THE MICROSCOPIC ANATOMY OF THE INTEGUMENT OF SHEEP

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INTRODUCTION

Interest in the biology of the skin of sheep and wool has steadily increased with the advent of more precise research procedures and instruments. However, the general structure of the skin of sheep has been neglected while researchers have directed their efforts toward studies of one skin product, i.e., wool. Wool is of great economic importance to many countries and therefore the state of a nation may depend upon the knowledge available in preserving or increasing the amount of wool production. Wodzicka (1958-111) states, "...these investigations have emphasized the scarcity of existing knowledge of the histological and physiological changes (other than those connected with the wool follicle and fibre) occurring in the skin of sheep during growth, and later in adult life."

This investigation is an attempt to contribute some knowledge of the general morphology of the skin of sheep.

REVIEW OF LITERATURE

> "Studies of the histology, physiology, and biochemistry of the skin of sheep are of interest, not only because of the economic value of leather and wool, but also because skin is the first tissue to come in direct contact with the environment and plays an important part in such vital processes as heat regulation and defense against virus and bacterial invasion."
> Wodzicka (1958-I)

According to historians, fabrics of wool were used as a clothing material by the Babylonians about 4000 B.C. and pictured on the earliest Egyptian monuments which date some time between 5000 and 4000 B.C. (Ensminger, 1955). For centuries efforts have been devoted to methods of improving the quality and increasing the quantity of wool produced by investigating possible applications resulting from the knowledge gained from various biological sciences. The microanatomy of sheep integument has been described in some detail by Ellenberger (1906), briefly mentioned by Sisson and Grossman (1953), and discussed on a comparative basis by Trautmann and Fiebiger (1957).

With the introduction of improved synthetic fibers, the production of wool as the chief purpose of the sheep industry has diminished. Sheep production now involves the efficient yield of both wool and mutton as a source of profit. The Romney x Southdown cross produces one of the best mutton type carcasses, while the Merino is noted for its poor mutton characteristics (Stephenson and Lambourne, 1960).

EPIDERMIS

The outer layer of the skin, the epidermis, consists of stratified squamous epithelium. Lyne (1957b) has stated that the fully differentiated epidermis of the fleece bearing area remains thin up to the time of birth and throughout postnatal life, and lacks a continuous stratum granulosum. Spöttel and Tänzer (1923) considered that the reason for the relatively slight development of the epidermis in sheep must be investigated relative to the dense hairy covering. Trautmann and Fiebiger (1957) attributed sheep as having the thinnest skin and Margolena (1963b) commented that the epidermis is usually too thin to permit the presence of a clearly defined stratum granulosum, not to mention the stratum lucidum. Margolena (1958) reported that the denser follicles are found on skin which is thin and less differentiated. Beltsville sheep having continuously growing wool have a higher follicular and skin metabolism. Within 90 to 100 days of intrauterine life, mitotic activity in both the dorsal and ventral epidermis is about 10 times as great just prior to and during the very early hair anlage as compared to the period of rapid proliferation and differentiation of the follicular cells (Margolena and Dolnick, 1953). Margolena (1959) stated that gestation in both sheep and goats is about 150 days. Within 1 to 2 months the epidermis as a primary skin layer differentiates into cells which form the tectorial epithelium, hair follicles, sweat glands and sebaceous glands (Priselkova, 1957a).

Stratum Basale: This consists of a single layer of columnar or cuboidal cells (Trautmann and Fiebiger, 1957; Lyne, 1957b) which gives rise to the other epidermal strata as well as the first wool follicles. Comparable to the skins of other domestic breeds, the cells of the basal layer as reported by Margolena (1963b) are not predominantly columnar but appear to be less differentiated and of the cuboidal type with their axes frequently oriented parallel to the surface of the skin. At birth, the stratum germanitivum may be incomplete (Lyne, 1957b).

Stratum Spinosum: The superficial portion of the stratum germanitivum is the stratum spinosum which consists of cell layers firmly attached by means of surface specialization called desmosomes (Bloom and Fawcett, 1962) which gave rise to the synonymous term prickle cell layer. At birth the stratum spinosum is an incomplete single layer of cells which become flatter with later growth as they approach the skin surface (Lyne, 1957b).

Stratum Granulosum: This layer is frequently absent or very poorly developed, except around the follicle and in the neck regions of the follicles (Lyne, 1957b).

Stratum Lucidum: This layer is generally found in the thick skin of the palms and the soles of human species located between the stratum corneum and the stratum granulosum. The stratum lucidum is found consistently as a homogenous and translucent layer in the ovine foot (Deane, et al., 1955) but is absent elsewhere.

Stratum Corneum and Periderm: The embryonic forerunner to the stratum corneum is a transitory layer of cells having a dense eosinophilic cytoplasm called the periderm. The periderm is the outermost layer of the epidermis and persists until the emergence of the first wool fibers (Lyne, 1957b). In vertical sections of the skin surface the periderm cells appear to be flattened and have deeply staining flattened nuclei; when viewed in horizontal sections the cells appear as large polygonal cells with distinct cell outlines and pale round nuclei. As the first wool fibers emerge, cells containing small, flattened pyknotic nuclei are seen immediately below the continuous layer of the periderm. These nucleated cells constitute the beginning of the stratum corneum which is at first parakeratotic (i.e., it shows imperfect cornification). Therefore, the keratinization of the epidermis takes place after the emergence of the first wool fibers which are called the primary wool fibers. The periderm cells remain above the stratum corneum until the development of the secondary wool follicles which develop after the primary wool follicles. The cells of the periderm flatten greatly but they do not pass through the stage of keratinization and are seen in the formation of the definitive stratum corneum. Thus, the stratum corneum has its typical structure with several layers of cornified cells after the emergence of the secondary fibers and the disappearance of the pyknotic nuclei (Lyne, 1957b).

DERMIS

The dermis, or corneum lies directly beneath the epidermis and is divided into a superficial papillary layer and a deeper reticular

layer which have indistinct borders (Bloom and Fawcett, 1962). The relative depth of the grain layer (papillary layer) to the full thickness of the dermis is small in the ox, greater in the goat, and still greater in sheep (Dempsey, 1948). Margolena (1960) found that in Rambouillet rams the depth of follicular penetration of the follicles in the dermis shows considerable uniformity, the maximum ranging from 3.75 to 4.40 mm. Mikhailova (1958) commented that the fiber structures of the dermis undergo a complex process of formation in the course of ontogenesis, which ranges from separate fine fibrils to wide mesh elastic networks and powerful bundles of intricately arranged collagen fibers. The more complex structure of the reticular layer is noted in sheepskin-yielding sheep, whereas in the fine fleece sheep the simpler structure of the reticular layer improves the quality of the wool.

Collagenous Fibers: Collagen fibers extend throughout the dermis and are distributed similarly in the pilar layer as in other animals (Mikhailova, 1958). Changes in the distribution of collagen fibers in the pilar layer relative to age or breed could not be found. However, there were changes in the reticular layer as the animals aged with increased complexity of the fiber arrangement occurring after five months. At this time the straight and undulating horizontal collagen bundles are replaced by intertwining horizontal and diagonal bundles forming bends in different directions. Also, changes with age due to interrelations of the skin layers and the increase in thickness of collagen fiber bundles continuously increases the relative thickness of the reticular layer in percentage of the total thickness of skin.

Elastic Fibers: At the level of the sebaceous glands an extensive network of elastic fibers is present, however, they are scanty in the region of the secretory parts of the sweat glands and more isolated in the reticular layer (Mikhailova, 1958). Trautmann and Fiebiger (1957) stated that in the ox, sheep and dog some elastic fibers join the collagenous bundles, whereas other elastic fibers form a fine network in the superficial layer of the dermis. Mikhailova (1958) added that it was not possible to establish a connection between the elastic fibers of the reticular layer and the overlying layers of the skin. Hair follicles are enmeshed in elastic fibers to varying degrees and, primary hair follicles have the strongest elastic framework, while secondary hair follicles have an elastic framework common to a whole group except for the largest and most peripheral of the secondaries which have a separate mesh of elastic fibers. Elastic fibers become considerably thicker with age in sheep.

Reticular Fibers: Mikhailova (1958) found that the reticular fibers in the skin of sheep are abundant in the fibrillar basement membrane. The basal membranes of the glands and hair follicles are constituted in part by reticular fibers because they are a direct continuation of the subepidermal basement membrane. Furthermore, reticular fibers are present in particularly large numbers in the basal membrane of sebaceous glands where they are distributed in the form of a dense small mesh network.

Mast Cells

In the skin, mast cells accumulate in the greatest number around

hair follicles, sebaceous and sweat glands, as well as in the immediate vicinity of small vessels (Selye, 1965). Additionally, in the human skin there are certain dendritic cells which contain faintly metachromatic material which are presumed to be closely related to the Langerhan's cells or Riehl's dendrite cells of the epidermis. Margolena (1963b) in a study of a Columbia-Southdale ram noted that mast cells, as judged by their metachromatically staining granules and the lighter blue nuclei after staining with thionine, were frequent at middermal and sudoriferous layers. When present, they ranged from 1 to 35 cells per sq mm of field examined.

Wool

It is a remarkable fact that wool growth continues even when the body tissues are being depleted by undernutrition. Although under these conditions the rate of wool growth is much reduced, the fleece is produced virtually at the expense of the other tissues (Marston, 1955). Margolena (1960) found considerable uniformity in the depth of follicular penetration in Rambouillet rams and concluded that fine wooled sheep do not undergo seasonal molt or molts, which would necessarily be associated with spectacular upward migrations of all or certain types of follicles. The growth of wool fibers is an exfoliate type of growth, in which cells of the new tissue are removed at the same rate as they are produced (Schinckel, 1962). Also, there are two major stages in the production of a hair fiber: a proliferative phase in which the cellular basis of the fiber components (cuticle, cortex and medulla) is produced by mitotic activity in the follicle

bulb and a keratinization phase in which the cellular mass produced in the bulb undergoes a series of complex physicochemical changes in the lower regions of the follicle.

Ryder (1962) in a study of unshorn Merino sheep found that the greatest amount of shedding occurs from late winter (March) to early autumn (August) with some variation between sheep in the months that shedding occurred. The British breeds and wild sheep shed most in late winter, with a smaller peak in late summer. Doney (1963) found that in the fleece of the Scottish Blackface sheep the shedding of the coarser fibers, termed kemps, is a true cyclic phenomenon. In the case of fine fibers, at all times, and some coarse fibers, in winter periods, the medullation varies from the unbroken type through interrupted and fragmental to nonmedullated (Doney and Smith, 1962).

Development of the Wool Follicle: In the lamb, follicle development begins at about 50 days of fetal age, and the majority of follicles are developed, i.e., initiated, before the lamb is born, but maturation, i.e., the growth of a fiber in the follicle, continues during the first month or so after birth (Ryder, 1965). The first stage in the formation of a follicle is the multiplication of cells to form a plug which corresponds to an aggregation of dermal cells (Hardy and Lyne, 1956). By cellular division the epidermal cells grow down into the dermis, the base of the follicle plug flattens to develop into the papilla and an outgrowth of cells produces a sweat gland beneath which another bud appears producing a sebaceous gland (Ryder, 1965). Then, the arrector pili muscle is formed in the dermis at the same side as

the glands, and extends at an angle from the lower part of the follicle up to the epidermis. The larger follicles are formed first and are termed primary follicles, acquire sweat glands, sebaceous glands and arrectores pilorum muscles. The secondary follicles form later, tend to be smaller than the primary follicles and develop only sebaceous glands. Secondary follicles can develop as a bud from another secondary follicle instead of from the epidermis and thus there are two types of secondary follicles, original and derived (Hardy and Lyne, 1956a).

The Development of the Follicle Population: Regional development of the primary follicles starts on the head, continues onto the legs, then spreads up onto the ventral trunk so the back is the last area in which follicles form (Wildman, 1932). The first primaries to be formed are central primary follicles; they are so named because some time later, i.e., about 75 days of fetal age another, smaller follicle, known as a lateral primary, forms on each side of the central primaries (Carter and Hardy, 1947). Stephenson (1959) found that the central primary anlagen, once present, possibly inhibits the initiation of new central primaries within a certain radius. The result is a row of three primary follicles known as a trio group in which the central primary tends to be bigger than the two laterals (Ryder, 1956). Narayan (1961) found that the trio percentage is higher in the carpet wool group and lower in the hairy wool group than the total of couplet and solitary groups.

Following completion of the primary trios, the secondary follicles begin to form at about 90 days of fetal life. Thyroidectomy of the

newborn lamb prevents the maturation of secondary wool follicles (Ferguson, et al., 1956). The secondaries develop on the ectal side of the primaries. The wool follicle is described as having an ectal side which is opposite the side of the follicle which is associated with the glands. The ental side of the follicle is that side of the acute angle of slope the fiber axis makes as it projects onto the skin surface (Auber, 1950). The first secondaries develop between the laterals and the central, and in some sheep a definite stage comprising a primary trio and the first two secondaries is obvious (Ryder, 1956b, 1960). The later secondaries form between the first secondaries and the primaries and in some breeds the later secondaries branch to develop several follicles (Ryder, 1965). Therefore, there are two types of follicles, primaries (P) and secondaries (S) which constitute the adult follicle population. Primary follicles are completely developed before birth, and by birth have formed long wool fibers. While some secondaries develop before birth, the majority develop after birth (Fraser, 1954). Therefore, changes in density merely reflect the normal skin expansion accompanying growth (Schinckel, 1955a). In medium wool type Merino, the majority of the adult secondary population develops during the period from birth to 28-35 days (Fraser, 1954). Lyne (1957a) described bundles of primary follicles consisting of two to six P follicles with a common neck and opening at the skin surface.

Follicle Density and Secondary to Primary Follicle Ratio: The number of follicles per sq cm might be between 3000 and 4000 in a Down breed, whereas in the Australian Merino the follicle density at

birth may be more than 10,000 (Ryder, 1965). In general, the greater the follicle density, the finer is the fleece (Carter, 1955; Ryder, 1957). When development of the follicle population is complete, the follicles are arranged in groups which consist ideally of three primaries and their associated secondaries, and constitute the smallest unit of fleece (Ryder, 1965). It is usually possible to distinguish the follicle groups, however, because they are separated by broader bands of connective tissue than the bands that separate the follicles within the group. As the secondary follicles tend to produce the finest fibers, the more secondaries a sheep has (i.e., the greater the S/P ratio) the finer will be the fleece. The mountain breeds have mean S/P ratio values of roughly 3 or 4:1, the longwools have mean values of 4 or 5:1 and the Down breeds have values of 5 or 6:1. The average S/P ratio in the Merino is about 20:1, which makes it unique in having large follicle groups. Carter and Clarke (1957b) commented that data suggest that the Merino is typically distinct from all other basic genotypes by virtue of a follicle group numerically about four times greater than in other breeds. The Merino has approximately 20% more follicle groups than the Southdown but group size is of the order of 300-400% greater (Schinckel, 1955b).

Fiber Growth in the Individual Follicle: After the follicle has completed its development in the lamb, wool fiber growth occurs in cycles in which periods of active growth alternate with periods when the follicle is at rest. It is usually at the end of the resting phase that the old fiber is shed from the follicle to make way for the

new one (Ryder, 1965). The follicles of crimped wool fibers have a deflected bulb, the position of the fiber in them is eccentric, and keratinization of the fiber is asymmetrical (Auber, 1950). This bend of the bulb and the curve of the follicle are associated with the waviness of crimp of wool fibers, because animals with straight hairs have straight follicles (Ryder, 1965). The crimping mechanism of the wool follicle is not yet fully understood, but it is thought to involve periodic movement of the bulb (Auber, 1950). The growing fiber is nourished from a blood supply in two parts (Ryder, 1965). There is a basket-like network of capillaries surrounding the lower third of the follicle, and capillaries enter the papilla around which the cell division, resulting in fiber growth, takes place (Ryder, 1965).

The fiber keratinizes about one-third of the way up the follicle in the keratinization region, which is basophilic, whereas the soft cellular part below is acidophilic, and the hard fully keratinized part above, is nitrophilic, i.e., it stains yellow with picric acid (Ryder, 1965). The cuticle of the fiber keratinizes first, and keratinization of the cortex begins at a lower level on one side than the other (Auber, 1950). Wool fibers have an inherent, continuous, bilaterality which extends the length of the fiber from the root to the tip (Horio and Kondo, 1953). The cortex of fully formed wool fibers have one side which takes up dye more readily than the other. The DA or dye accessible side (the orthocortex) always lies on the outside of the curve of the crimp. Fraser and Rogers (1953) termed the orthocortex the S segment and the paracortex the H segment. Thus, the least stable,

basophil segment is the DA, S, or orthocortex, and the more stable, acidophil element is the non-DA, H, or paracortex (Montagna, 1962). Numerous studies of crimped and noncrimped wool fibers demonstrate that crimp is associated with the chemical and physical differences between orthocortex and paracortex parts of the fiber (Fraser and Short, 1960).

