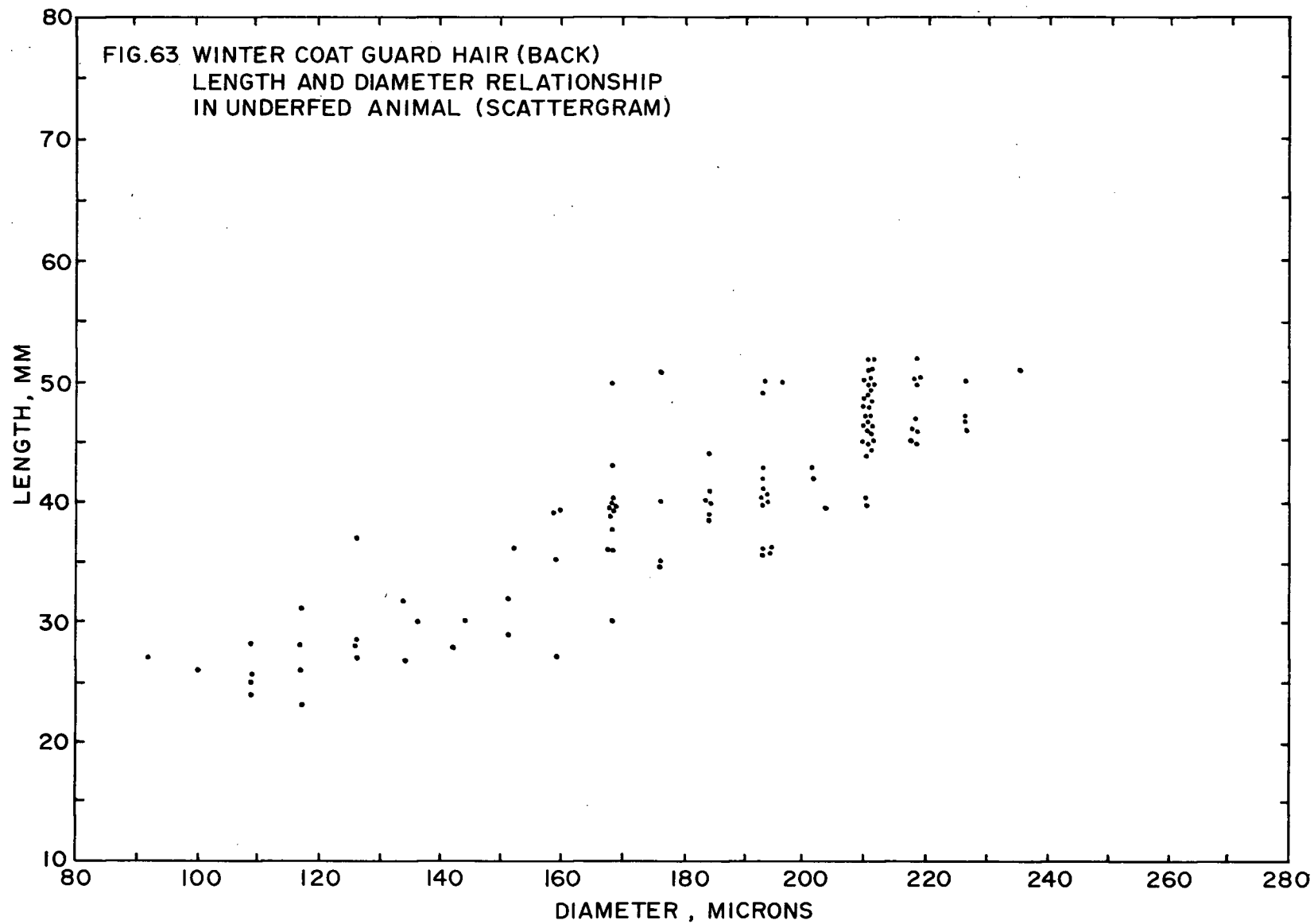


FIG 61





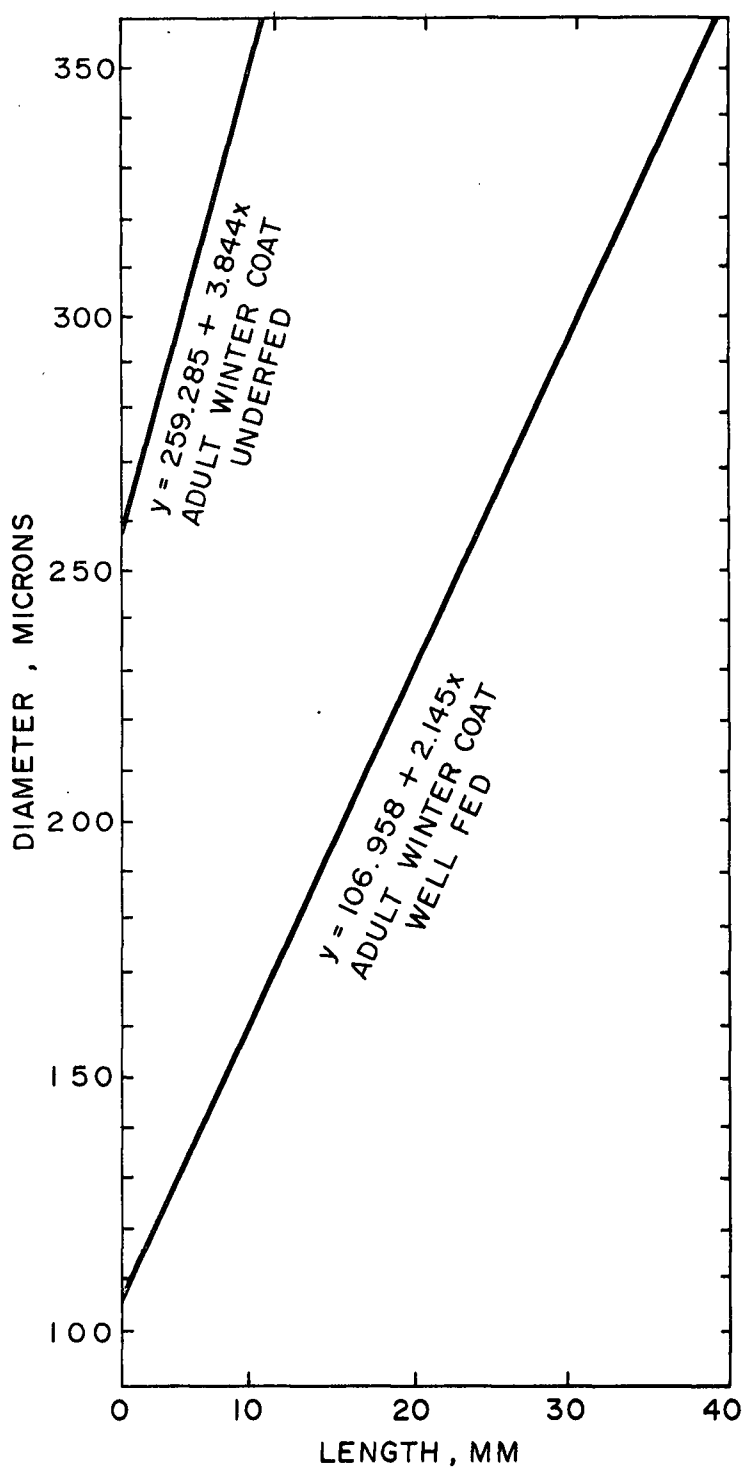


FIG.64 REGRESSION LINES COMPARING LENGTH AND DIAMETER RELATIONSHIP BETWEEN WELL FED AND UNDERFED WINTER COAT GUARD HAIR SAMPLES

and the hair base lies near the vicinity of the arrector pili muscle attachment. The hair base has a brush end and is enclosed in an epidermal capsule. The follicle base is connected to the hair base by a cord of undifferentiated cells. The bulb of the hair follicle is greatly reduced in size. The dermal papilla is rounded and half enclosed by the bulb. In relation to the bulb it is proportionately greater than that found in actively growing follicles. The cells at the base of the follicle covering the dermal papilla are much larger and prominently nucleated. Some melanocytes are also present within this region. The follicle has lost its inner root sheath and the epidermal capsule is of external root sheath origin. The follicle as well as dermal papilla are enclosed by a layer of cells of connective tissue. This layer is separated from external root sheath by a glassy membrane visible at places. Generally the parts of the resting follicles lying below the attachment of arrector pili muscle are straight but often get bent slightly to one side.

When the hairs were plucked out at this stage the remaining external root sheath was pulled out and mostly destroyed. The connective tissue elements as well as the glassy membrane are present in the follicular region. The process of regeneration and repair starts immediately and within a week the bulbs of the follicles have descended to lower depths. The cord of the undifferentiated cells above the bulb has increased in length and is the cause of this elongation. The dermal papilla has been rounded and is mostly enclosed by the follicle bulb. The melanocytes are no longer restricted to layers immediately above the dermal papilla but none occur along the length of the growing follicle.

The newly developing follicle is often twisted along its length.

In a 4th week sample the follicle bulb has become enlarged and the dermal cell elements are rounded. The dermal papilla is enclosed by the follicle bulb, which in turn has reached the level of the sweat gland (distal end). The same state continues in the 5th week also. Blood vessels are present in the papilla and a membrane separates the follicle cells from the papilla cells. By the 6th week the large guard hairs have emerged on the surface. These follicles grow at a faster rate than the intermediate guard hair follicles. In the well fed animals the regeneration process starts immediately and the the 4th week large guard hairs are emerging on the surface. In the underfed animals most of the follicles experience arrested growth after reaching the stage when they produce a long cord of undifferentiated cells with follicle bulb enclosing three fourths of dermal papilla.

### Summary

Underfed animals have shorter and more slender hairs than well fed controls; the hairs also weigh less. There is non-consistent demonstrable difference in tensile strength of hairs from control and experimental animals. Also undernourishment seemed to have no effect on the percentage of woolly undercoat.