Auber (1950) described the differential forces in fiber growth which cause the flat cells (scales) of the cuticle to overlap one another rather like the tiles of a roof. The overlapping edges of the scales of the cuticle point towards the tip of the fiber, and interlock with the scales of the inner sheath cuticle (Ryder, 1965). This interlocking probably helps to hold the fiber in the follicle, and makes it necessary for the inner sheath to grow up with the fiber.

The Histochemistry of Wool Fiber Growth: It has been long known that the main chemical change that takes place in the fiber on keratinization is the oxidation of two adjacent thiol (SH) groups (in molecules of cysteine) to form a dithio (S-S) link (within a molecule of cysteine), and it has always been assumed that the new bond formed links two of the long chain protein molecules of the keratin (Ryder, 1965). Copper is a trace element that is essential for fiber crimping to take place (Marston, 1955). A local store of energy in the form of glycogen is found in the outer sheath, and this disappears during fiber shedding. This glycogen may function to supply glucose via the follicle blood vessels into the papilla (Ryder, 1965). It has been possible to detect an acid phosphatase in the outer sheath. Glycogen

is detected by the periodic acid Schiff reaction and more recently glycogen has been demonstrated in the unkeratinized part of the fiber to provide energy in keratinization (Ryder, 1958).

The Types of Fiber in the Adult Fleece: Three main kinds of fibers are recognized in adult sheep; these are wool fibers, hairy fibers and kemps. Fine wool is tightly crimped, of small diameter (about 15 μ) and lack a medulla. However, Ross (1962) commented that in Merino ewes half of the animals studied contained a high proportion of medullated fibers in the summer months when wool production was high. Ryder (1963) stated that evidence suggests that there has been little change in diameter, and that it is remarkable how close the average diameter of the fine fibers approaches 20 μ from 400 B.C. through the 2nd century A.D. and the Middle Ages to the present day (Ryder, 1964). Other limiting values of mean fiber thickness to be expected for the various strains as flock means under maximal conditions of nutrition are of the following order: Fine Merinos, 20-22 μ; Medium Merinos, 23-26 μ; Strong Merinos, 27-30 μ (Carter and Clarke, 1957a). Medium wool of Down breeds is of medium diameter (25-30 μ), less tightly crimped, and often medullated. The medulla is usually narrow and is frequently interrupted along the length (Ryder, 1965). Jones (1962) reported that in a sample of Lincoln wool a small percentage of the fibers contains two medullae and in rare cases, the fragments of a third one. Doney and Smith (1962) found that the multiple medullae are most commonly found among the fine wool fibers, derived from secondary follicles, of which about 70% in the Scottish Blackface were

medullated. Wildman (1944) described and illustrated five grades of medullation: lattice, unbroken, interrupted, fragmental and non-medullated. Kemp fibers are coarse (100 μ in diameter) and have a large latticed medulla occupying most of the width of the fiber. The kemp fiber is fairly short with a pointed tip and the crimp is in a shallow wave often directed in one plane only (Doney and Smith, 1961). In a study by Doney and Smith (1961), wide variation in amount of kemp was found among Scottish Blackface sheep. Differences ranged from two sheep in which no kemp fibers were found at the mid-side position in any stage of fiber development to one sheep in which over 50% of the 'primary' fibers were kemp. Hairs or coarse wool fibers are intermediate between wool and kemp, and are called heterotypes because they have a medulla in the wide part of the fiber grown in summer, but are nonmedullated in the narrow length grown in winter, also, there are very few kemp fibers produced in winter and these are very much lighter than those produced in summer (Doney, 1964). Carter (1955) found that the fine wools represent fibers developed from secondary follicles while coarse wools and kemps originated from primary follicles. Nevertheless, hair and wool can grow in both primary and secondary follicles as in the Down sheep where both primary and secondary follicles grow wool fibers (Ryder, 1965).

"Anomalous" or "doggy" wool refers to wool in which crimp frequency and amplitude are less than that of the normal growth of the flock. The staple has a lock formation resembling canine rather than ovine coats, hence the colloquial name (Glynn, et al., 1960). Ahmad and Lang (1957) have described peculiarities in the differentiation of

ortho- and paracortex in some or all of the fibers in doggy wool. Jones (1961) has found that the area percentage of paracortex in the doggy wool cross section is slightly higher than in normal wool from the same flock source. Chapman and Short (1964) stated that when wool growth is doggy, matrix cell hyperplasia apparently decreases, although cell size is maintained. This could result from nutrients being available in limited supply, so that eventually when a large proportion of follicles have grossly hyperplastic outer root sheaths, a situation apparently exists in which the nutrient demand of the outer root sheaths has preference. While occasional cystic sebaceous glands may be seen in the skin of sheep growing normal wool, particularly in aged sheep, the proportion of follicles with enlargements and cysts of the outer root sheaths increases with severity of crimp deterioration (Chapman, et al., 1960).

Differences in Fleece Type: Differences in fleece type between breeds, between flocks, and between individual sheep within a breed are due to genetic differences which are often associated with differences in secondary/primary follicle ratio. There are also similar genetic differences associated with differences in S/P ratio, in the kind of wool grown from different parts of the body. Usually the wool is finest on the shoulder and coarsest on the breech (Stephenson, 1956). A coarse fleece, such as that of the Scottish Blackface, has more regional variation over the body than the fine fleece of a Down sheep. A concept of follicle competition has been put forward to explain differences in fleece structure (Fraser and Short, 1960). Follicles

are thought to compete for available nutrients during development and after maturity. Therefore, follicles could compete for fiber-forming substances. There seems to be no genetic association between body weight and fleece weight (Schinckel, 1956). Short (1955) further substantiated the hypothesis of competition between follicles for the precursors of wool keratin by finding that wool production per unit area of skin is independent of fiber density. During development the successful follicles which have competed for follicle-forming substance will have a greater efficiency throughout their subsequent life than the less successful (Fraser and Short, 1952). However, as follicle efficiency implies the relation of follicle input (fiber-forming substrate) to follicle output (fiber mass) and as the former of these cannot be measured, no unequivocal measurement of fiber competition may be made (Ross, 1962).

The Birthcoat

In sheep a proportion of the skin follicles grow fibers some time before birth and newborn lambs therefore have a well developed birthcoat (Fraser and Short, 1960). Dry (1933a, 1933b, 1934), following the observations of Duerden and Seale (1927) and Duerden (1932) first indicated that the structure of the birthcoat allowed identification of the effects of factors that operated before birth. Dry had also completed many studies on the New Zealand Romney Marsh breed which placed some emphasis on the relation of the structure of the birthcoat to the characteristics of the adult fleece. Fraser (1951) combined the seven grade system of Dry (1934), for assessing the variation of the

number of these fibers at a standard mid-back position, and the five grade system of White (Rendel, 1954), for describing the variation of the coverage of the body with regions of high density, into a single twelve grade scale. Since coverage and density are closely correlated, this twelve grade scale proved to be worthwhile. Duerden and Seale (1927) first discovered that some fibers in the birthcoats of Merino lambs have sickle shaped tip curls, making it possible to separate birthcoat fibers into sickle types and other fibers. Dry (1934, 1940) evolved a detailed system of classifying fibers which was based on this initial separation.

Schinckel and Short (1960) have found that prenatal conditions are probably important in the determination of the total number of follicles on an animal while postnatal conditions influence the life long capacity of the individual follicles to produce fibers. Galpin (1947) concluded that among Romney Marsh sheep, under excellent nutritional conditions, all sheep produce the same amount of wool per unit area of skin on a given body region.

Sebaceous Glands

Sebaceous glands explanted from sheep fetuses of normal size and structure were differentiated *in vitro*, and, for the first time in any species, the formation of rudimentary sudoriferous glands with a holocrine secretion *in vitro* has been reported by Hardy and Lyne (1956b). The essential features of a primary follicle are the accessory structures, sweat gland, sebaceous gland and arrector pili muscle, in addition to its position in a hair follicle group (Fraser and Short,

1960). The secondary, or later developing follicles, show no sudoriferous gland or muscle, and may or may not possess a sebaceous gland (Margolena, 1959). Priselkova and Zornia (1957) have found a superficial and large venous plexus under the deep sebaceous glands.

The sebaceous glands of sheep persist throughout life and in follicles which contain shedding hair or wool, that portion of the follicle stretching from the level of the sebaceous gland to the orifice at the surface of the skin, is also permanent (Margolena, 1962). The larger sebaceous glands, that is, glands associated with the primary follicles, range from 0.25 to 0.45 mm in length in the breeds examined in animals $2\frac{1}{2}$ to 3 years of age (Margolena, 1963a).

Sweat Glands

The majority of the tubular skin glands of domestic animals are apocrine and are associated with hair follicles, except the tactile hair follicle (Trautmann and Fiebiger, 1957). In the fine wooled Merino, sudoriferous glands are naturally forced to follow a more or less winding path. The gland turns fairly abruptly and frequently has a twist into the duct and empties in the neck of the follicle (Margolena, 1962). The exact place where the gland becomes relegated into a duct seems to be frequently determined by the region where the arrector pili muscle encounters it on its slanting way toward the point of attachment to the follicular sheath. Margolena also reported that sudoriferous glands develop somewhat faster than the sebaceous but there is little, if any, activity in the sudoriferous glands until the end of gestation. Furthermore, the epithelium consists of one row of

columnar, cuboidal or flattened cells, which are supported and partially controlled by a myoepithelium with acidophilic cytoplasm. The apocrine glands of sheep and goats function apparently by true secretion and by means of extruding and discharging amorphous particles of cellular origin. The ducts of sudoriferous glands are composed of two layered stratified cuboidal epithelial cells. The cells of the luminal layer are fairly regular and cuboidal, while those of the outer layer are more or less flattened out about the first ones. She also reported that the sudoriferous glands of the wooled sheep reach below the follicles, and it is possible to speak of a sudoriferous layer. In the Hampshire sheep the sudoriferous glands spread out between and under the follicles, while those of the Merino tend to accumulate forming lobes and diverticulae under the follicles (Margolena, 1962).

According to Ellenberger (1906) the sweat glands of goats are similar to that of the sheep but are less developed. In sheep the secretory tubule is glomiform, whereas in goats it is serpentine (Trautmann and Fiebiger, 1957). Moreover, the planum nasale of sheep and goat bears modified tubular serous glands. Priselkova (1957b) found that the excretory ducts of three or four glands in the muzzle merge and exit in one common excretory duct to secure a steady cooling and lowering of the temperature in the muzzle. Dry as reported by Fraser and Short (1960) stated that Hefford found sweat glands attached to follicles containing curly tip fibers with numerous curls in the tip, whereas follicles growing curly tips with only few curls are without sweat glands, i.e., primary follicles form curly tips with more crimps than those formed by secondary follicles.

The *in vitro* studies of Hardy and Lyne (1956b) showed that the sudoriferous glands do not attain a size or degree of development comparable with that in the fetus of 10 days or more, but always remain in a rudimentary state. The sweat glands, as an accessory structure of the primary follicle, are on the ental side of the follicle while the secondary follicles are on the ectal aspect (Narayan, 1960).

Hair Muscle: At the same time as the follicle plug forms the papilla, an erector muscle is formed in the dermis at the same side as the glands, and this extends at an angle from the lower part of the follicle up to the epidermis (Ryder, 1965). Narayan (1960) found that, in Rajasthan sheep, the primary central follicles are usually associated with two strands of muscles. Though occasionally primary lateral follicles are also associated with two strands of muscle, it is more usual to find them associated with only one. In bundles of primary follicles the muscle is attached to only one of the follicles of the bundle (Lyne, 1957a). Ryder (1965) stated that contraction of this muscle in some animals raises the hair and causes it to "stand on end", but the erector muscle does not seem to function in sheep. Trautmann and Fiebiger (1957) stated that the arrectores pilorum muscles are conspicuously thick in sheep.

Follicular Folds: Auber (1950) in an anatomical study of the wool fibers noted the existence of follicular folds in the wool follicle. Narayan (1960) found transverse corrugations in the follicle. Montagna (1962) described similar folds in sheep below the opening of the sebaceous duct to the hair follicle.

Studies on the Thickness of the Skin of Sheep: Wodzicka (1958-I) in skin thickness studies, using frozen sections, showed that the amount of subcutaneous tissue inadvertently removed is too small to affect measurement, being less than 0.1 mm. She also reported that skin can be preserved in a refrigerator (at 4° C) without alteration in thickness, however, it increases in thickness when kept in a deep freeze (at -15° C). Upon comparative examination of frozen sections it was observed that careful removal of the skin from the animal using a scalpel results in uniform samples corresponding to the dermis and epidermis which is removed with the pelt at slaughter. Wodzicka noted that there is a steep dorsoventral gradient in skin thickness on either side of the medial dorsal line, which shows a high degree of bilateral asymmetry; the skin is thicker near the vertebral column. The skin is thicker near the tail along the back of the sheep, and in the oldest sheep thicker toward the neck. Furthermore, there is an area of uniform skin thickness, in the middle of the back, on either side of and parallel to the vertebral column, which is suggested as a suitable sampling area. Clarke, et al., (1937) measured the thickness of "partly cured lamb skin with the microscope used on sections cut for histological examination," but gave no details on histological techniques or methods of measuring. Nicov (1931) used a "pinch" type of instrument and Carstens and Kinzelbach (1933) regarded this as an accurate method and preferable to histological sections since the skin would not have to be removed from the animal. Wodzicka (1958-I) using a specially developed skin thickness instrument compared results with measurements using an eyepiece graticule and demonstrated accuracy to

0.1 mm.

The dorsoventral gradient in skin thickness reported by Wodzicka (1958-I) is similar to the one found by Carter (1943) in the density of follicle population of the adult Merino where more follicles occurred in the areas of thicker skin. There is also a weak anteroposterior gradient which did not agree with the findings in skin thickness by Wodzicka (1958-I).

In searching for a uniform sampling area it is difficult to define precise positions in the animal, moreover, it is uncertain that the same gradients in skin thickness occur in lambs as in older animals (Wodzicka, 1958-II). On skin thickness studies conducted during growth she found no correlation between skin thickness and age, live weight, or live-weight gain. The skin initially increases in thickness, then decreases and finally remains at the same value at the end of the experiment while measurements of fat and nitrogen content continue to increase throughout. There is no significant correlation between skin thickness and wool staple length, count or percentage hairiness. The results of Wodzicka (1958-II) showed that within 10 days of birth, the skin of a lamb is as thick as at 5 months of age and between 1 and 4 to 10 weeks after birth, skin increases in thickness by approximately 14%. Also changes in the wool follicle and fiber population occur in the Romney breed. It was concluded that possibly both follicle formation and skin thickness are a reflection of the physiological activity of the skin and that a peak of this activity is reached 5 to 12 weeks after birth. It was also noted that a rise and decline in skin thickness within the first 5 months after birth could be derived from shearing

since results obtained in a shearing experiment indicate that skin thickness increases markedly after shearing. Wodzicka-Tomaszewska (1960) postulated that the increase in thickness after shearing is an effect of cold due to the violent change in the sheep's proprioclimate. Wodzicka (1958-111) noted that the skin of lambs increases in thickness after shearing and that shorn lambs tend to have thicker pelts than unshorn ones.

Lyne (1964) stated that changes in skin thickness parallel changes in body weight and also agreed that increase in skin thickness which follows shearing is probably due to cold stress. Hutchinson (1957) considered that "measurable changes in thickness, weight or protein content of the skin may adequately reflect changes in nutrition and thus provide a useful measure of the incidence and magnitude of seasonal nutritional stresses which commonly occur under grazing conditions."

Attempts to relate skin thickness and regional wool development are lacking in the literature. However, Chapman and Young (1957) found a dorsoventral gradient in decreasing wool production, with wethers having a different anteroposterior pattern from that of the ewes and rams. This data revealed that wool production varies considerably from position to position over the body of a sheep, the upper shoulder yielding more than twice as much wool as the belly. Doney and Weiler (1959) found no consistent trend in mean clean fiber weights of the various body regions; likewise, no consistent trend was found in the mean greasy fiber weights. The skin of the sheep varies in thickness from 0.5 to 3 mm, but differs greatly in fineness and in other respects in various breeds (Sisson and Grossman, 1953).

MATERIALS AND METHODS

Source of Animals

Eight sheep, predominantly Southdown, including 3 rams, 4 ewes, and a wether were used in this investigation (Table 1). These animals were obtained from the Meats Laboratory, Michigan State University. The age of the animals varied from 1 to 6 years. Sections from two additional rams were procured for study of special anatomical structures of the scrotum and other glandular areas.

Technique

The sheep were killed by electrocution and the skin from thirty-five body regions was removed immediately and fixed in Lavdowsky's mixture (Guyer, 1949) of 95% ethyl alcohol, glacial acetic acid, 10% formalin, and distilled water. The tissues were removed from this fixative after 5 days and stored in 90% ethyl alcohol until the time of dehydration and infiltration.