Woolly under hairs are difficult to pluck, since during the attempted plucking they get broken off at the skin surface. The hair cycle induced artificially by plucking hairs is mainly concerned with guard hairs. The regeneration of plucked follicles starts immediately, but in the underfed animal appears to have been arrested for a longer time in a transitional stage. In

control animal the follicle regeneration and hair development is faster, and that of the large guard hairs is faster than that of the intermediate guard hair follicle. In control animal the large guard hairs have begun to emerge on the surface in the 4th week and by the 6th week most of the other guard hairs have emerged. In experimental animals the large guard hairs emerge by the 6th week and the rest by the 8th week.

Experimental animals were observed to chew off hairs on the body; this gave rise to bare patches on the flanks.



## Chapter VIII

GENERAL DISCUSSION

The families cervidae and bovidae are the two major groups in the wide and diverse assemblage of the existing ungulates (Simpson 1945). However knowledge of the ungulate pilary system has been virtually confined to the Bovid genera Bos, Ovis, and Capra. It is therefore of particular interest to compare the information on these with the details from a cervid form i.e. Odocoileus hemionus columbianus, and to see whether any significant evolutionary or adaptive trends emerge.

Follicle development and Anatomy

Embryologically the cervid follicle development fits into the general mammalian pattern; and goes through the same developmental stages. Unfortunately no known-aged series of deer fetuses was available, and to develop such a series would have involved a long-range special breeding programme. Consequently no comparisons on the timing of stages of follicle development or emergence of hairs on the body, have been made with other ungulates. However these have been related to designated size stages in embryogeny. As regards the development and the relative size of the follicle accessories the deer resembles domestic sheep. The secretory portion of the deer sweat gland, however, is quite sinuous. This is not so in sheep or cattle, and in the light of present knowledge appears to be a unique cervid feature. Sokolov (1963) states that in wild artiodactyl of U.S.S.R. some sweat glands disappear completely during the winter and the secretory portion

of the others is reduced.

No such seasonal changes in these glands have been encountered in Odocoileus hemionus columbianus, and the sweat gland features remain constant.

In the genera studied by Sokolov it would, however, be of interest to document in detail the redevelopment of a sweat gland that had regressed during the previous winter. It is not stated if the sweat gland referred above are of eccrine or apocrine type. In Odocoileus they are all apocrine type.

In Odocoileus, as in cattle, sheep and goats, each follicle is associated with no more than one sebaceous gland and this may be completely missing in some of the smallest follicles. In larger follicles the sebaceous gland is often bilobed; but no distinctive acinii have been observed in these lobes. Sokolov (1963) states that the number of sebaceous glands at each hair varies from one to three. This is not so in Odocoileus, but like Alces the sebaceous glands in Odocoileus do appear to be more developed and enlarged in summer. This may indicate a more active role during this season.

The hair follicles of Odocoileus, sheep, and goats have been classified into primaries and secondaries. The primaries can be further divided into central primaries and lateral primaries. All the primaries are associated with sweat gland, sebaceous gland and A. pilii muscle. The secondaries have in turn been divided into first formed and later formed. The first formed secondaries are larger, as in goats, mouflon, and some domestic sheep breeds. The Odocoileus differs from these in the possession of a sweat gland, and an A. pilii muscle in addition to the sebaceous gland.

This has not been recorded before. Such an occurrence, however, raises doubts about the validity of the standard characteristics distinguishing a primary from a secondary follicle. It raises the question whether there is at all any fundamental primary and secondary follicle types. It is possible that they are different stages of continuum, reflecting, in their size and morphology, the gradual depletion of the follicle-forming substance. In case of cattle each of the hair follicles possesses a sweat gland, sebaceous gland and A. pili muscle; but the follicles develop at different sequential ages. Consequently they have been called first formed, later formed and last formed. By accepted definition however they all are homologous to the primary follicles of sheep, goats and deer.

Anatomically all the basic cell layers constituting the follicles are common to the ungulates. The following features are noteworthy for Odocoileus. The external root sheath is well developed and uniform around the follicle as opposed to sheep where it is better developed on the ental side. Unlike sheep in deer the glassy membrane is also often clearly visible in the basal bulb region, where the external root sheath is considerably reduced. In Odocoileus an additional glassy membrane occurs between the external and internal root sheath. This has not been reported in sheep, goat or cattle. It would be interesting to know how widespread this characteristic is among the cervidae and its functional utility. Henle's layer of inner root sheath is large and stains more heavily with Haematoxylin and Eosin than the adjoining Huxley's layer lying on its inner side. Both layers are single celled but in the latter the cells are smaller. In

deer Henle's layer is of uniform thickness unlike that in sheep where it is thicker on the ental side.

The developing primary follicles in Odocoileus are characterized by the presence of an ental swelling. No evidence was observed to indicate that the A. pilii muscle had anything to do with it. My observations support Lyne and Heideman's (1959) contention that there is no cause-and-effect relationship between the ental swelling and the A. pilii muscle. There was however a consistent relationship between this muscle and the sweat gland — they always occurred together.

As in cattle the trio follicle grouping is clearly apparent in the developmental stages but gets somewhat obscured subsequently owing to growth of the body and resultant stretching of the skin. In deer the first formed secondary follicles are larger than in the goat and a follicle grouping of five (three primaries and two first formed secondaries) becomes prominent. This has also been observed in goat, mouflon, and some breeds of domestic sheep, but not in cattle. In sheep the secondary follicle group is located entirely between the primaries, but in deer and goats it is only wedged between the primaries. In goats the first formed secondary follicle forms the apex of this wedge but this is not always the case in deer.

In the course of the hair follicle development in Odocoileus some of the central primaries follow a different path. They are only a stage or two ahead in development in respect of other central primary follicles but grow at a much faster rate and attain large size. This is particularly obvious in a 269 and 287 mm foetus. Occasionally the neck region of these follicle appear

bulbous, but no definite sinus has been detected there. These follicles are very similar to the tylotrichs discussed by Straile (1961) and are morphological types lying in between the vibrissa follicle and the normal hair follicle. The discrepancy in follicle size is noticeable prenatally, but subsequently these follicles cannot be distinguished clearly from other adjoining primary follicles. These specialized follicles produce a long guard hair — obvious on the skin surface of 287 mm fetus. These have been called large guard hairs. In adult pelage they can be identified by their length — which is  $1\frac{1}{2}$  times longer than other guard hairs; and occur scattered about 2.5 mm apart. Their stimulation produces a twitching response in animals — thus giving support to the suspected sensory nature of the follicles in which they arise. Flerov (1960) refers to large guard hairs occurring in cervid forms like Dama, Capreolus, but makes no reference to their development or likely function. In cattle about six percent of hair follicles have been reported to be of giant size at maturity and not during development. There are no data on the types or function of hairs produced by these follicles. In goat and sheep, no reference to such follicles or hairs was noticed. My observation thus probably are the first definitive account of the development and likely function of the large guard hairs in ungulates. They appear to be characteristic of forest-inhabiting cervids but not of the plains and uplands dwelling ovinae and caprinae.

The primaries and first formed secondaries in deer form medullated hairs. Those arising in primaries constitute the guard hairs. The first formed secondaries give rise to medullated hairs of transitional type present only in the first fawn pelage. The

other secondaries give rise to non medullated woolly under hairs. Some of the natal primary follicles instead of producing normal guard hairs give rise in the fawn birth coat, to white tipped hairs characteristic of the white spots. These same follicles in the subsequent hair cycles produce normal guard hairs. Thus the primary follicles are capable of producing different hair types during the animal's life span. This has been shown to occur in merino where follicles first producing medullated hairs, in later hair cycles produce non medullated hairs, Wildman (1937).

The dermal papillae vary with the type of hair being produced, they are spatulate in heavily medullated hairs and have a pointed apex in hairs having small medulla or no medulla at all. In the follicles producing white tipped hair the dermal papilla however has a pointed apex. Also in the white tipped hairs the cortex is relatively well developed vis a vis the medulla and the medulla itself lacks the intracellular cavities present in other deer guard hairs. This is a unique Odocoileus feature and not recorded for other ungulates.

The duration of hair follicle development is also variable with follicle types. Lyne (1965) states that it is inversely proportional to the mature size of the hair follicle. This is true for deer guard hairs where the smaller guard hairs come to rest earlier than the large guard hairs. But the deer secondary follicles pose a problem. The first formed secondaries behave like smaller primaries, and precede them in coming to rest. The later formed secondaries, which are smaller in size follow a cycle of their own and have no relationship with the primary and first formed secondary. All primary follicles and first formed secondaries are well formed at birth and are functional, the later

formed secondaries continue to form post natively and become functional only in the fawn winter coat. This does not however increase the follicular density in the postnatal stages. As increase in body size and resulting dilution of follicle population more than compensates for the new secondaries being formed. Ryder (1966) states that in goats the first formed hairs reached resting stage first. This is of great interest as it contradicts the normal trend of events in ungulates. Also in deer the rate of follicle growth, as opposed to the rate of follicle development, is variable in different follicles. Thus the large guard hair follicles though only a stage or two ahead of their contemporaries in development are none the less much longer (at least in foetal material) and this can only be brought about by a faster rate of cell division. The factors responsible for this differing growth rate are not well known. The various hair follicles are in close proximity of each other and the governing factors must operate in some subtle way.