The tissues were dehydrated and cleared by four changes of dioxane (Bucher and Blackely, 1936) and infiltrated in paraffin using the vacuum method for one hour and fifteen minutes. The tissues were embedded in Bioloid[1] (melting point 56-58° C).

Additional modifications in fixation, dehydration, clearing and embedding medium were used to determine accurate histological readings in skin thickness (Table 1).

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[1] Will Corporation and Subsidiaries Laboratory Supplies, Rochester 3, New York.

Horizontal and vertical sections were cut at 6 microns. The following stains were employed: (1) Harris hematoxylin and eosin (Malewitz and Smith modification, 1955), (2) Alcian Blue--Periodic Acid Schiff reagent, (3) Mallory's triple stain (Crossmon's modification, 1937), (4) Ziehl-Neelsen's stain described by Margolena (1963c), (5) the differential staining method for elastic fibers, collagenic fibers and keratin employed by Margolena and Dolnick (1951), (6) Crystal Violet according to Clarke and Maddocks (1963), (7) Weigert's iron hematoxylin and VanGieson's picro-acid fuchsin described by Berres (1961), (8) New fuchsin-hematoxylin-eosin used by Williган, et al., (1961), (9) Modified Bielschowski-Gros method according to the technique described in "Histopathologic Technic and Practical Histochemistry" by Lillie (1965), (10) 0.5% aqueous Nile blue sulphate as employed by Nay, et al., (1959), (11) the May-Grünwald-Giemsa stain for mast cells as used by Strumia (1935), (12) Papanicolaou staining method (1954), and (13) the dermatologic stain used by Pinkus (1944).

Measurements

The thickness of the epidermis and dermis was measured by means of an ocular micrometer. Measurements were taken at 6 different places including the highest and lowest points in a representative field of the skin sections and the average thickness was determined. As the thickness of the skin varied from place to place the range of the thickness was recorded. Average skin thickness for individual animals was determined separately according to ewe, ram and wether (Tables 2, 3, 4, 5 and 6).

PLATE I

Body areas from which specimens were taken

	Section No.
A. Head	
1. Forehead	1
2. Lower lip	24
3. Muzzle and upper lip	25
4. Base of ear	26
5. Top of ear	27
6. Lower jaw	28
7. Infraorbital pouch	29
8. Upper eyelid	31
9. Lower eyelid	32
B. Neck	
1. Dorsal cervical region	2
2. Ventral cervical region	6
3. Lateral cervical region	12
C. Thorax	
1. Dorsal thoracic region	3
2. Ventral thoracic region	7
3. Lateral Thoracic region	13
D. Trunk	
1. Lumbar region	4
2. Ventral abdominal region	8
3. Lateral abdominal region	14
4. Udder or scrotum	9
5. Teat	30
6. Dorsal tailhead region	5
7. Dorsal perianal region	21
8. Ventral perianal region	22
9. Ventral surface of tail	35
E. Pectoral Limb	
1. Axillary region	10
2. Pectoral limb (lateral above knee)	16
3. Lateral to the metacarpo-phalangeal joint	17
4. Junction of hoof with skin	23
F. Pelvic Limb	
1. Hip region	15
2. Lateral between stifle and hock	18
3. Lateral metatarsal region	19
4. Lateral hock region	20
5. Interdigital region	33
6. Skin of inguinal folds	34
7. Medial pelvic limb	11

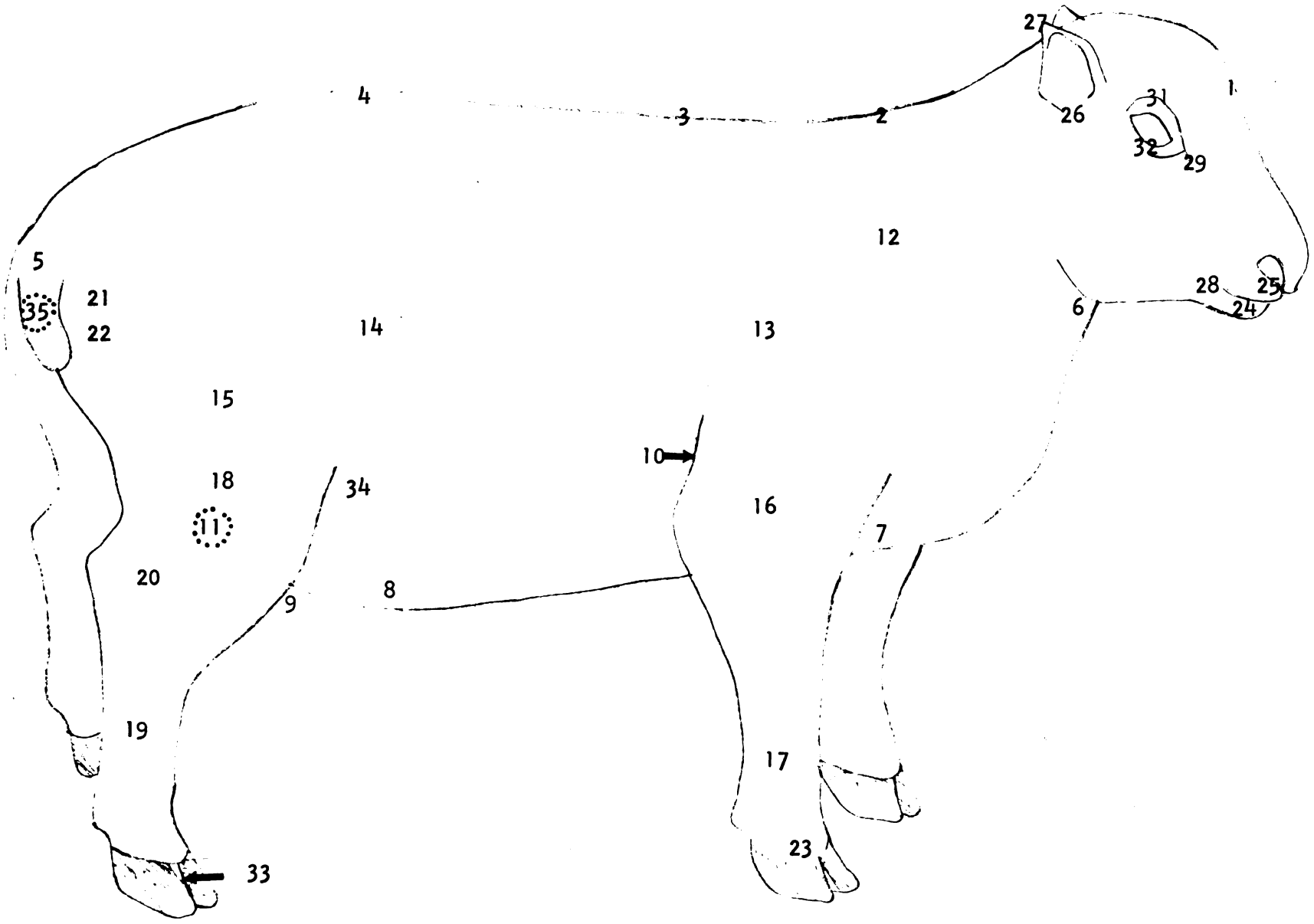
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TABLE 1. Processing methods used for individual animal specimens

ANIMAL	BREED	SEX	AGE	FIXATIVE	DEHYDRANT	CLEARANT	EMBEDDING MEDIUM
A	Shropshire	Ewe	1 yr.	FAA; 70% alcohol	Dioxane	Dioxane	Bioloid
B	Suffolk	Ewe	1 yr.	FAA; 70% alcohol	Dioxane	Dioxane	Bioloid
C	Merino	Ram	3 yrs.	10% formalin; 70% alcohol	Dioxane	Dioxane	Tissuemat
D	Southdown	Ram	1½ yrs.	Buffered formalin	80%, 95% and absolute alcohol	Chloroform	Paraplast
E	Southdown	Ewe	1 yr.	Neutral-formal-saline	80%, 95% and absolute alcohol	Chloroform	Paraplast
F	Southdown	Ewe	1 yr.	Buffered formalin	80%, 95% and absolute alcohol	Chloroform	Paraplast
G	Southdown	Wether	1 yr.	Buffered formalin	80%, 95% and absolute alcohol	Chloroform	Paraplast
H	Southdown	Ram	6 yrs.	10% formalin	80%, 95% and absolute alcohol	Xylene	Paraplast

TABLE 2. Average measurements (microns) of total epidermal thickness in sheep

REGION	ANIMAL AGE (yrs)	EA 1	EB 1	EE 1	EF 1	RC 3	RD 1½	WG 1	AVERAGE
Forehead		33	33	26	70	46	59	44	44
Dorsal cervical		25	21	23	35	39	23	28	28
Dorsal thoracic		27	25	31	21	55	23	17	28
Dorsal abdominal		25	33	26	28	39	32	27	30
Dorsal tailhead		26	26	24	42	43	43	33	34
Ventral cervical		29	32	22	52	31	30	18	31
Ventral thoracic		21	35	19	43	37	26	35	31
Ventral abdominal		17	19	31	46	37	20	34	29
Udder/Scrotum		24	32	36	60	62	25	33	38/40
Axilla		22	36	23	24	41	35	40	32
Flank		20	22	20	20	50	21	27	26
Lateral cervical		16	16	21	25	33	25	18	22
Lateral thoracic		19	25	24	23	28	26	25	24
Lateral abdominal		17	26	23	28	22	24	17	22
Hip		40	26	26	39	26	25	19	29
Pectoral limb		19	16	27	27	24	32	22	24
Metacarpo-phalangeal joint		26	25	41	23	39	30	20	29
Pelvic limb									
Lateral stifle and hock		21	20	31	40	25	27	32	28
Lateral metatarsal		35	33	37	43	52	20	25	35
Lateral hock		26	33	30	26	26	10	19	24
Dorsal perianal		49	26	48	75	69	25	43	48
Ventral perianal		72	76	39	46	65	36	30	52
Junction of periople		20	24	63	59	62	30	44	43
Lower jaw		20	36	31	19	42	18	22	27
Ventral surface tail		25	51	25	25	65	42	22	36
	AVERAGE	27	30	30	38	42	28	28	

Key: E=ewe, R=ram, W=wether, A-G=animal designation.

TABLE 3. Average measurements (microns) of total dermal thickness in sheep

REGION	ANIMAL AGE (yrs)	EA 1	EB 1	EE 1	EF 1	RC 3	RD 1½	WG 1	AVERAGE
Forehead		2417	2772	2120	3080	2226	3964	2359	2705
Dorsal cervical		4569	2438	3191	3774	1643	2745	3975	3191
Dorsal thoracic		5790	3058	2666	3339	2253	2348	4176	3376
Dorsal abdominal		2157	2846	3026	2788	2056	2931	4002	2829
Dorsal tailhead		2878	3387	2730	2793	2332	3588	3260	2995
Ventral cervical		2290	2200	2359	2449	3180	2756	4214	2778
Ventral thoracic		3207	4600	1988	3032	3816	2205	2465	3044
Ventral abdominal		2708	2989	2067	2915	3286	2083	2380	2633
Udder/Scrotum		2401	2544	2067	3949	2571	1511	2215	274/210
Axilla		2306	3095	1272	2046	4134	1564	2942	2480
Flank		3472	4097	3366	2841	2677	2019	3175	3092
Lateral cervical		3615	2422	2465	3396	2215	3328	3816	3037
Lateral thoracic		2634	2221	2624	2253	2099	2364	2438	2376
Lateral abdominal		2878	2745	2013	2655	2353	2231	3101	2568
Hip		2836	4123	2788	2499	2327	2396	3419	2913
Pectoral limb		1998	4240	2332	2703	2056	2104	3366	2686
Metacarpo-phalangeal joint		2608	2094	2014	2242	2348	1908	2316	2219
Pelvic limb									
Lateral stifle and hock		2215	3800	3975	1802	3196	2178	3419	2941
Lateral metatarsal		2422	4426	2703	2936	4198	1781	1908	2911
Lateral hock		3551	2374	2783	4600	2051	1622	2412	2770
Dorsal perianal		2359	3085	2385	2327	4903	3222	2825	3015
Ventral perianal		2889	4108	3498	3224	2867	3154	3339	3297
Junction of periople		2014	3694	1988	2221	4108	2173	2147	2608
Lower jaw		1760	1776	1284	1786	3048	2576	2067	2171
Ventral surface tail		2889	3169	2825	3339	2571	3560	4770	3303
	AVERAGE	2835	3129	2537	2840	2821	2492	3060	

Key: E=ewe, R=ram, W=wether, A-G=animal designation.

TABLE 4. Average measurements (microns) epidermal and dermal thickness in sheep

REGION	EPIDERMIS Average	DERMIS Average
Forehead	44	2705
Dorsal cervical	28	3191
Dorsal thoracic	28	3376
Dorsal abdominal	30	2829
Dorsal tailhead	34	2995
Ventral cervical	31	2778
Ventral thoracic	31	3044
Ventral abdominal	29	2633
Udder/Scrotum	38/40	247/210
Axilla	32	2480
Flank	26	3092
Lateral cervical	22	3037
Lateral thoracic	24	2376
Lateral abdominal	22	2568
Hip	29	2913
Pectoral limb	24	2686
Metacarpo-phalangeal joint	29	2219
Pelvic limb		
Lateral stifle and hock	28	2941
Lateral metatarsal	35	2911
Lateral hock	24	2770
Dorsal perianal	48	3015
Ventral perianal	52	3297
Junction of periople	43	2608
Lower jaw	27	2171
Ventral surface tail	36	3303

TABLE 5. Average measurements in millimeters of total skin thickness in sheep

REGIONS	ANIMAL	EA	EB	EE	EF	RC	RD	WG	AVERAGE
	AGE (yrs)	1	1	1	1	3	1½	1	
Forehead		2.4	2.8	2.1	3.1	2.3	4.0	2.4	2.7
Dorsal cervical		4.6	2.5	3.2	3.8	1.7	2.8	4.0	3.2
Dorsal thoracic		5.8	3.1	2.7	3.4	2.3	2.4	4.2	3.4
Dorsal abdominal		2.2	2.9	3.1	2.8	2.1	3.0	4.0	2.9
Dorsal tailhead		2.9	3.4	2.8	2.8	2.4	3.6	3.3	3.0
Ventral cervical		2.3	2.2	2.4	2.5	3.2	2.8	4.2	2.8
Ventral thoracic		3.2	4.6	2.0	3.1	3.9	2.2	2.5	3.1
Ventral abdominal		2.7	3.0	2.1	3.0	3.3	2.1	2.4	2.7
Udder/Scrotum		2.4	2.6	2.1	4.0	2.6	1.5	2.2	2.8/2.1
Axilla		2.3	3.1	1.3	2.1	4.2	1.6	3.0	2.5
Flank		3.5	4.1	3.4	2.9	2.7	2.0	3.2	3.1
Lateral cervical		3.6	2.4	2.5	3.4	2.2	3.4	3.8	3.0
Lateral thoracic		2.7	2.2	2.6	2.3	2.1	2.4	2.5	2.4
Lateral abdominal		2.9	2.8	2.0	2.7	2.4	2.3	3.1	2.6
Hip		2.9	4.1	2.8	2.5	2.4	2.4	3.4	2.9
Pectoral limb		2.0	4.3	2.4	2.7	2.1	2.1	3.4	2.7
Metacarpo-phalangeal joint		2.6	2.1	2.1	2.3	2.4	1.9	2.3	2.2
Pelvic limb									
Lateral stifle and hock		2.2	3.8	4.0	1.8	3.2	2.2	3.5	3.0
Lateral metatarsal		2.5	4.5	2.7	3.0	4.2	1.8	1.9	2.9
Lateral hock		3.6	2.4	2.8	4.6	2.1	1.6	2.4	2.8
Dorsal perianal		2.4	3.1	2.4	2.4	5.0	3.2	2.9	3.1
Ventral perianal		3.0	4.2	3.5	3.3	2.9	3.2	3.4	3.4
Junction of periople		2.0	3.6	2.1	2.3	4.2	2.2	2.2	2.7
Lower jaw		1.8	1.8	2.2	1.8	3.1	2.6	2.1	2.2
Ventral surface tail		2.9	3.2	2.8	3.4	2.6	3.6	4.8	3.3
	AVERAGE	2.9	3.2	2.6	2.9	2.9	2.5	3.1	

Key: E=ewe, R=ram, W=wether, A-G=animal designation.