Paired follicles present in cattle have also been detected in the deer. These generally are confined to later formed secondaries, one of which is of larger size. These follicles arise independently very near each other but the hairs produced by them emerge through a common aperture. This has not been recorded for sheep or goats.

Branching follicles involving three to four secondaries of successively smaller size arising from a later formed secondary have also been recorded in deer. These are absent in cattle but present in sheep and goats. Branching of the secondaries are particularly well developed in merino sheep where upto six or

seven wool fibres may emerge from a follicular aperture. However in as much as this condition has not been reported for wild sheep, it must be regarded as a mutation selected during generations of husbandry. The normal ungulate pattern is for not more than two to three hairs, from simple branched follicles to emerge from a single aperture. In addition the merino skin, unlike any that of other ungulate, is greatly folded, which increase the number of follicles on the body.

### Epidermis and dermis

During the course of follicle development the epidermis and the dermis undergo certain changes. The collagen fibres in the reticular layers of the dermis increase in size and with maturity some may even be formed in the papillary layer. In the epidermis the stratum spinosum increases in size as follicles are formed but at maturity is hardly distinguishable as a discrete lamina as there is a continuum of cells from the basal layer to the peeling stratum corneum. Sokolov (1963) states that the dermis, and in particular it's papillary layer, is thicker in summer than in winter. This is also true of the stratum spinosum. Stratum corneum however behaves in reverse fashion. This has not been definitively established in Odocoileus.

Ling (1965) states that most of the animals undergo a moult prenatally or immediately after birth. There was never any indication of this in Odocoileus. Of course during embryonic development the 'periderm' is sloughed and replaced by the stratum corneum, but hairs are not yet present at this time.



### Hair types and morphology

The deer in course of its life cycle bears four characteristic coats. When the black tail fawns are born in summer they bear the birth coat. This coat has summer coat characteristics. The important point of difference being that here there is a distinctive undercoat. In adult deer it is only restricted to the winter coat. Also the hairs constituting the birth coat undercoat are mostly of transitional type (and not true woolly) and have fragmental medulla. They arise in the smaller of the primary follicles and the first formed secondaries. The later formed secondaries which give rise to the non medullated woolly under hair of the fawn and adult winter coat are still forming and not functional. As many of the birth coat undercoat hairs arise in primary hair follicles and as it is present in a summer type of pelage it may be considered in part homologous to cattle undercoat. In cattle all the hair follicles are structurally comparable to the primary follicles of deer, sheep and goat, and the undercoat is present generally in both summer and winter pelages. The points of difference being that in cattle the undercoat hairs arise in follicles homologous to deer primary follicles and are all non medullated. They are not woolly. The presence of an undercoat in an essentially summer type of coat, as occurring in the fawn birth coat may be directly related to the need of the fawn for better insulation in its early stages. An adult deer in the summer appears to have no such insulation need, and the undercoat is conspicuously lacking.

The characteristic fluffy appearance of the newly born fawn can be attributed to greater follicular density which is

subsequently reduced by expansion of the skin area without equivalent increase in follicle elaboration. The greater follicle density resulting in greater hair concentration also undoubtedly contributes to better insulation in early stages of fawns life. This may also occur in the newly born of other ungulates but is strikingly noticeable in the black tail.

At first glance the white-tipped hairs of the fawn birth coat appeared similar to heterotypes (hairs with weak basal end but well formed distal end) formed in sheep. Morphometric (length and diameter) study of hair samples revealed no essential morphometric difference between these hairs and those occurring near them. The differences are only of colouration whose basis lies in the biochemistry of the hair follicles. The difference of the cortex and the medulla have been referred to earlier.

The hair types present on the body of the black tail resemble those present on the body of the goat; in respect of their general form. The beard type of hairs in deer is restricted to the tail and inguinum. The large and the intermediate guard hairs of deer are the kemp type and comparable to kemps of the goat. The smallest of deer intermediate guard hairs, and those constituting the bulk of the under coat in fawn birth coat, and are in form similar to intermediate type hairs in the goat. The hairs arising in first formed secondaries are also of intermediate type. The woolly under hairs constituting the undercoat of the deer are comparable to the woolly undercoat hairs of the goat. This is different from the hair types formed in that in sheep, the undercoat overtops the coarse outer coat hairs.

The general characteristics of pelage of non-woolly animal remains constant, although there may be some variation in detail with changing seasons. Fibres may vary greatly in length and diameter but all grade into one another from one extreme to the other. "Usually the coarser fibres extend well beyond the others and approximate to a loose definitive coat while the finer fibres are closely disposed and suggest woolly undercoat". Thus essentially all the fibres are of one type. Cattle fall into this category. In mouflon the undercoat reached the same length as the overcoat, whereas in the case of goat the under wool was shorter than that of mouflon and thus like that in deer Ryder (1966).

In deer no awns have been observed. It is also interesting to recollect that Friend & Hesselton (1966) observed in an Odocoileus virginianus patches on the body where the woolly under hairs had overtopped guard hairs which were not visible externally. This condition of exposed wool has been reported as a rare anomaly. No doubt it is genetically regulated and occurs as a mutant state.

If one were to trace the development of woolly coat in ungulates studies, cattle would represent the primitive non-woolly type; deer and goat represent the primitive woolly type; the mouflon has a greater development of wool; next come domestic sheep breeds, terminating in the merino, which represents the woolly coat at its highest development so far.

The cuticular scale characteristics of the hair types are of interest within a group such as the ungulates; these have been found to depend on the physical dimensions of the hair and not on it's morphological type (Mahal et al 1951). Appleyard (1960)

refers to scale patterns on hairs from genus Cervus and states that coarse hairs have at their base an "irregular petal" scale pattern, while at mid-way and at the tip it is "irregular waved mosaic" with 'smooth' margins and inter marginal distance 'close'. In the case of black tail only some of the very thick guard hairs bear "irregular petal" scale pattern on the base - all the others bear "irregular mosaic" to "irregular waved mosaic" Appleyard's (1960) statement that all fine hairs in Cervus bear fragmental medulla is of interest, as in the case of black tail the fine woolly under hairs are non-medullated. They also bear a scale pattern which resembles a variation of the coronal type as referred to by Mahal et al (1951) rather than the irregular waved mosaic pattern as suggested by Appleyard (1960). If one is to take into account the black tail hair scale morphology in comparison with cattle, sheep and goat, then black tail can be said to resemble sheep. "Rippled crenate" scale margins present in regions of cattle and goat hairs were at no time observed on black tail hairs.

The narrowing of the latticed medulla in the base of the guard hairs in deer is more abrupt than that in the sheep. Also branched hair fibres of the type referred by Ryder (1960, 1966) as occurring in the mouflon and the goat have not been observed in Odocoileus.

Adult Odocoileus have two distinct seasonal pelages and these replace each other alternately according to the season. These coats differ from each other in respect of hair dimensions and colouration. The summer coat hairs are longer, more slender and in general the pelage presents a reddish-yellow appearance. The

winter coat hairs on the other hand presents an overall greyish appearance; have larger diameter, and more crimped nature of the hair shaft. The summer coat hairs (intermediate guard hairs) presented no distinctive length to diameter relationship pattern whereas hair growing from the same follicles in winter have had a distinctive correlation between length and diameter i.e. increasing length. The winter coat is also characterized by possession of woolly undercoat - arising in secondary follicles. This is absent in the summer coat.

These changes in hair colouration and morphology are of particular significance because the same follicles produce these two types of hairs. The changing activity pattern of the melanocytes, and the variations in biochemical reactions involved producing melanin, pheomelanin etc., would be of particular interest to study. The follicles producing 'white-tipped' hairs in fawn are also of interest as it is obvious that during the formation of the white tip the melanocytes are behaving very differently. Billingham and Silvers (1960) suggest that white colouring or "spotting" may be due to a genetic barrier preventing melanocytes from reaching their end organ from the neural crest or at least failing to differentiate. The follicles producing white-tipped hairs however often show a brownish pigmentation. Perhaps this is because the white tip has already been formed, and the rest of the hair body which is pigmented is in the process of formation. Such sharp changes of colouration have not been referred to in goat, mouflon, domestic sheep, or in cattle.

The length and diameter variation in summer hairs produced by the same follicle is also of great interest, and reflects

functional plasticity on the part of the hair follicles. The environmental conditions may also have a bearing on these normally occurring changes. The hair length can be varied either by increased rate of growth, or longer period of growth. In deer the former appears likely as no noticeable change in the duration of hair growth was detected in the present study. Use of autoradiographic techniques may help to elucidate this issue. The major factor responsible for the changes in hair diameter is the medulla, but the processes governing its formation are not clear. This must vary in different body regions of the same coat too, for in adults the abdominal hairs have a much larger development of the medulla.

#### Adaptive value

The major function performed by Odocoileus pelage is in adapting the animal to its environment and activities within the pelage like the hair growth cycles and the timing of moult are oriented towards meeting the above mentioned objective. The deer winter coat has features adapted to increase the insulation capacity. These are, productions of heavily medullated hairs, and the presence of a well developed woolly undercoat. The crinkly nature of the intermediate guard hairs is helpful for proper accommodation of the woolly undercoat. The greater variation in the length of individual winter coat guard hairs, enables them to be arranged compactly and thus provide better insulation. The significance of the medulla in deer insulation is further attested by the fact that the Southern Californian forms living in dry arid conditions have in their winter coat hairs much less proportion

of medulla, (resulting in smaller hair diameter) than noticed in the identical region of the Alaskan forms living under very cold winter conditions. The absence of woolly undercoat in summer and the longer hairs makes summer coat often, more amenable to air circulation, and thus well suited for warm summer conditions.

As a further adaptation to thermoregulation, the pinnae of deer in height of summer appears naked and sharing a sparse "down" of small hairs. I did not determine whether or not there was a seasonal reduction in the number of follicles producing hairs, however this seems probable. The blood supply here is profuse and it is tempting to suggest that this may have some thermoregulatory function in the deer.

Production of a woolly undercoat is not the only way in which cervids have adapted to winter conditions. The sub genus Przewalskium a cervine form inhabiting cold Tibetan highlands has in its winter coat no woolly undercoat (Flerov 1960). Instead it's winter coat consists of thick heavily medullated hairs. This supports the contention that in deer hair medulla is of great importance in securing adequate insulation. It would be of great interest to examine this coat histologically as well as to compare insulation capacity of this type of coat with that where a woolly undercoat is also present.

Woolly undercoat is present in goats and mouflon and is dominant in the domestic sheep, and provides effective insulation in cold conditions. In cattle however the situation is different. Dowling (1959) has concluded that here the summer hairs are shorter than winter hairs and possess greater medullation and hair diameter. The winter coat fibres are on the other hand long and

non-medullated. Dowling further contends that "thicker shorter medullated fibres which are stiffer enhance air movement at the skin surface. This would provide a greater opportunity for evaporation of moisture. Further the more medullated the fibre the more effective would be the reflection of the infra red wave lengths of solar radiation. He also found on experimentation that animals with medullated coat were more heat-tolerant than those having hairs without or with small medulla. In Odocoileus the mechanism is obviously different and heavy medullation facilitates better insulation. Apparently in cattle the winter insulation is affected only by having a longer coat, which may provide better body coverage. Like deer in cattle too there is greater variation in hair length of winter coat hairs.

### Moult

In deer the summer and winter coats are assumed by the animal through a process of moulting, just before the onset of the summer and winter seasons respectively. Thus the deer overcoat moults twice namely in spring, and late summer to early autumn, and the woolly undercoat moults only once a year namely in spring. The primary and later formed secondary follicles thus have different cycles. The goat has comparatively a very primitive cycle. Here both primary and secondary follicles undergo a similar cycle i.e of activity in summer and inactivity in winter. In summer the goat lacks woolly undercoat. In mouflon both the primary and secondary follicles are shed in spring, and the pelage is devoid of woolly undercoat in summer. Some primaries are also shed again in autumn, but there is no moult as such. This is homologous to



deer autumn moult. This is also true of primitive domestic sheep and to a lesser extent in the more highly evolved domestic sheep.