TABLE 6. Average measurements in millimeters of total skin thickness of special areas

AREAS / ANIMAL AGE (yrs)	EA 1	EB 1	EE 1	EF 1	RC 3	RD 1½	WG 1	AVERAGE
Lower lip	3.7	3.6	2.0	3.2	3.5	1.8	1.8	2.8
Muzzle and upper lip	1.8	2.9	2.2	1.6	2.2	1.5	3.0	2.2
Base of ear	1.6	3.0	2.4	2.2	2.0	2.6	3.9	2.5
Top of ear	.9	1.0	.8	.5	3.0	1.1	1.1	1.2
Infraorbital pouch	3.6	1.9	2.1	2.5	4.0	3.1	3.1	2.9
Cross section of teat/penis	2.8	3.4	2.8	3.9	3.2	2.5	2.6	3.2/2.8
Eyelid, upper	4.3	1.5	1.5	1.8	3.0	1.2	1.6	2.1
Eyelid, lower	3.3	1.4	.26	2.5	2.2	2.1	3.3	2.5
Interdigital region	2.0	1.6	3.0	1.7	4.3	2.8	1.7	2.4
Skin of inguinal folds	1.1	2.0	1.3	1.1	1.4	1.9	1.6	1.5

Key: E=ewe, R=ram, W=wether, A-G=animal designation.

RESULTS AND DISCUSSION

SKIN THICKNESS

A comparison of the skin thickness of various breeds of sheep yields relatively accurate information as to type of wool produced. A total of thirty-five sampling sites were chosen from the skin for skin thickness measurements (Plate I). In general, the thickest skin is on the dorsal and lateral surfaces and the thinnest skin on the ventral and medial surfaces of the hide. The thickest skin is present in the forehead, dorsal neck, dorsal thorax, tailhead, lumbar region and ventral perianal areas of both male and female sheep (Table 5). Strickland (1958) found the thickest skin in the dorsal neck, lumbar, and sacral regions of the cat. Goldsberry and Calhoun (1959) reported the skin of Hereford and Angus cattle thickest in the head, neck and brisket. The skin of the top of the pinna and of the inguinal folds in both sexes (Table 6) are the thinnest. There was no apparent difference in average total skin thickness of all areas when the ram (2.6 mm), ewe (2.6 mm) and wether (2.7 mm) were compared. The average skin thickness of the general body areas of the adult sheep was 2.7 mm. From the previous work done on swine (Marcarian, 1962), cattle (Goldsberry and Calhoun, 1959) and goat (Sar, 1963) it would appear that the skin of sheep is thicker than the skin of swine (2.2 mm), considerably thinner than that of cattle (6 mm) and slightly thinner than the skin of the goat (2.9 mm).

The thickest epidermis is found in the dorsal and ventral perianal

region and forehead (Table 2). The thinnest epidermis occurs at the lateral surfaces of the abdominal, cervical and hock regions (Table 2). The average total epidermal thickness varies from 27 microns in a Shropshire ewe to 42 microns in a Merino ram. The maximum epidermal thickness encountered was 390 microns in the muzzle.

The thickest dermal areas are present in the dorsal thoracic, ventral perianal, and ventral surface of tail (Table 3). The thinnest dermal regions were found in the udder, scrotum, axilla, lower jaw and skin of inguinal folds (Table 3). The thickness of the dermal region corresponds closely to total skin thickness. The thickness of the epidermis varies considerably and thick epidermis is not always associated with thick skin regions. Dermal thickness exhibited a gradient density pattern as ventral and medial aspects of the animal were approached (Table 4).

EPIDERMIS

The epidermis of the sheep includes four distinct layers, stratum corneum, stratum granulosum, stratum spinosum and stratum basale. The stratum lucidum is indistinct in some areas of the muzzle while in others it appears more evident (Plate XXVII).

Stratum Corneum: The stratum corneum is present in all regions of the animal studied. The hoof, muzzle, lip and interdigital areas has a prominent stratum corneum (Plates II, V, XXIII, XXIV, XXVII). The stratified squamous epithelium of the infraorbital pouch is typical of that related to special glandular regions of the sheep, in

that it shows a more prominent stratum corneum (Plate XVIII). Nuclear fragments are at times visible but the stratum corneum is largely devoid of nuclei. The entire layer appears homogenous and structural detail such as cellular membranes cannot be clearly defined (Plate II). Large amounts of keratin are found near the orifice of the teat (Plate XXI).

Stratum Lucidum: Webb and Calhoun (1954) found a definite stratum lucidum in the planum nasale of the dog as did Strickland (1958) in the planum nasale of the cat. In sheep, only areas of the muzzle and lip shows the typical translucent, acidophilic layer characteristic of the stratum lucidum. This layer like the stratum corneum is anucleate and homogenous.

Stratum Granulosum: The stratum granulosum layer is the most noticeable layer of the epidermis due to the high amount of darkly staining keratohyaline granules. This layer is even more prominent in the regions of thick epidermis such as the hoof, muzzle and lip (Plate II, XXIII, XXVII). The cells are arranged in layers that seem to be separate from one another and are fusiform in shape. The cells appear to approach the degenerate state as chromatolysis, karyolysis and indistinct cell boundaries become more evident.

Stratum Spinosum: This layer of polyhedral cells has prominent 'intercellular bridges' which give rise to the descriptive term, spiny cell layer. The 'intercellular bridges' or desmosomes are strikingly prominent in the muzzle and lip region. The cells of the stratum

spinosum and stratum germanitivum are similar in that the long axis of these cells lie parallel to the skin surface. This layer constitutes a large bulk of the epidermis.

Stratum Basale: The stratum basale rests upon the dermis and the long axes of its cell are perpendicular to the basement membrane. In the pigmented regions of the body, as of the muzzle and perianal area, these cells exhibit cytoplasmic melanin granules in both stained and unstained sections. Some of the cells of the stratum basale have numerous cytoplasmic processes and contain large amounts of melanin which are distinguished by its affinity for gold chloride (Plate XXIX). These dendritic processes extend into the dermoepidermal junction and between other cells of the stratum basale. A few of these cells show mitotic activity.

DERMIS

The dermis or corium lies directly beneath the basement membrane of the epidermis and gives support to the ancillary structures of the skin. The dermis contains two layers, the superficial papillary layer and the deeper reticular layer. These two layers blend indistinctly with each other (Plate V, VI). The dermis consists of dense areolar connective tissue.

Papillary Layer: The papillary layer receives the elongated epidermal pegs and contributes its own dermal papillae as a counterpart. Among areas of very thin skin such as the interdigital gland (Plate XXIV), infraorbital pouch (Plate XVIII) and inguinal folds, the

dermal papillae appear flattened and may be absent. The muzzle (Plate XXVII) and hoof area (Plate XXIII) have dermal papillae characterized by branches and are therefore termed compound papillae. The collagenous bundles of fibers are loosely arranged and course haphazardly throughout the upper portion of the dermis. The fibroblasts of the papillary layer appear more rounded and less compressed (Plate XXXII) than those of the reticular layer of the dermis. Elastic fibers are prevalent in the papillary layer of the dermis (Plate XXX). In the area of the muzzle, the skeletal muscle fibers are continuous with elastic fibers of the dermis. These elastic fibers end as flaring points of attachment to the collagenous fibers (Plate XXX). The connective tissue sheaths of the wool follicles and the sebaceous gland have many elastic fibers which interconnect with each other (Plate XXXI). The fibers themselves are fine and branched frequently. In the dermoepidermal junction the elastic fibers traverse the basement membrane of the stratified squamous epithelium. They also form a network in the papillary layer of the dermis (Plate XXXII). The elastic fibers are less numerous in the deeper parts of the dermis and extend as fine filaments into subcutaneous tissue.

Mast Cells

The May-Grünwald-Giemsa stain indicates that groups of mast cells are located between wool follicle groups (Plate XII). These cells are scattered in few places as discrete members of the cellular population of the dermis. Many of the mast cells occur in "nests" proximal to wool follicles, capillaries, sweat glands, sebaceous glands and arrector

pili muscles. The scrotum, eyelids, infraorbital pouch, interdigital region and skin of the inguinal folds show large numbers of mast cells. Metachromasia is present in various degrees due to varying content of sulfated acid mucopolysaccharides within the cells.

Wool Follicles

The features of the wool fiber are consistent with that described in the literature. When the accessory arrector pili muscle is found, that follicle to which it is attached is termed a primary wool follicle. The secondary wool follicles do not have all of the accessory structures but can be associated with a sebaceous gland (Plate XII, XIII, XIV). The size of the wool follicles varies according to the primary or secondary nature of that follicle. The primary follicles are larger and frequently contain a medulla (Plate X). In transverse skin sections taken near the skin surface, the secondary wool follicles share a common epidermal sheath and emerge collectively to the skin surface (Plate XI). Some follicle groups contain only secondary follicles determined by size and lack of the accessory structures. Cuticular scales are prominent on the outer portion of the wool fiber and inner portions of the wool follicle (Plate IX). The cortex of the wool fiber also appears scale-like when it is viewed in oblique section (Plate VII).

Follicular Folds: Follicular folds are present in both primary and secondary wool follicles. The components of the inner epithelial root sheath (Henle's layer, Huxley's layer and the cuticle of the sheath) form ridges which point towards the direction of the skin surface (Plate IV). The inner epithelial root sheath diminishes and

finally ends beneath the opening of the sebaceous gland (Trautmann and Fiebiger, 1957). Therefore, no follicular folds are present above the level of the opening of the sebaceous glands (Plate II, III, IV). These folds appear as cytoplasmic outgrowths which form transverse corrugations possibly to maintain the sebum at superior levels of the wool follicle where it performs its most protective functions. The follicular folds form a continuous structure which is spiral in shape. A possible mechanism for the production of follicular folds is suggested from the fact that more folds are present in older than younger follicles. The cuticle of the wool fiber is known to interlock with the cuticle of the inner epithelial root sheath and therefore the two necessarily grow together. Thus, the upward migration due to the growth of the cuticle of the inner epithelial root sheath is halted by the opening of the sebaceous gland where the components of the inner epithelial root sheath collect into corrugations producing the follicular folds.

Arrector Pili Muscle: The muscle associated with the wool follicle is smooth in nature and is situated obliquely. The arrectores pilorum muscles originate in the superficial layer of the dermis, pass between lobules of the sebaceous glands and attach on the lower third of the follicle (Plate V). In agreement with the findings of Ryder (1960), no arrectores pilorum muscles are associated with the secondary wool follicles. In the scrotum, smooth muscle fibers occur which do not attach to wool follicles. The smooth muscle fibers terminate in elastic fibers near the connective tissue capsule of the hair follicle and the papillary layer of the dermis. The arrectores pilorum muscles

are especially large in dorsal and ventral perianal, dorsal cervical, and thoracic regions.

Tactile Hair

The tactile or sinus hair is similar to that of other ungulate types and is found in the muzzle and eyelid region. The tactile hair is enclosed by a blood sinus which is interposed between the inner and outer connective tissue sheath (Plate XXXVI). The outer layer of the connective tissue sheath is dense and serves as a point of attachment for skeletal muscle fibers. In transverse section the skeletal muscle fibers are closely approximated to the connective tissue sheath (Plate XXVI). Fibroelastic trabeculae are seen connecting the outer and internal layer of the connective tissue sheaths and are bathed on all sides by blood. Nerve fibers ascend in a parallel fashion in the inner layer of the connective tissue sheath (Plate XXVII). Some of the tactile hairs have small sebaceous glands connected to them but arrector pili muscle fibers and sweat glands are absent (Plate XXVII).

Sebaceous Glands

In sheep the sebaceous glands are associated with the upper one-third of the wool follicle where the duct of the sebaceous gland traverses the outer epithelial sheath of the follicle (Plate IV). The duct of the sebaceous gland, in some instances extends a relatively long distance while in others, the sebaceous gland closely approximates the hair follicle. The glandular epithelium is lobulated and separated by connective tissue trabeculae. The trabeculae are more numerous in the multilobulated sebaceous gland characteristic of the dorsal perianal

region (Plate VI). The sebaceous gland of the dorsal perianal region is associated with a wool follicle which upon oblique sectioning reveals large ductal areas. The largest of the ducts receives openings of other sebaceous gland ducts which in turn are continuous with the gland alveolus (Plate VI). In cross sections of skin, sebaceous gland lobules are associated with the primary and secondary wool follicles in various numbers (Plate XII). In cross sections taken at the level of the entrance of the sebaceous gland into the wool follicle the ducts of the sebaceous gland possesses a portion of stratified squamous epithelium which is continuous with the individual lobules (Plate XIII). The stratified squamous epithelium arises from the outer epithelial root sheath of the wool follicle. The cells of the outermost layer of the ductal epithelium remain flat and encircle the mass of glandular cells which are polygonal shaped. The thin layer of basal cells rest upon a basement membrane which is embryologically derived from the wool follicle (Plate XIII-6). The central cells of the sebaceous gland nearest the duct appear to be in a state of degeneration with vacuolated cytoplasm and nuclear fragments. The nuclei of these cells stain lightly and possess varying numbers of nucleoli.

The tarsal glands of the upper and lower eyelids are not associated with a wool follicle but their ducts open directly on palpebral conjunctival epithelium (Plate XVI). The main duct of the tarsal gland is joined by other lesser ducts from the many lobules which serve to collect the sebum before secretion occurs at the margin of the lid. The large tarsal glands have a connective tissue capsule with fibers which circularly encapsulate the gland. Collagenous fibers also

separate the glandular epithelium into numerous lobules. A detailed study of the eye adnexa of sheep has been presented by Sinha (1965).

The infraorbital pouch consists of a mixture of saccular sweat glands and a large number of multilobulated sebaceous glands (Plate XVIII).

Sweat Glands

Sweat glands are distributed throughout the skin areas investigated. There is a wide variance in size and number according to specific skin areas. Large coiled glands are found mainly in the regions of the scrotum, interdigital pouch, infraorbital pouch and prepuce (Plates XV, XIX, XX, XXII and XXIV). The sweat glands are most numerous in the region of the interdigital gland (Plate XIX and XXIV) where the columnar cells have apical projections which extend into the lumen of the gland (Plate XIX). In some sections the lumina of the apocrine sweat glands have secretory material which appears to be the pinched off cytoplasmic cellular projections of the columnar cells. In the region of the infraorbital pouch the sweat glands are large and saccular with cuboidal epithelium (Plate XVIII). The sweat glands of the other body regions are located deep in the corium below the levels of the sebaceous gland and the major portion of the wool follicle (Plate III). At times the sweat gland traverses a course parallel and in close proximity to the wool follicle (Plate VIII). The excretory duct of the sweat gland opens into the neck of the hair follicle above the opening of the sebaceous gland.

Myoepithelial or myoid cells are interposed between the basement

membrane and the cells lining the lumen of the sweat gland. The apocrine cells of the interdigital region are especially prominent due to a heavy layer of these cells (Plate XX). The myoepithelial cells are longitudinally oriented with respect to the sweat gland so that in cross section of a sweat gland these modified muscle cells are cut transversely.

In the region of the prepuce the sweat glands are arranged in long columns (Plate XXII). These glands are highly coiled and arise deep within the dermis. The sweat gland of this area are relatively small in size but numerous.

SPECIAL BODY AREAS

Planum Nasale: Five layers of epidermis are present in the anterior portions of the planum nasale (Plate XXVII). Mitotic figures and cells which are highly pigmented are found in the stratum basale (Plate XXIX). There are compound dermal papillae in this region which extend proximal to the stratum corneum (Plate XXVII). Bands of skeletal muscle fibers extend into the dermal papillae which end in elastic fibers that continue to course proximal to the dermoepidermal junction (Plate XXX). Nasolabial glands appear serous in nature but are poorly represented as small groups of multilobular glands.

The dermal papillae contain many capillaries which divide frequently to project smaller branches of vessels near the epidermis. The division of these vessels occurs mainly at the base of an epidermal peg so that one vessel gives rise to smaller vessels that separate from one another and enter different papillae (Plate XXV).

Using a modified Bielschowski-Gros silver stain many sensory nerve endings are found in the skin sections of the planum nasale and lip. In the dermis of the planum nasale a nerve process with a terminal bulb and a branching collateral fiber is found (Plate XXXIII). The connective tissue of the dermis seems to outline the lateral margins of the end bulb but does not appear to be an enveloping layer (Plate XXIV). Near the border of the lip a complicated arrangement of nerves is seen.

Pinna: The pinna is characterized by the presence of elastic cartilage covered by the thinnest skin found in all body regions (Table 2). Wool follicles are denser on the convex side of the ear in comparison to the concave side. There are also more wool follicles at the base of the ear when compared to the same amount of area at the tip of the ear. The skin is much thicker at the base of the ear than at the tip. The cartilage of the pinna contains foramina through which the dermis of one side becomes continuous with the dermis of the other side. Blood vessels are frequently found at such points. While skeletal muscle is found at the base of the ear, none was found on either side of the elastic cartilage from the mid-portion to the tip of the pinna.

Teat: The skin of the teat of sheep contains wool follicles associated with sweat and sebaceous glands. The epidermis consists of four typical layers making up the stratified squamous epithelium and has few rete pegs which are flattened. The epidermis of the teat is continuous with the lining epithelium of the teat canal (Plate XXI).

The orifice of the nonfunctioning teat is filled with large amounts of keratin (Plate XXI). Large saccular apocrine sweat glands with myoepithelial cells can be found. No smooth muscle is present in the teat except the arrector pili muscle of the wool follicle.

SUMMARY AND CONCLUSIONS

Eight adult sheep, predominantly Southdown, including 3 rams, 4 ewes, and a wether varying from one to six years of age were used in this investigation. Variations in skin thickness were determined with relation to sex, body regions and individuals of approximately the same age. The thinnest skin is in the pinna and the thickest skin is on the forehead and the dorsal and lateral aspects of the body. The skin of the sheep becomes thinner on the ventral and medial aspects thus establishing a density gradient.

The epidermis of sheep generally consists of four layers: stratum corneum, stratum granulosum, stratum spinosum and the stratum basale. The stratum lucidum occurs only in the planum nasale, lip and hoof margin. The stratum granulosum has prominent keratohyaline granules while pigment granules are present in the stratum basale. The stratum basale contains melanocytes with numerous cytoplasmic processes.

The dermis has a papillary and reticular layer which blend into each other. In areas of thin skin the rete pegs are absent or flattened making the demarcation more difficult to distinguish. The dermis contains collagenous, elastic and reticular fibers. Large numbers of mast cells are present in the dermis near blood vessels, arrectores pilorum muscles and sweat glands.

The wool follicle group in the sheep contain both primary and secondary follicles. The primary wool follicles are characterized by the presence of the sweat glands, sebaceous glands, and the arrector pili muscles. The secondary follicles are smaller and are associated

only with sebaceous glands. The smallest unit of the follicle population consists of three primaries and approximately fifteen to sixty secondary wool follicles.

The inner epithelial root sheath forms follicular folds beneath the opening of the sebaceous gland into both the primary and secondary wool follicle. It is postulated that these corrugations maintain the secretion of the sebaceous gland at a level within the follicle advantageous to the wool fiber.

The arrectores pilorum muscles are relatively large in the dorsal and ventral perianal, dorsal cervical, and thoracic regions. Smooth muscles are found in the teat and scrotum which are not associated with wool follicles. Myoepithelial cells surround the secretory cells of sweat gland tubules. Skeletal muscle fibers are conspicuous in areas of the muzzle, forehead, eyelid and perianal regions. Skeletal muscle fibers, originating from deeper structures, attach to the connective tissue capsule of the tactile hair.

Tactile hairs are present in the muzzle and eyelid regions. These have the characteristic blood sinus and conform to the typical ungulate pattern. Nerve fibers are especially prominent enveloping the connective tissue sheath of the tactile hair in a longitudinal fashion. Relatively small sebaceous glands are associated with the superior portion of the tactile hair.

Branched sebaceous glands are prominent in the special glandular region of the infraorbital pouch and perianal area. The tarsal gland consists of a large multilobulated sebaceous gland.

The sweat glands of the sheep are of the apocrine type and especially dominate the interdigital and inguinal areas. Large coiled apocrine glands are found in the skin of the scrotum, perianal region, prepuce and lateral metatarsal region.

In the planum nasale numerous nerve fibers terminate as free nerve endings in the papillary layer of the dermis or extend into the epidermis.

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PLATES

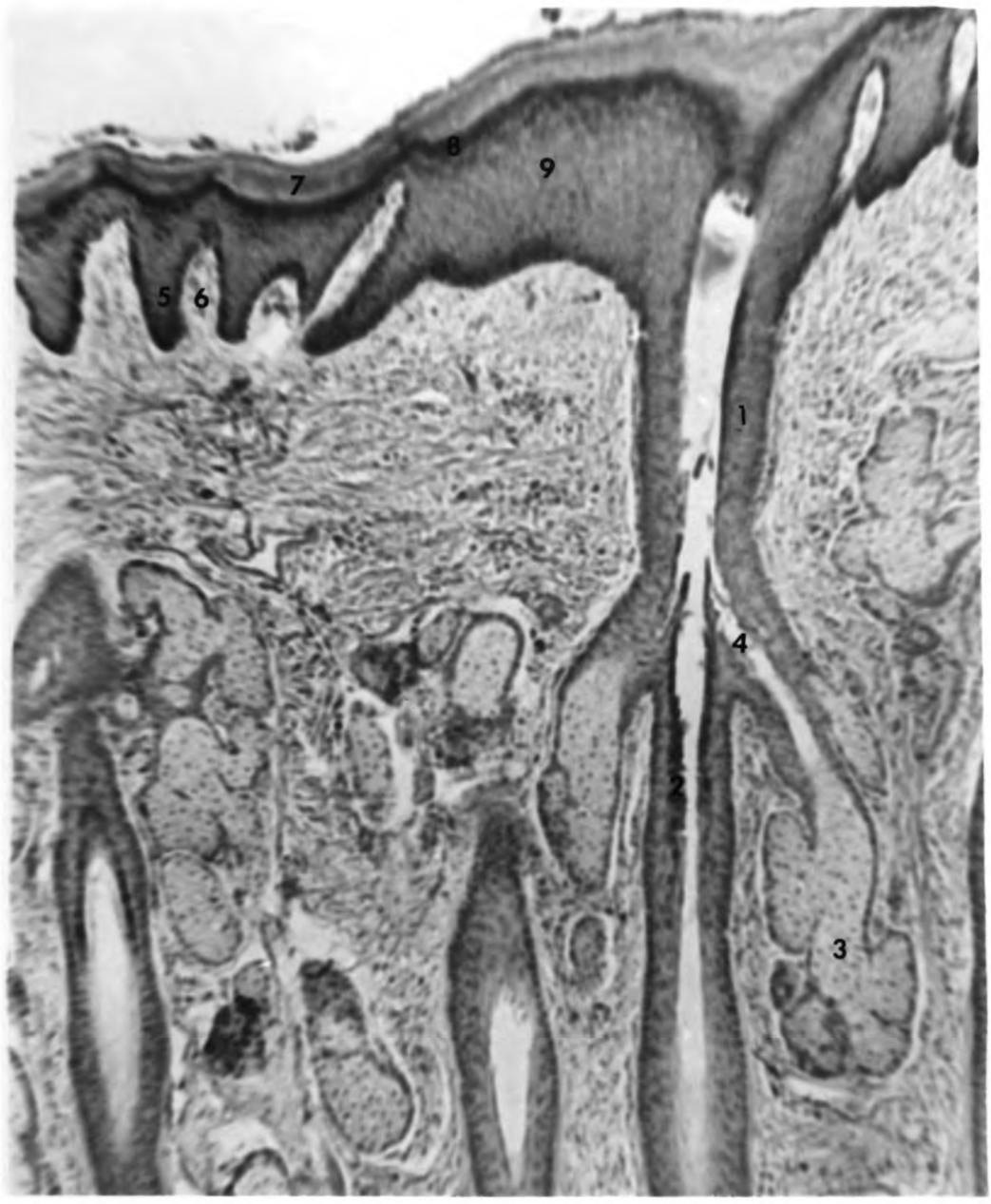

PLATE II

Vertical section of skin near lower lip. 1. wool follicle; 2. follicular folds; 3. sebaceous gland; 4. duct of sebaceous gland; 5. rete peg; 6. dermal papilla; 7. stratum corneum; 8. stratum granulosum; 9. stratum spinosum.
H. and E. stain. 96X

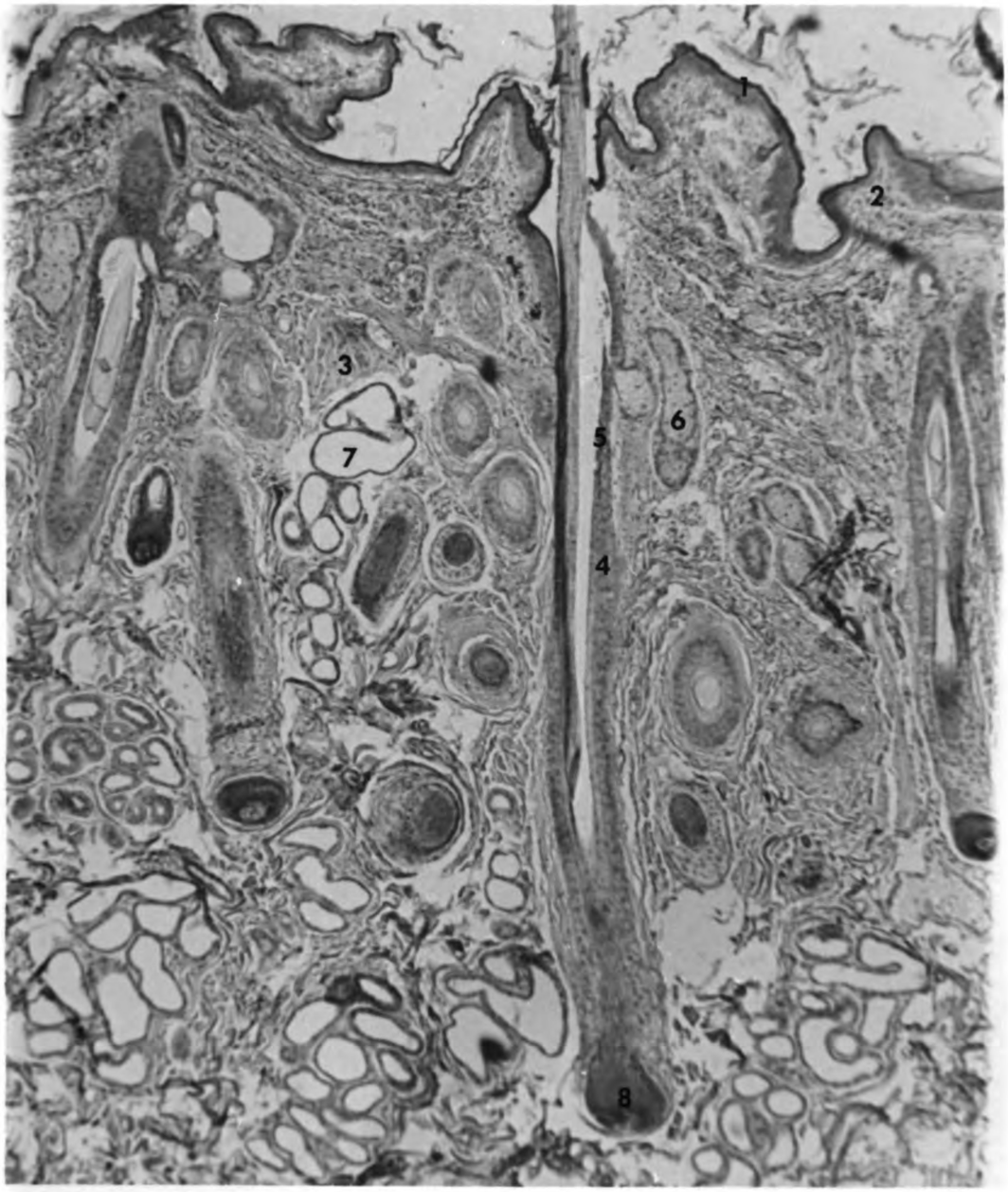

PLATE III

Vertical section of skin of pelvic limb (lateral between stifle and hock). 1. epidermis; 2. papillary layer of dermis; 3. arrector pili muscle; 4. wool follicle; 5. follicular folds; 6. sebaceous gland; 7. sweat gland; 8. wool follicle bulb. H. and E. stain. 77X

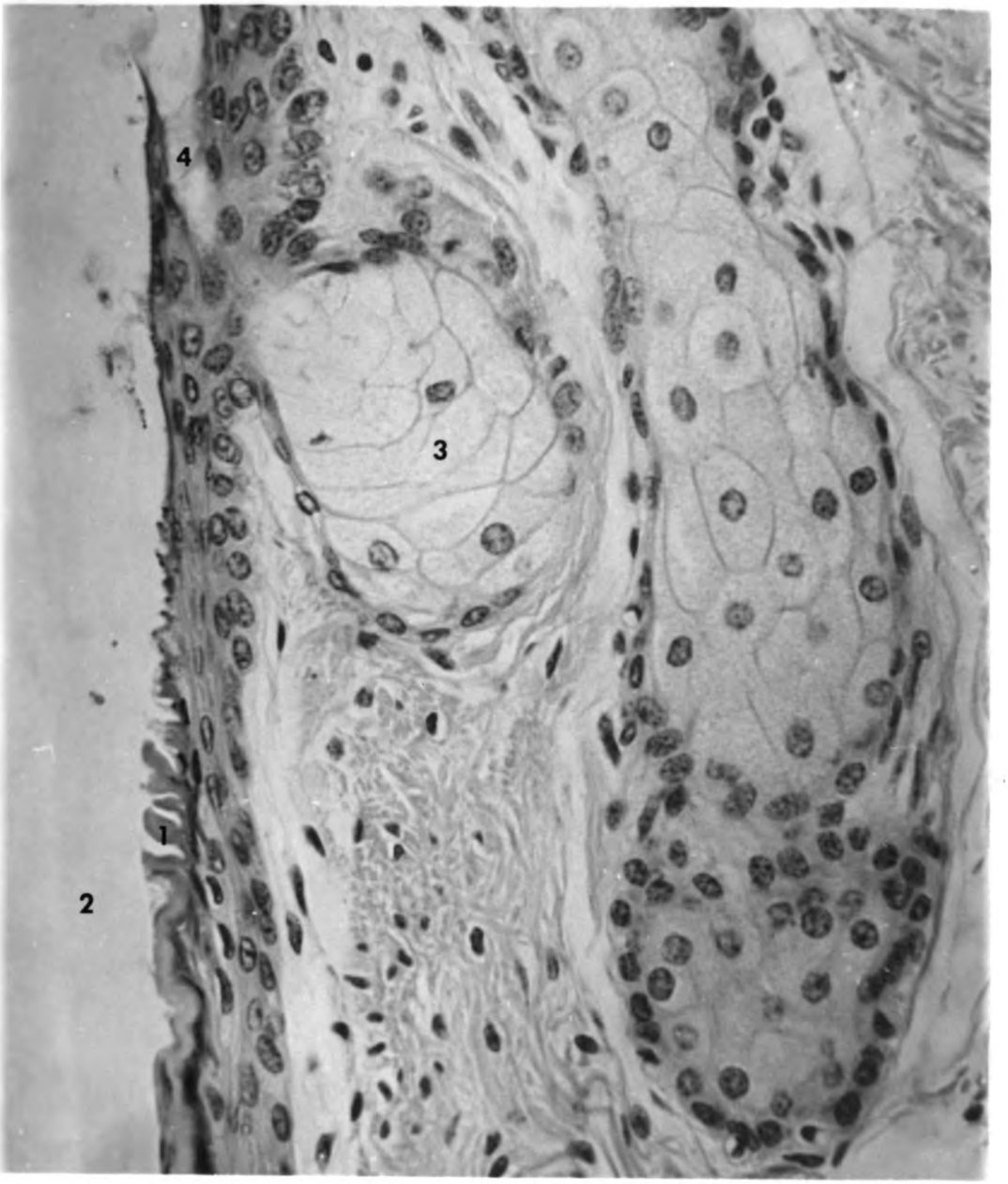

PLATE IV

Vertical section of follicular folds and sebaceous glands.
1. follicular folds; 2. lumen of wool follicle; 3. sebaceous gland; 4. opening of sebaceous gland.
H. and E. stain. 576X