In cattle, although some hairs are constantly being shed all the year around (very much unlike deer), two distinct shedding periods have been observed namely in spring and the autumn. The overcoat and undercoat are shed and replaced twice a year.

In Odocoileus spring and autumn moults have different directions. The autumn moult is caudad while the spring moult begins on the flanks and proceeds both cephalad and caudad. In fawn birth coat the moult is caudad. The factors responsible for it are not known. The extent to which the formation of new hair acts as a physiological or physical stimulus in shedding of the old hair is also of interest, in investigating moult patterns. It would also be of great significance to find out if there is any phase difference in activity of hair follicles over different regions of the body and the effect of any that this has on the timing and the direction of the moult. Ling (1965) has rightly stressed the need to investigate these aspects.

The direction of moult in the deer fawn has been discussed earlier. No corresponding observations are available on young ones of goat and cattle. Ryder (1960) has stated that the birth coat of the mouflon was shed between four and six months of age. Here the shedding began (in U.K.) in August. The coat was peeling in mats of outer hair mixed with wool. The new coat was already coming in. During September there was birth coat remaining on the shoulder, and this was soon lost. Masses of wool from the birth coat however tended to remain attached to the tips of the new hair coat and was lost when the new coat was shed the follow-

ing spring. In Odocoileus fawn moult takes longer than in the mouflon lamb, and there was no masses of undercoat left behind. In mouflon adult Ryder (1960), the trend is ventrad. The spring moult begins from the anterior and ventral parts and the loins are last to moult. There is no autumn moult as such but only partial shedding of overcoat hairs.

In most of the domestic sheep even the spring moult has no direction as such but consists of overhair and woolly masses peeling off. Though the wool is dominant in the coat, kempts have been observed to have a partial shedding in autumn. In Wiltshire horn sheep however Slee (1959) reports a spring moult pattern very similar to that of the mouflon. The domestic sheep at times have a tendency to shed their hairs before the new hairs have emerged on the surface; giving rise to occurrence of bald patches on the body. This never occurs in mouflon, goat, cattle and Odocoileus.

In cattle approximately four months are required to complete moult from winter to summer coat but the change over from summer to winter requires less time. In deer the duration of the moult as well as time required to complete growth is same for both coats. But summer coat is borne on the deer body in resting stage for two months as against five months for the resting winter coat. The progress of moult has not been recorded in full detail for cattle. Hayman and Nay (1960) report that the new summer coat first appears on the neck and the back of thighs and gradually extends in area over the shoulders and the back. In Bos taurus the mid side is the last to moult, into the summer coat. In Bos indicus however the back and the rump are the last to moult into the summer coat. No definite moult pattern has been recorded for

change over the summer to winter coat.

Cowan (1956) states that in the black tail males normally moult a month ahead of the female with young. The female without fawns are said to moult the same time as the males. The delay in moulting of does with fawns is very likely due to the additional demands of lactation. Nutritional and disease stress has been known to delay moulting in animals and therefore the likelihood that stress of raising fawns brings about a delay in moulting seems reasonable. In mammals having a delayed implantation there is generally a relationship between implantation of the blastocyst and moulting. In deer however oestrus occurs in the latter part of the autumn moult and the implantation a month later, the young being born when the spring moult is complete.

In cattle, sheep, goat, the pelage has not been recorded to be of any behavioural significance. Odocoileus is an exception; Cowan and Geist (1961) report that when in aggressive state Odocoileus elevates its pelage as part of a threat display. The same was reported by Geist for the dorsal ridge hairs of Oreamnus display.

#### Effect of adverse nutrition

Adverse nutrition was observed to have significant effect on the black tail pelage. In experimentally starved black tail the large guard hairs were lost but no general premature shedding of the coat occurred. The experimental animals did exhibit tendency to chew off hairs from flanks exposing bare patches on the sides and considerably affecting the insulation capacity of the pelage. It appears however unlikely that in the wild where

roughage is available in quantity, if not in quality, such chewing off will take place. The hairs borne by underfed animals were of smaller dimensions and had proportionately better developed cortex, which made them slightly stiff. Statistical analysis of data collected on hair length and diameter from underfed animals and its subsequent regression analysis indicated that in the underfed animals though the actual length and diameter was less, the relative increase in diameter for any unit of hair length was greater than that found in well fed animals' hairs. Thus when the nutrients are limited the growth in hair diameter enjoys a priority over growth in length. Hair diameter is primarily determined by the extent of the medulla and its presence also helps in providing insulation. This can be interpreted in support of importance of the medulla in providing adequate insulation. A poor diet is also supposed to reduce the breaking strength of hair fibres. A test on deer fibres however proved inconclusive.

In course of an artificially induced hair cycle, the process of follicle regeneration and production of new hair is considerably slower than that in well fed animals. No delay in moulting was observed in the experimental black tail deer.

In the black tail the rate of hair growth was much faster around biopsy sampling sites, than that in adjoining area. This has been observed in other species and has been explained as a consequence of increased mitotic activity characteristic of areas with healing wounds Montagna (1956). However it has not been recorded in sheep and cattle, where skin biopsies are often taken.

In cattle, Hayman and Nay (1960) nutritional stress is known to prolong spring shedding. Also the proportion of partially

medullated hairs in the winter coat increased. In undernourished animals the winter coat had developed more rapidly, grew longer and was retained late on into the spring, than in case of well fed animals. This is in contrast to deer. The guard hair diameter also appears to be reduced in underfed animals. No hair shedding due to adverse nutrition was noticed.

In sheep adverse nutrition produced no hair shedding. A decrease in hair length was more evident than decrease in diameter. In deer both were evident. A poor diet also reduces breaking strength of the hair fibre in sheep. No comparable data are available for the goat.

In conclusion it can be said that the present study has revealed a number of features of the cervid pilary system which was hitherto an obscure and relatively unknown entity. The embryological development of the follicles has been studied and the presence of tylotrich-like follicles definitively established. A morphological study of the pelage types and the hairs that constitute them has been made and has revealed the remarkable morphometric and pigment differences in hairs produced by the same follicles during the course of a year, and also in different age-related pelages. The dynamics of the pelage i.e hair cycles and patterns of moult in the course of a year have also been studied. The main function of cervid pelage is assumed to be to adapt the animal to its environment, in particular by providing adequate insulation. In contrast to the cattle this has been done in deer by the presence of a well developed medulla as well as a woolly undercoat in winter pelage. The deer summer coat has in contrast no woolly undercoat and much smaller medulla development.