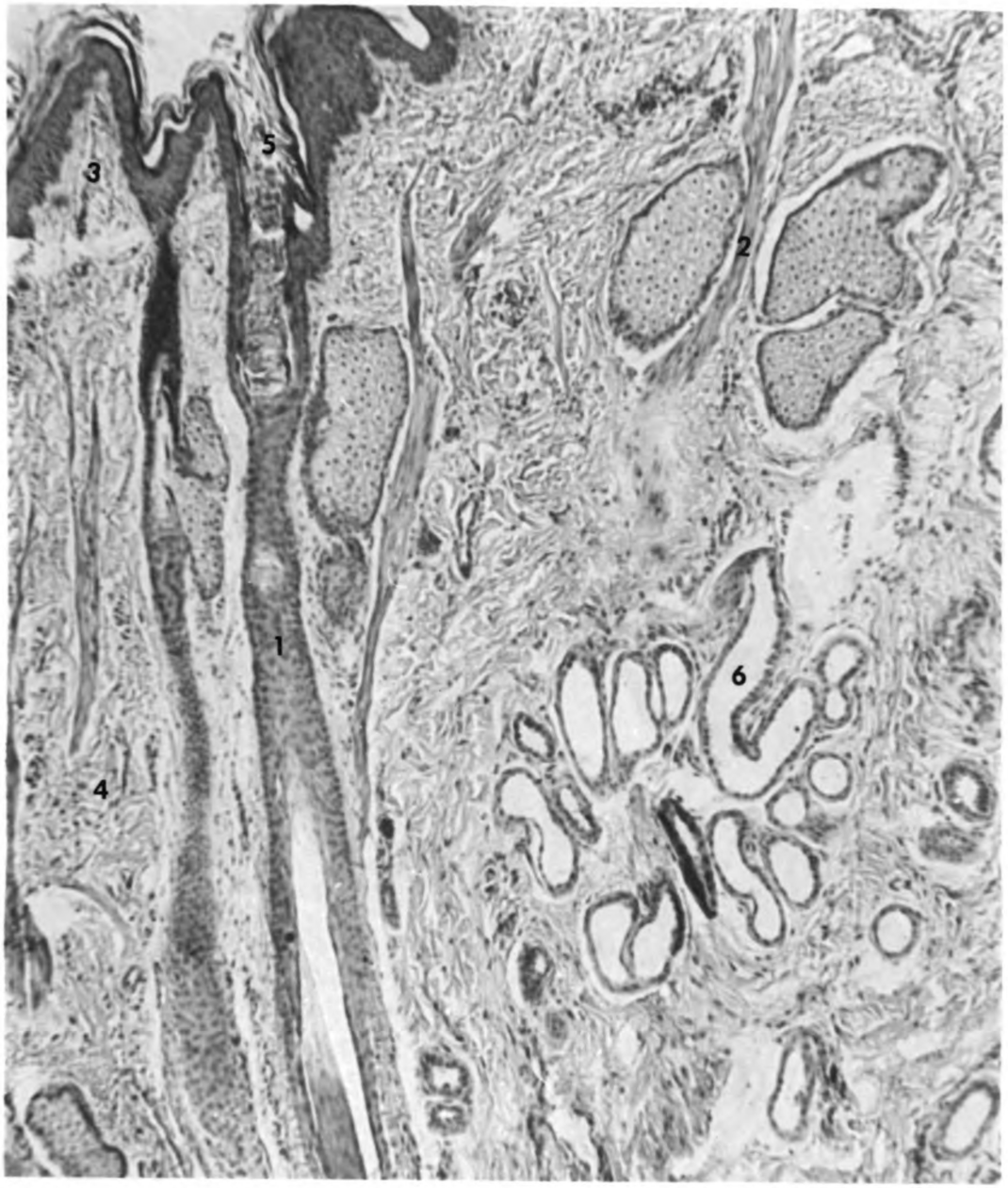

PLATE V

Vertical section of skin from interdigital region. 1. wool follicle; 2. arrector pili muscle passing between sebaceous gland lobules; 3. papillary layer of dermis; 4. reticular layer of dermis; 5. lumen of follicle with accumulation of the stratum corneum; 6. sweat gland.
H. and E. stain. 96X

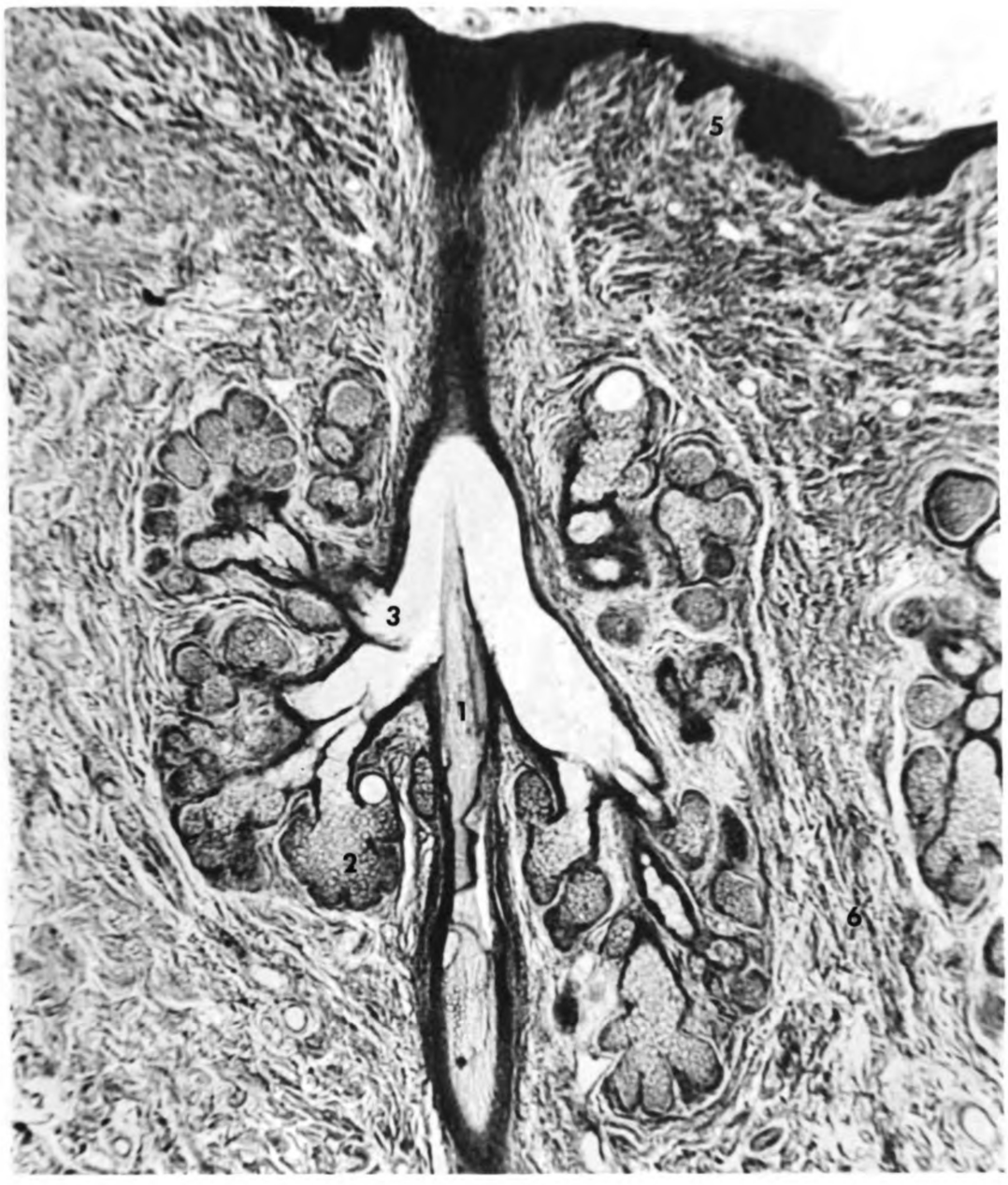

PLATE VI

Vertical section of wool follicle from dorsal perianal region. 1. wool follicle; 2. multilobulated sebaceous gland; 3. opening of sebaceous gland; 4. epidermis; 5. papillary layer of dermis; 6. reticular layer of dermis.
H. and E. stain. 352X

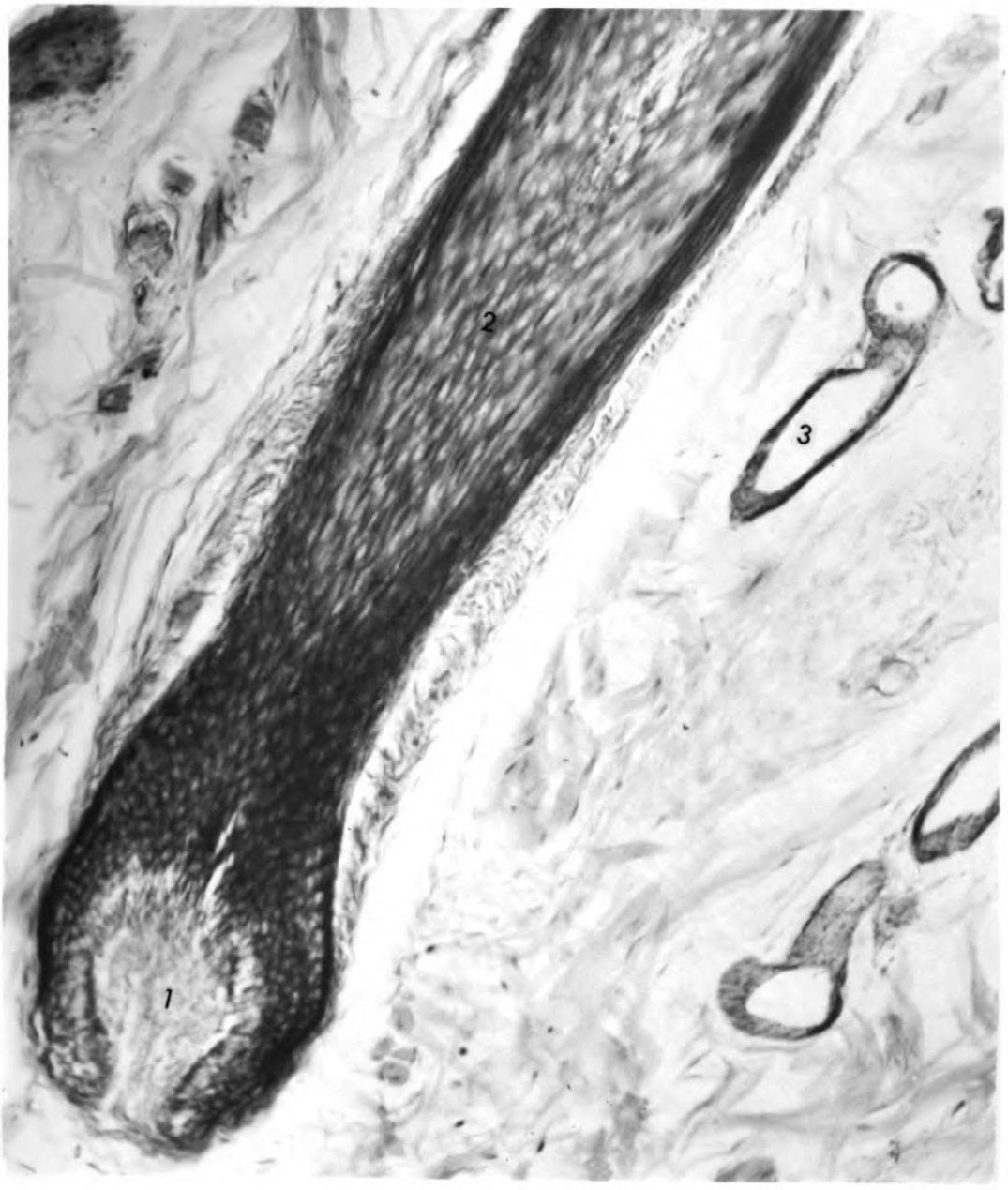

PLATE VII

Oblique section of wool follicle showing cortical scales.
1. papilla of wool bulb; 2. cortical scales pointed towards skin surface; 3. sweat gland.
May-Grünwald Giemsa stain. 210X

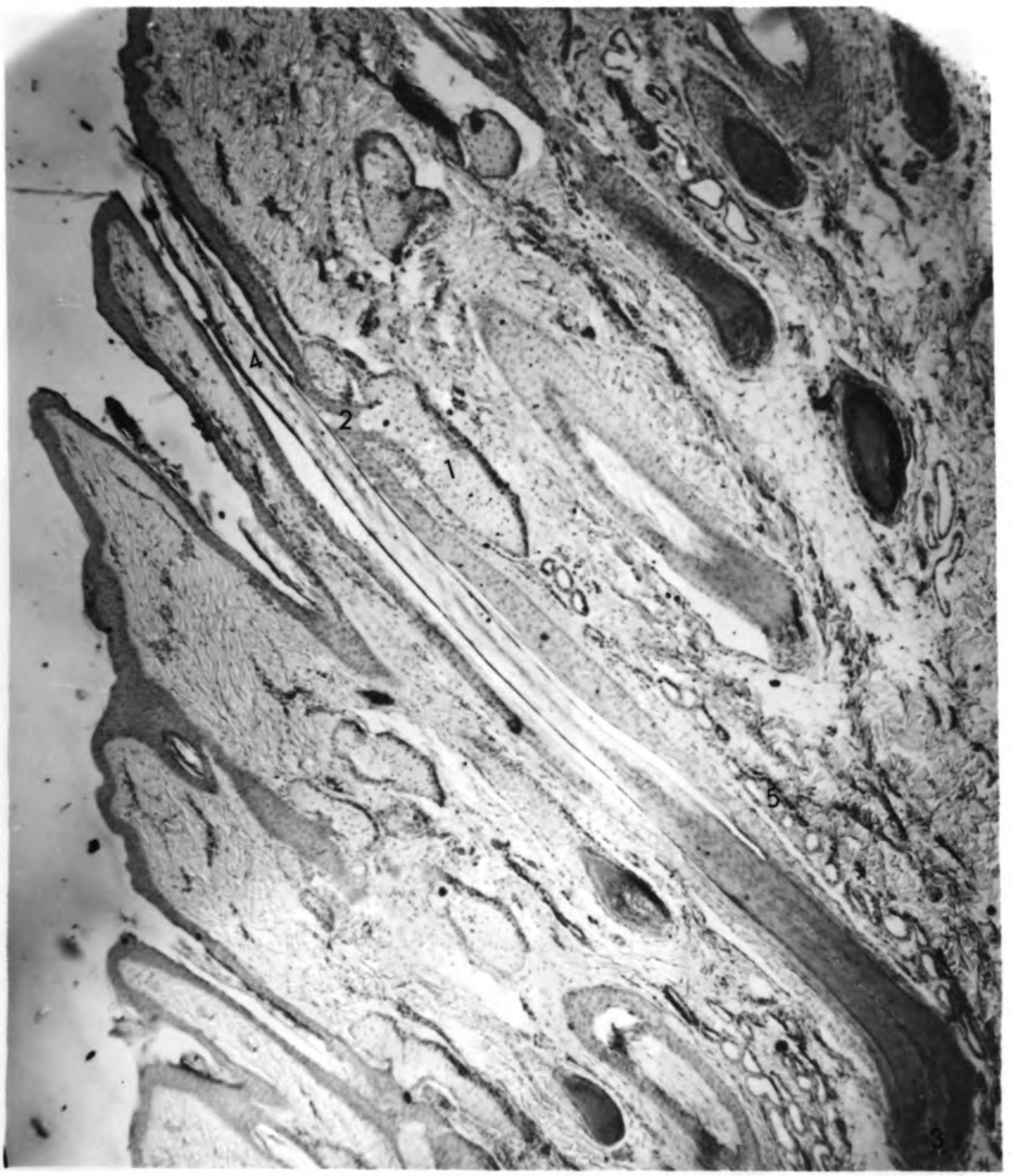

PLATE VIII

Vertical section of wool follicle. 1. sebaceous gland; 2. opening of sebaceous gland; 3. wool papilla; 4. wool fiber; 5. sweat gland.
H. and E. stain. 43X

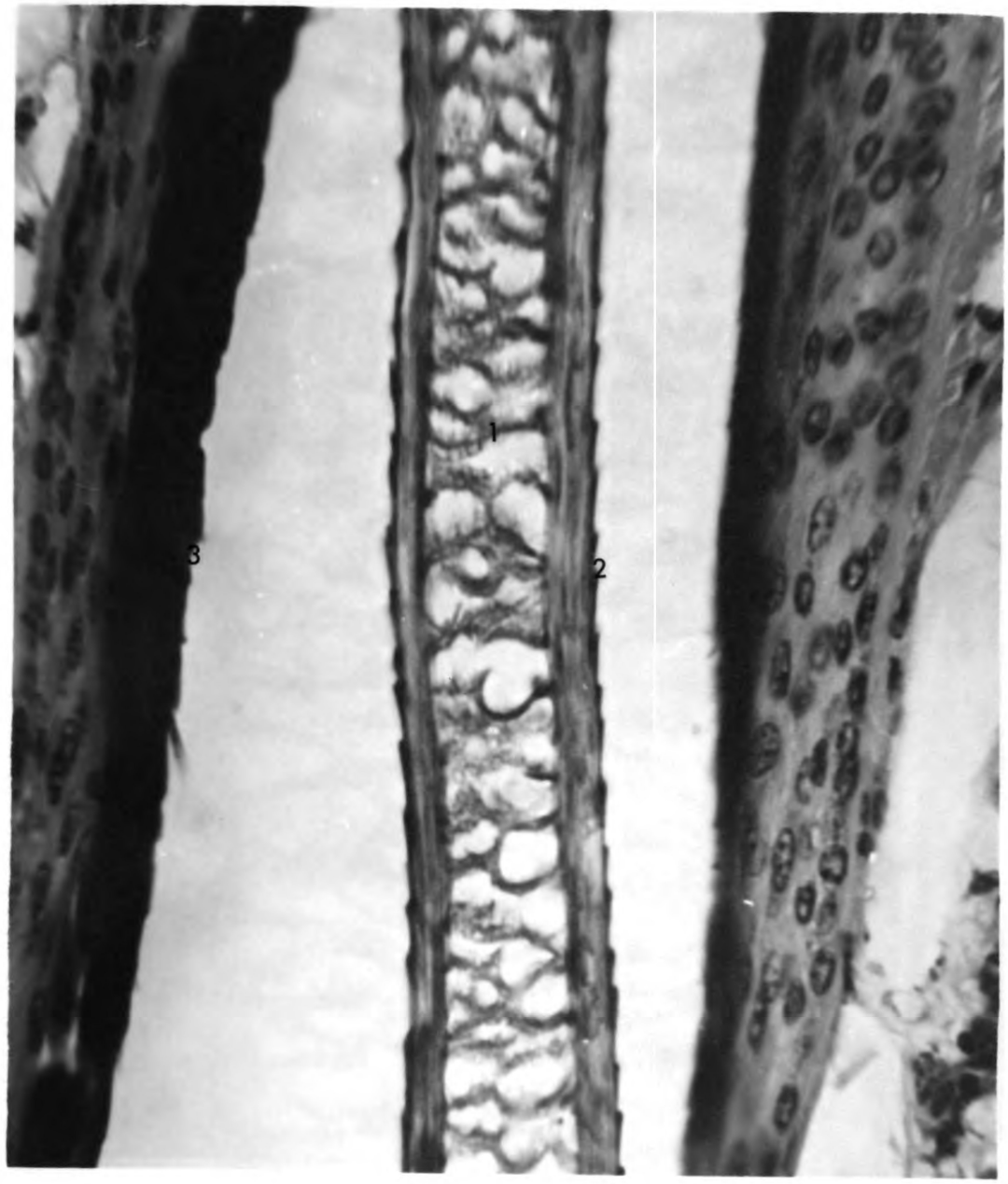

PLATE IX

Vertical section of wool follicle from infraorbital pouch. 1. lamellated structure of medulla; 2. cuticular scales of wool fiber pointed towards skin surface; 3. cuticular scales of inner epithelial root sheath pointed away from skin surface.
H. and E. stain and New Fuchsin. 576X

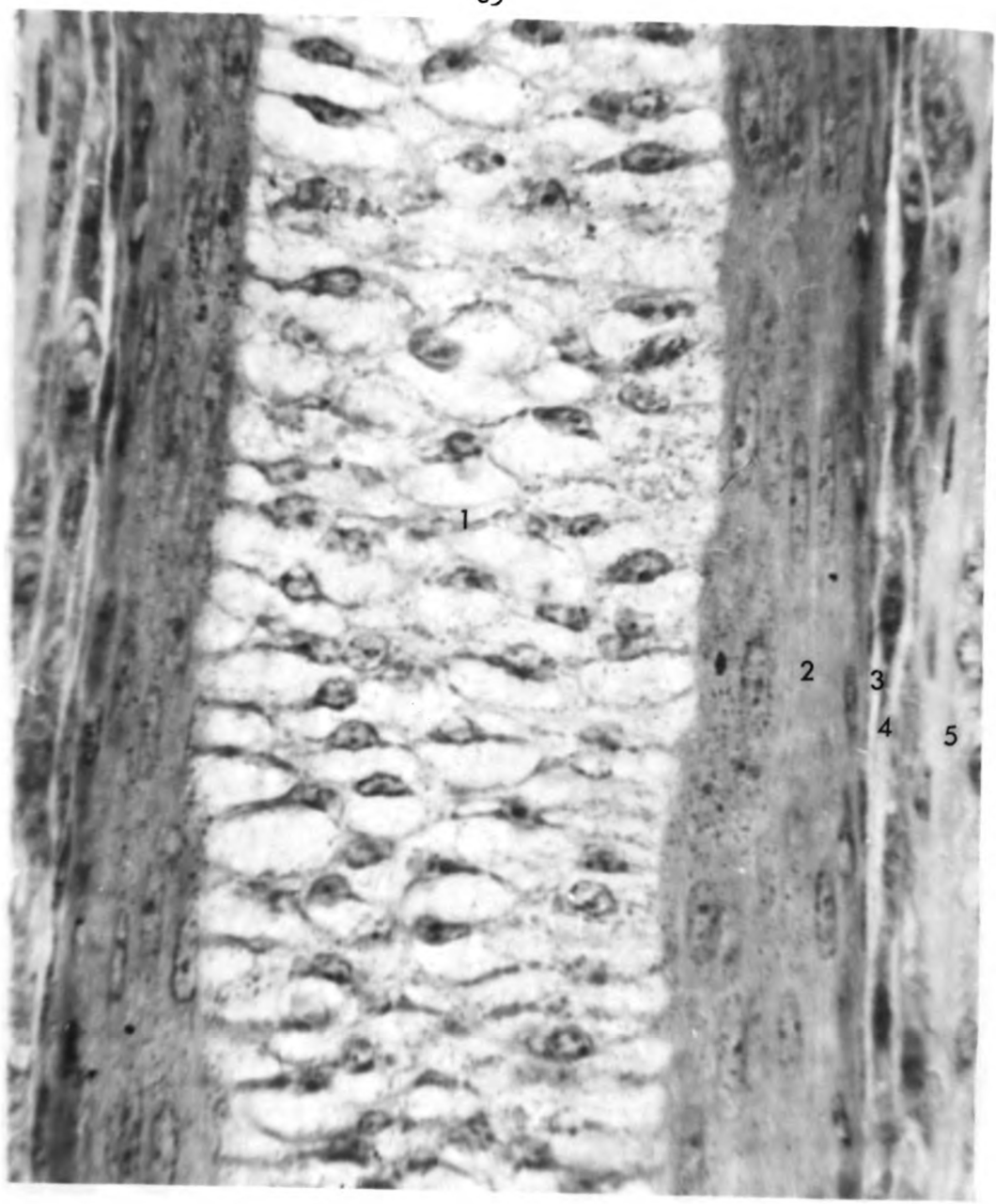

PLATE X

Vertical section of wool shaft and wool follicle structure.
1. medulla showing laminated appearance; 2. cortex of wool;
3. cuticle of wool fiber; 4. cuticle of inner root sheath;
5. Huxley's layer.
H. and E. stain. 768X

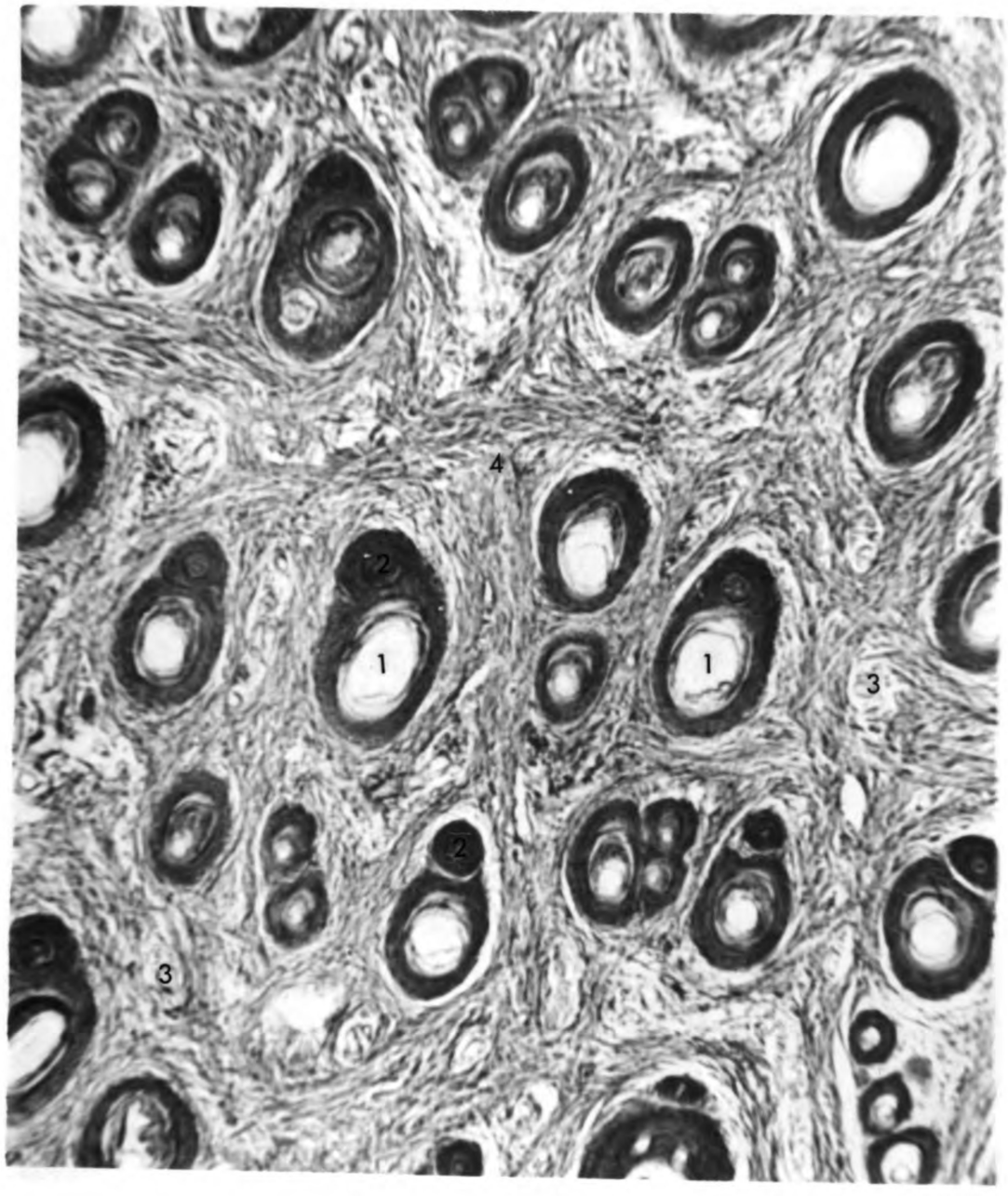

PLATE XI

Horizontal section from pelvic limb. 1. primary wool follicles; 2. secondary wool follicles; 3. capillaries; 4. collagenous fibers forming connective tissue capsule.
H. and E. stain. 104X

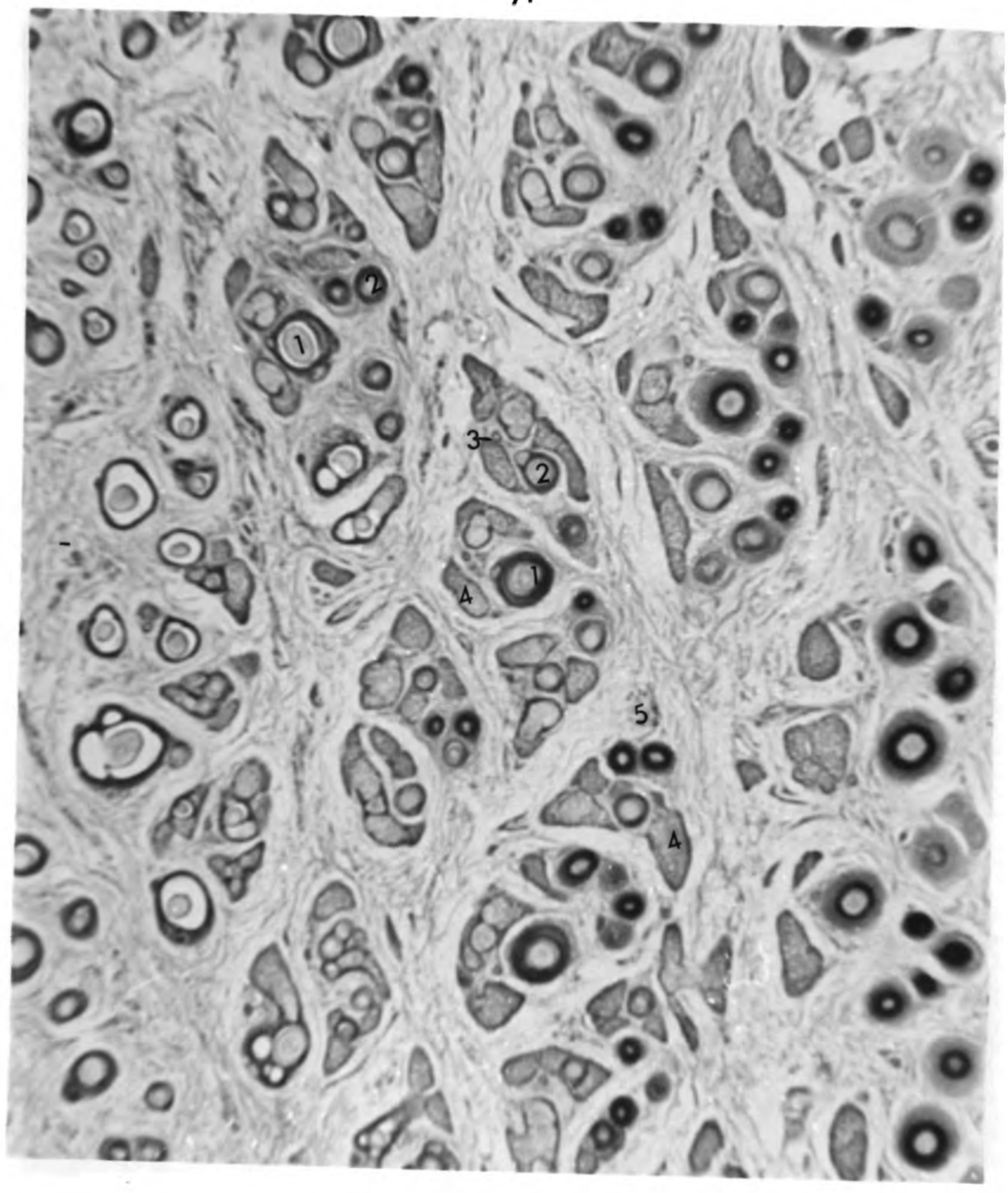

PLATE XII

Horizontal section through skin at tip of ear showing the arrangement of wool follicle groups. 1. primary wool follicle; 2. secondary wool follicle; 3. duct of sweat gland; 4. sebaceous glands; 5. mast cells. May-Grünwald Giemsa stain. 58X

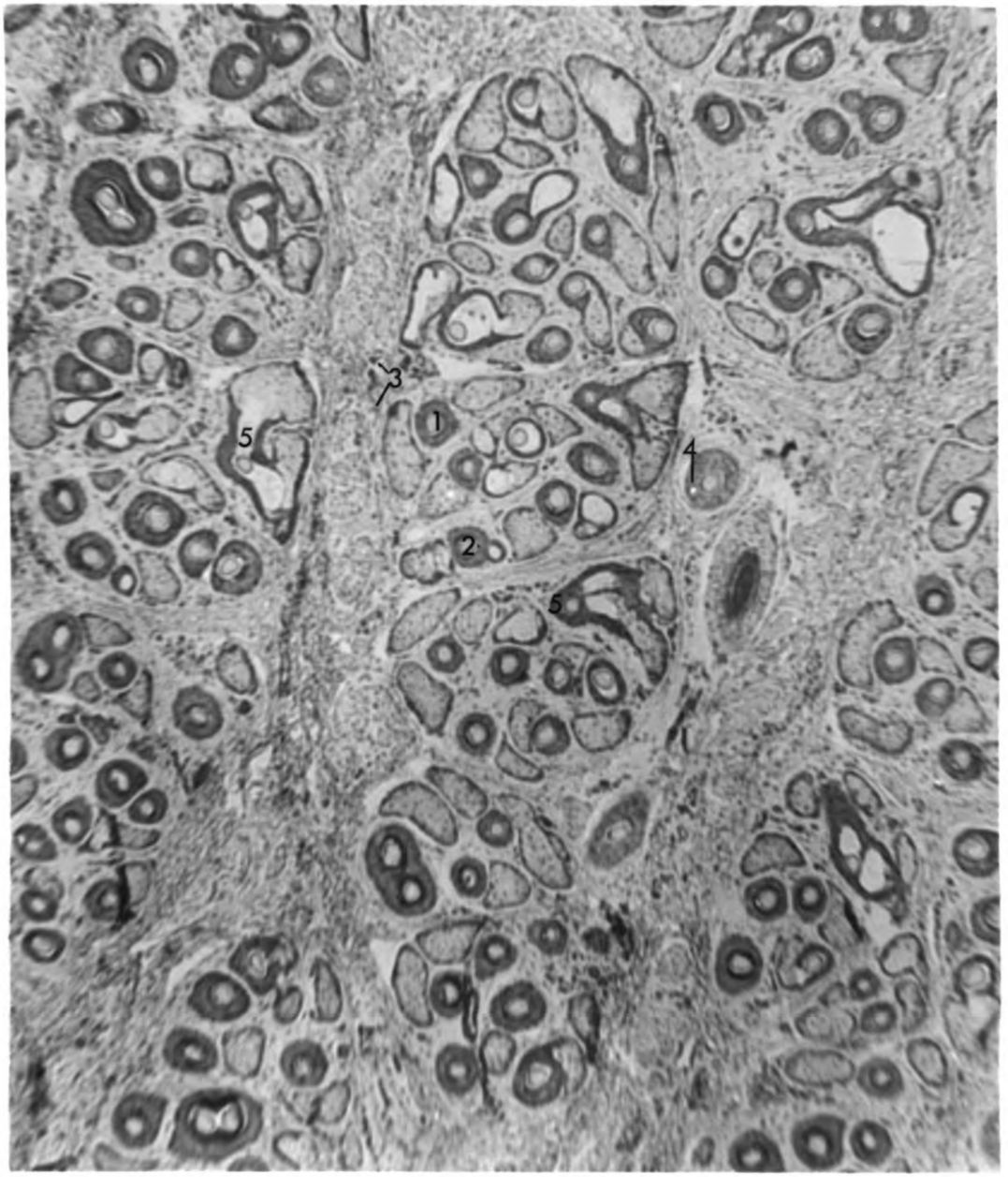

PLATE XIII

Horizontal section of wool follicle groups. 1. primary wool follicle; 2. secondary wool follicle; 3. capillaries; 4. ducts of sweat glands; 5. sebaceous gland duct relationship illustrating the presence of squamous epithelium around duct.
H. and E. stain. 62X