Adverse nutrition has been noticed to reduce deer hair length, and diameter, as well as the capacity of the animal to regrow hairs on plucked sites. However for a unit increase in length, the relative increase of hair diameter was greater in underfed animals than in well fed animals. Thus even under stress emphasis is put on diameter increase (i.e. increased medulla leading to relatively greater insulation) than on length may be significant.

This study has revealed few characteristics of the follicles, hair, or pelage that can be regarded as of systematic significance. The two annual moults, the presence of the second glassy layer, the sinuous rather than tight coiled sweat gland and all are described only from deer and may be characteristic of the cervidae. However with only one species studied in that detail this cannot be certain.

A number of other characteristics of the hair and pelage appear to be related to the size of the animal rather than its relationships. Thus Odocoileus resembles the size similar to that of goat and sheep more closely than it does cattle in many aspects of hair and pelage.

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## APPENDIX I

WEEKLY WEIGHT DATA

<u>Date</u>	<u>U16</u>	<u>TR</u>	<u>U26</u>	<u>W4</u>
27 Aug 66	194	160	184	127
3rd Sept. 66	199	160	191	132
9th Sept. 66	190.5	161	192	138
17 Sept. 66	194	160	192	138
24 Sept. 66	192	160	201	140
1st Oct. 66	193	160	201	140
8 Oct. 66	190	160	202	142
15 Oct. 66	186	162	207	145
22 Oct. 66	183	160	202	144
29 Oct. 66	176	156	200	146
5 Nov. 66	172	140	195	142
12 Nov. 66	164	-	192	138
26 Nov. 66	155	-	195	142
2 Dec. 66	154	128	185	126
10 Dec. 66	154	-	182	124
17 Dec. 66	147	-	179	120
24 Dec. 66	142	128	176	121
7 Jan. 67	143	128	176	121
14 Jan. 67	146	-	175	121
22 Jan. 67	146	-	176	121
27 Jan. 67	147	-	174	123
4 Feb. 67	147	-	173	121
18 Feb. 67	148	125	170	124
25 Feb. 67	148	-	160	126
4 March 67	147	126	160	126
12 March 67	150	-	166	128
18 March 67	151	-	166	128
25 March 67	152	125	166	130
18 April 67	154	125	164	131
8 April 67	154	126	164	132
15 April 67	156	125	160	132
22 April 67	158	127	168	134
29 April 67	158	127	168	134
6th May 67	159	127	168	134
13 May 67	159	-	170	137
18 May 67	159	127	170	139
10 June 67	155	123	171	142
1st July 67	158	125	176	147
8 July 67	158	122	178	148
15 July 67	157	122	177	153

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APPENDIX IIFEED INTAKE IN CALORIES (WEEKLY AVERAGE)

<u>Date 1966</u>	<u>U16</u>	<u>TR</u>	<u>U26</u>	<u>W4</u>
Aug. 26 to Sept. 1	4685.20	4673.13	7124.11	6527.26
Sept. 2 to Sept. 8	4609.71	4571.54	5828.82	5803.73
Sept. 9 to Sept. 15	4317.64	3644.59	6108.16	5633.73
Sept. 16 to Sept. 21	3949.37	3809.68	13803.15	5117.67
Sept. 22 to Sept. 28	3149.33	3111.24	5841.52	5584.27
Sept. 29 to Oct. 5	2565.18	2641.38	5193.87	5295.46
Oct. 6 to Oct. 12	2742.97	6285.98	5117.67	5740.24
Oct. 13 to Oct. 19	2146.11	2209.61	4139.85	4876.46
Oct. 20 to Oct. 26	2031.82	2044.52	2806.4	4876.39
Oct. 27 to Nov. 2	1968.33	393.66	2349.30	4762.10
Nov. 3 to Nov. 9	2323.89	914.03	2781.06	5041.48
Nov. 10 to Nov. 16	2311.21	177.78	2946.15	4089.06

APPENDIX II (cont'd)FEED INTAKE IN CALORIES (WEEKLY AVERAGE)

<u>Date 1966</u>	<u>U16</u>	<u>TR</u>	<u>U26</u>	<u>W4</u>
Nov...17 to Nov. 22	2311.21	179.0	2844.69	4000.17
Nov. 23 to Nov. 29	2514.41	747.96	3212.83	4317.64
Nov. 30 to Dec. 6	3136.64	1981.09	3581.10	5651.03
Dec. 7 to Dec. 13	5592.92	2539.78	3873.17	5270.05
Dec. 14 to Dec. 20	2869.96	2435.20	3365.21	5790.72
Dec. 21 to Dec. 27	4038.26	3060.44	3708.09	5689.12
Dec. 28 to Jan. 3	5765.32	2488.99	3657.29	6222.49
1967				
Jan. 4 to Jan. 10	5562.14	2857.26	4228.75	5857.17
Jan. 11 to Jan. 17	5790.72	2374.71	3898.57	3644.69
Jan. 18 to Jan. 24	5041.48	2958.85	4470.03	5065.29
Jan. 25 to Jan. 31	4876.39	2412.79	4863.69	4330.34
Feb. 1 to Feb. 7	5854.22	2285.80	4063.57	3923.79

APPENDIX II (cont'd)FEED INTAKE IN CALORIES (WEEKLY AVERAGE)

<u>Date 1967</u>	<u>U16</u>	<u>TR</u>	<u>U26</u>	<u>W4</u>
Feb. 8 to Feb. 14	5346.34	2376.69	4063.57	3949.37
Feb. 15 to Feb. 21	5155.77	3123.93	4076.36	4216.05
Feb. 22 to Feb. 28	5562.14	2463.59	4076.36	4266.84
March 1 to March 7	5866.92	2552.48	3822.38	4177.95
March 8 to March 14	5460.55	2679.47	4216.05	4622.41
March 15 to March 21	5689.44	2946.15	3736.49	3949.30
March 22 to March 28	5816.12	3238.74	3784.28	4139.89
March 29 to April 4	5358.95	2933.46	3467.38	4558.92
April 5 to April 11	5155.77	2933.46	3923.97	4203.35
April 12 to April 18	5033.38	2984.25	4127.15	4367.17
April 19 to April 25	4749.70	3085.84	3923.97	4203.35
April 26 to May 2	4495.42	3009.65	3911.27	4139.85

APPENDIX II (cont'd)FEED INTAKE IN CALORIES (WEEKLY AVERAGE)

Date 1967	U16	TR	U26	W4
May 3				
to				
May 9	4292.24	2933.46	3809.08	4139.86
May 10				
to				
May 16	4089.06	2933.46	3708.08	4812.90
May 17				
to				
May 23	3987.47	2831.92	3835.08	4089.05
May 24				
to				
May 30	3911.28	2755.67	4038.26	3987.47
May 31				
to				
June 6	3987.47	2755.67	4419.23	4660.57
June 7				
to				
June 13	3962.07	2986.25	6381.13	4647.81
June 14				
to				
June 20	4089.06	2933.46	3923.97	4419.23
June 21				
to				
June 27	4089.06	2933.46	3923.97	4419.23
June 28				
to				
July 4	4089.06	2984.25	4774.80	4431.93
July 5				
to				
July 11	4089.06	2933.46	4863.69	5041.48
July 12				
to				
July 18	4089.06	2933.46	4749.40	4914.49
July 19				
to				
July 25	4089.06	2933.46	5295.46	5295.46
July 26				
to				
July 31	4089.06	2933.46	5126.14	5052.06

APPENDIX IIIHISTOLOGICAL TREATMENT

Skin biopsy samples taken by means of a trephine were fixed in Bouin's fluid for 24 hours and transferred to 70% alcohol for storage. The foetal material available was already fixed and preserved in formol saline.

Subsequently the fixed material was treated as follows. Where hairs were present they were cut by means of fine surgical scissors as close to the skin surface as possible, taking care to leave enough length to adequately indicate the hair orientation vis a vis the skin surface. Using a sharp single edge ("Gem") safety razor blade and a dissecting microscope the tissue material was halved into two along the plane of the hairs. As far as possible attempt was made to cut the hair follicles along their whole length. The material so cut was dehydrated and cleared in a Tissue Tek Automatic tissue processing machine, using the following routine:-

WAX EMBEDDING

	<u>SKIN</u> Foetal	<u>SKIN</u> Adult
10% Formalin	Storage	Storage
70% Alcohol (i)	24 hrs.	24 hrs.
70% Alcohol (ii)	4 hrs.	4 hrs.
90% Alcohol (i)	2 hrs.	2 hrs.
90% Alcohol (ii)	2 hrs.	2 hrs.
Absolute Alcohol (i)	1 hr.	1 hr.
Absolute Alcohol (ii)	1 hr.	1 hr.
Absolute Alcohol (iii)	1 hr.	1 hr.
Xylene or Chloroform (i)	1 1/2 hrs.	1 1/2 hrs.
Xylene or Chloroform (ii)	1 1/2 hrs.	1 1/2 hrs.
Wax (i)	2 hrs.	4 hrs.
Wax + 5% Bees wax (ii)	2 hrs.	4 hrs.
	<u>18 hrs.</u>	<u>22 hrs.</u>

Of the two portions of each sample, one was embedded in wax with its longitudinally cut surface facing the base of the mould, while in case of the other half it was the skin surface which was facing the mould base. The blocks were duly labelled. On sectioning, the former gave longitudinal section of the hair follicles while the latter gave surface (Transverse section). 8 to 10  $\mu$  thick sections were cut on a rotary microtome, mounted, and stained as follows using the following methods.

- a) Haematoxylin and eosin
- b) Mallory's triple stain: a rapid one step method.  
(Cason, J.E., 1950. Stain Technology, 25: p. 225)
- c) Verhoeff's and Van Giesons method. Gurr (1952)

Skin samples were also taken from tanned deer hides (Summer coat and winter coat) and were treated as follows:-

The samples were placed in a 0.5% solution of trisodium phosphate for three days, dehydrated via alcohol and cleared in cedarwood oil and embedded in 56° M. Pt. wax. The blocks were sectioned at 8  $\mu$  to 10  $\mu$  and sections stained with Haematoxylin and eosin.

APPENDIX IVKEY TO ABBREVIATIONS USED IN ILLUSTRATIONS

Ap	Arrector pili muscle
Bf	Branching follicles
CH	Club hair
CO	Cortex
Cp	Central primary follicle
Cts	Connective tissue sheath
Cap	Capsule
CIGF	Central intermediate guard hair follicle
D	Dermis
Dp	Dermal papilla
Dil.p.	Dilated portion
DDC	Dedifferentiated cells
E	Epidermis
ES	Ental swelling
F	Fibrocytes
FB	Follicle bulb
FF	Follicle folds
FS	First formed secondary follicles
Fib	Fibres
FBS	Follicle base
Fan	Follicle anlagen
GF	Growing follicle
GM	Glassy membrane
Gr	Cells containing 'Keratohyaline granules
H	Keratinized hair
HC	Hair canal
He	Henle's layer
HN	Hair cone
Hu	Huxley's layer
HF	Hair follicle
Hcu	Hair cuticle
IS	Internal root sheath
IGH	Intermediate guard hairs
ISC	Internal root sheath cuticle
Int.Ca	Intracellular cavities
LP	Lateral primary follicles
LS	Later formed secondary follicles
Lu	Lumen
LGH	Large guard hairs
LGHF	Large guard hair follicle
LIGF	Lateral intermediate guard hair follicles
M	Medulla
Mec	Mesenchymal cells
Mel	Melanocytes
NH	New hair

## APPENDIX IV (cont'd)

OS	Outer sheath (External root sheath)
p	Periderm
PF	Paired follicles
PP	Pre papilla
PLF	Plucked follicle
SbC	Sebaceous cells
SbG	Sebaceous gland
SC	Stratum corneum
SGe	Stratum germinativum
SGr	Stratum granulosum
Sb O	Sebaceous gland opening
SSP	Stratum spinosum
SWD	Sweat duct
SWG	Sweat gland
SW O	Sweat gland opening
T	Trio grouping
Tr	Transitional hair
UDC	Undifferentiated cells
WtpF	White tipped hair follicles
WtP	White tipped hair
WuH	Woolly under hair