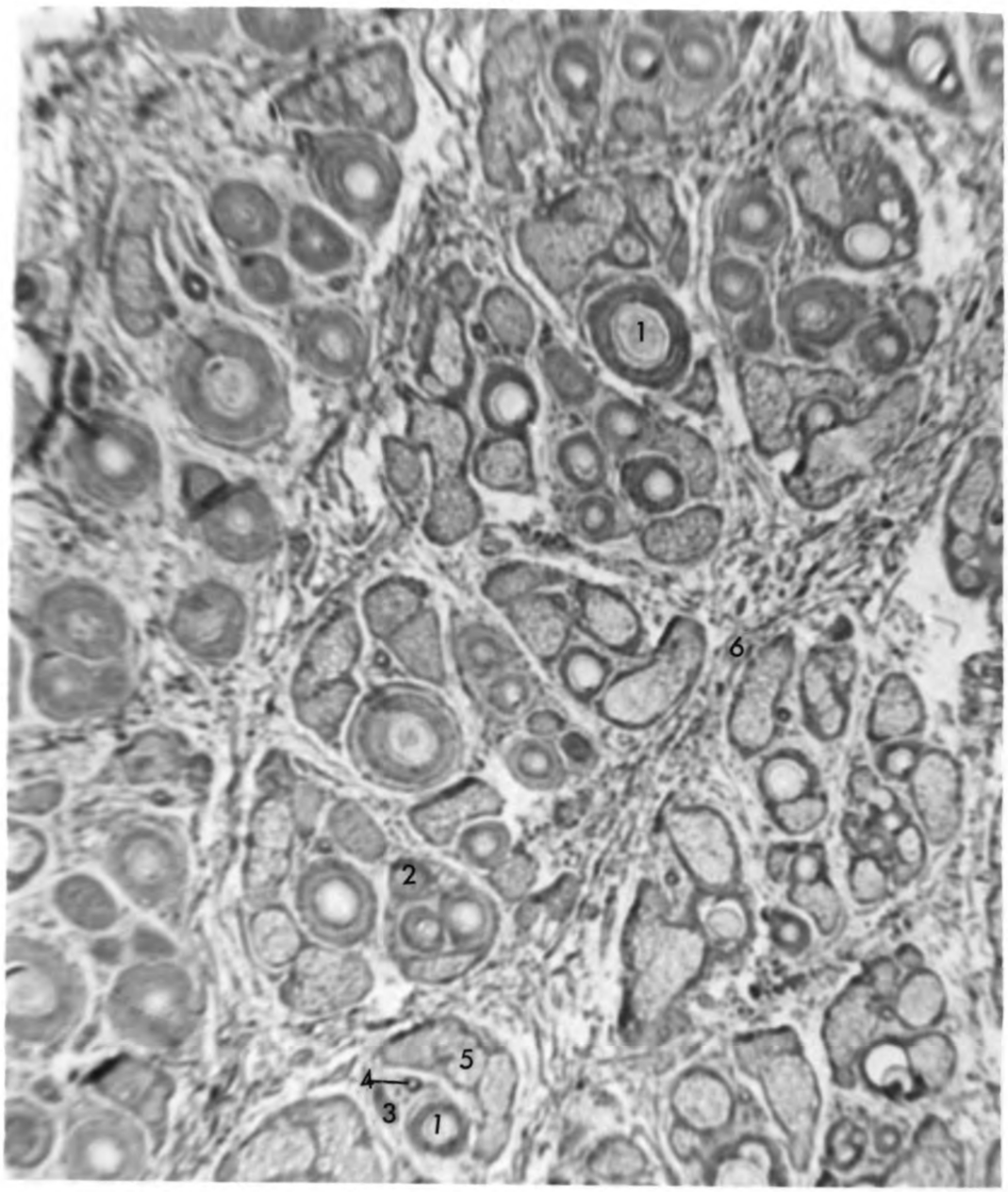

PLATE XIV

Horizontal section of wool follicle groups. 1. primary wool follicle; 2. secondary wool follicle; 3. arrector pili muscle; 4. duct of sweat gland; 5. sebaceous gland; 6. heavy collagenous fibers surrounding follicle group.
H. and E. stain. 80X

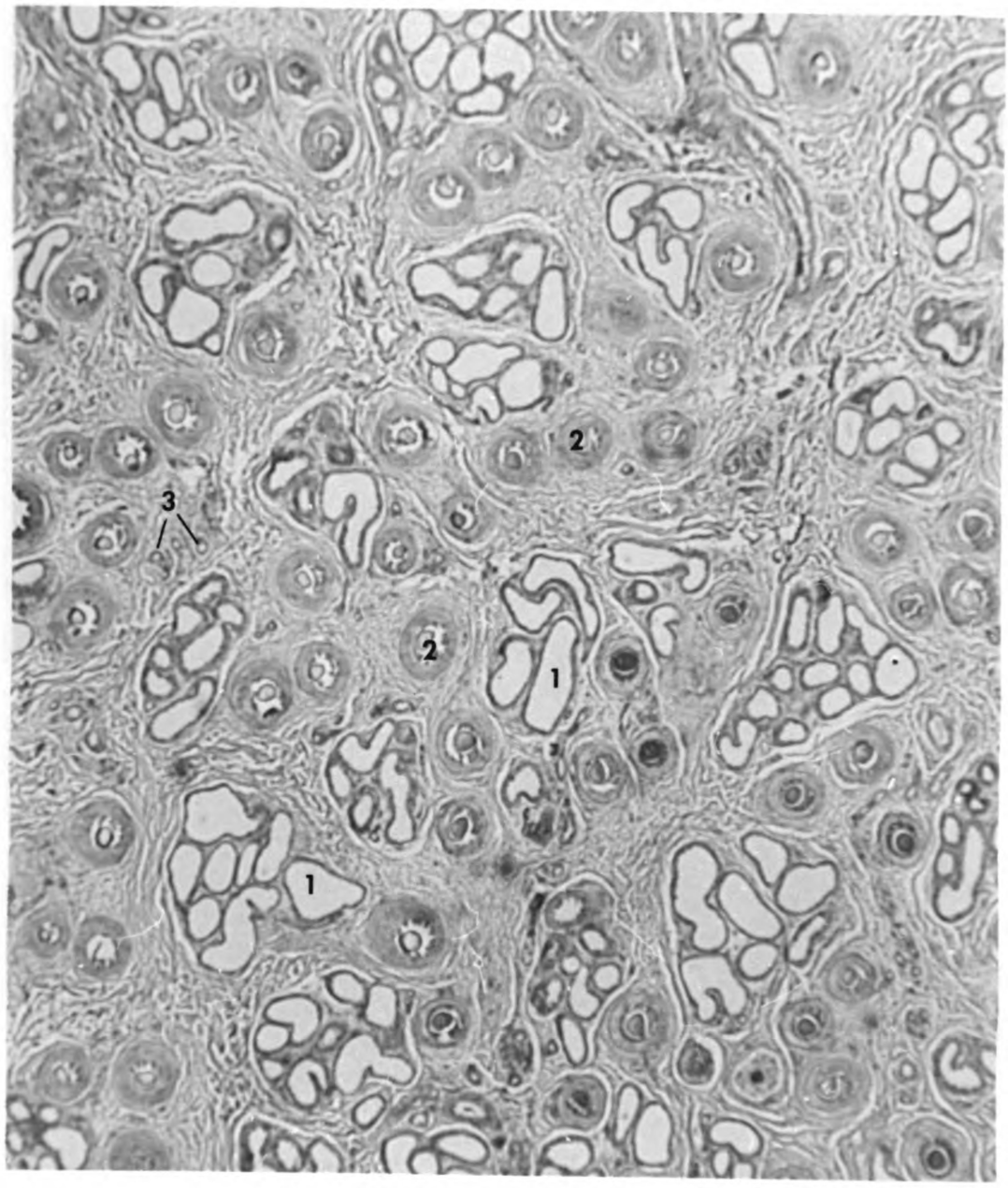

PLATE XV

Horizontal section of scrotal skin. 1. saccular sweat glands; 2. wool follicles; 3. capillaries.
H. and E. stain. 60X

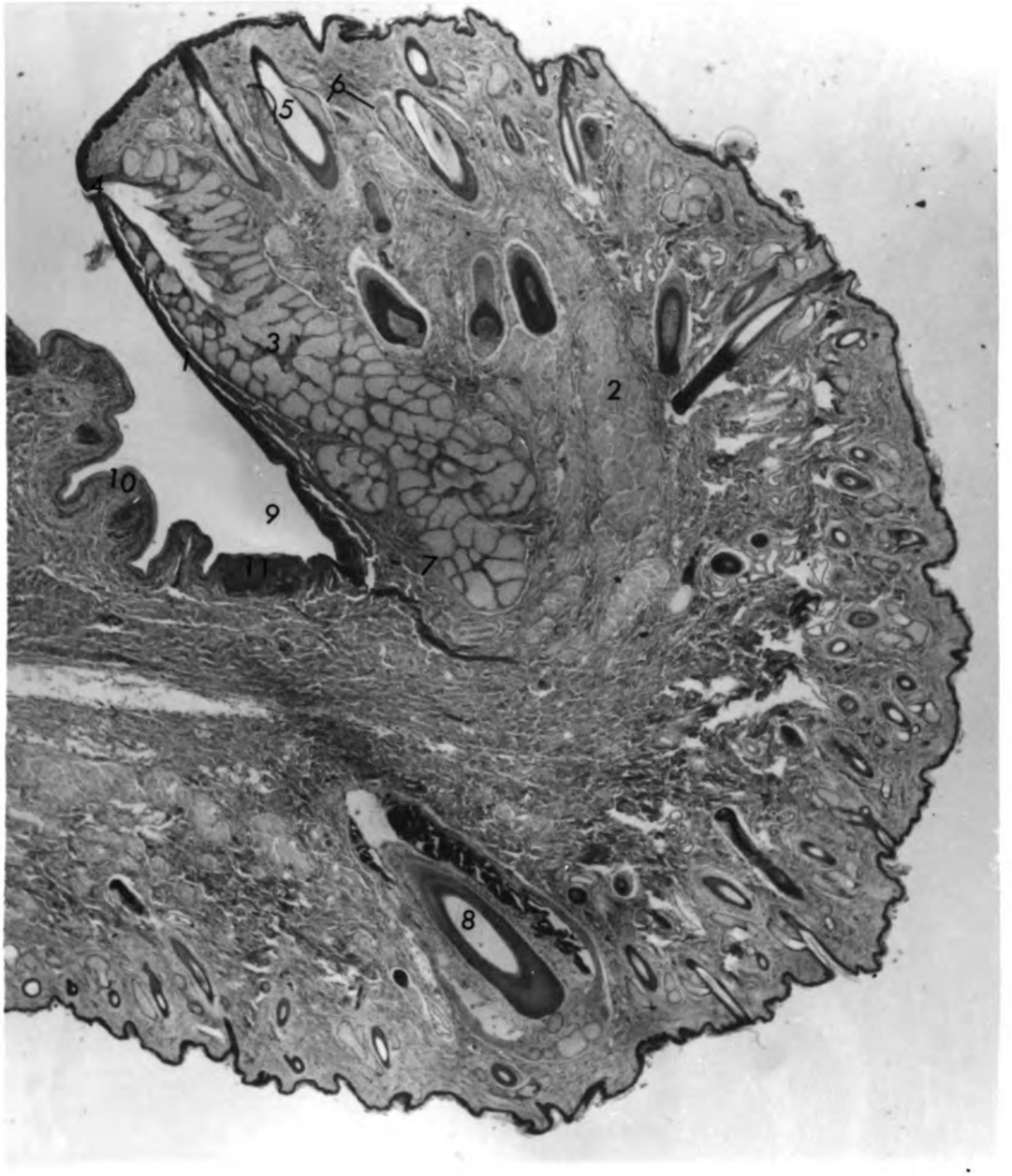

PLATE XVI

Vertical section of upper eyelid. 1. palpebral conjunctival epithelium; 2. orbicularis oris muscle; 3. tarsal (Meibomian) gland; 4. excretory duct of tarsal gland; 5. cilia; 6. sebaceous glands of cilia (Zeis); 7. connective tissue sheath encircling the tarsal gland; 8. tactile hair; 9. fornix; 10. bulbar conjunctival folds; 11. lymph nodules.
Papanicoloau stain. 17X

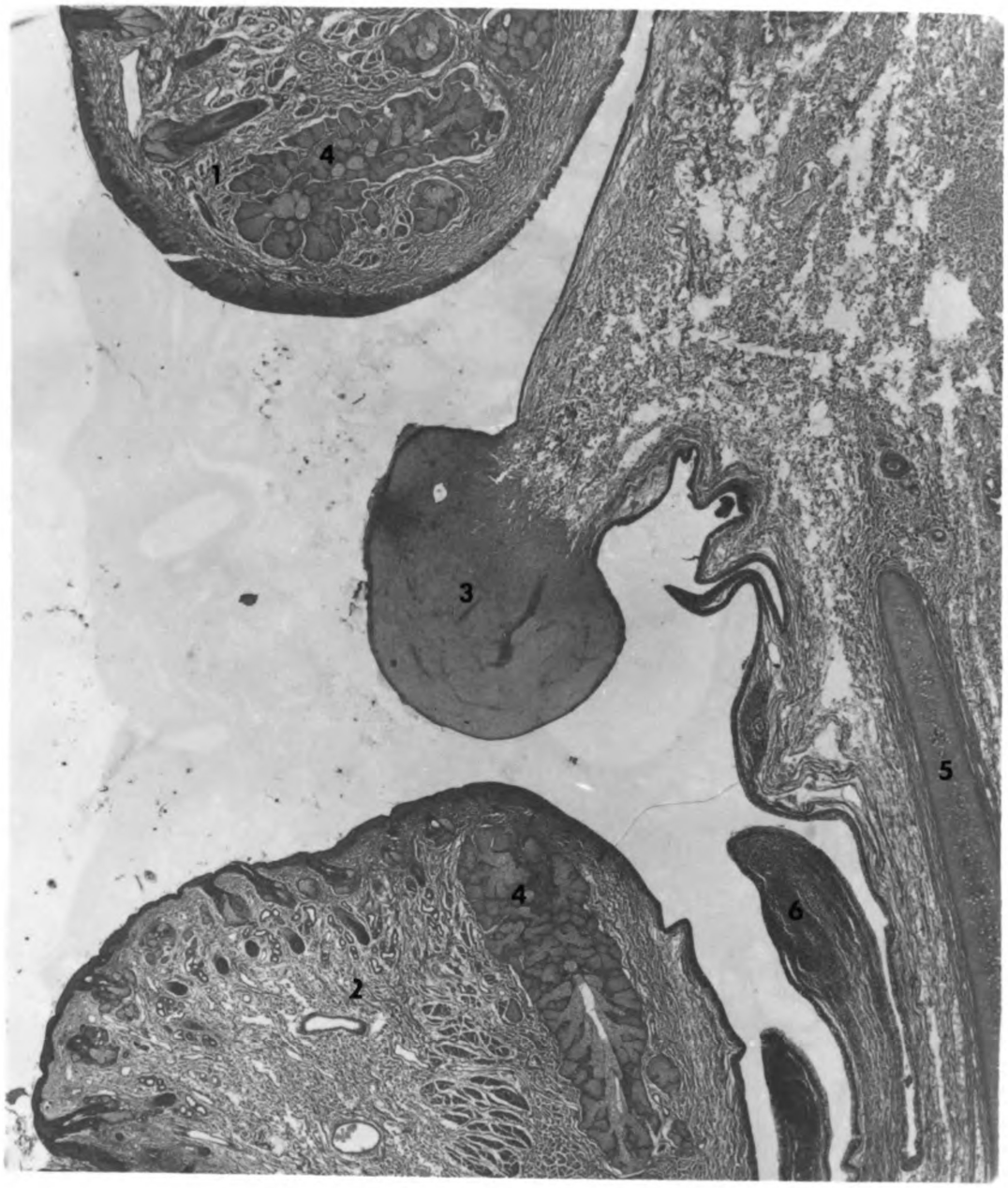

PLATE XVII

Vertical section of third eyelid. 1. upper eyelid; 2. lower eyelid; 3. third eyelid; 4. Meibomian glands; 5. nictitans hyaline cartilage; 6. lymph nodules.
H. and E. stain. 45X

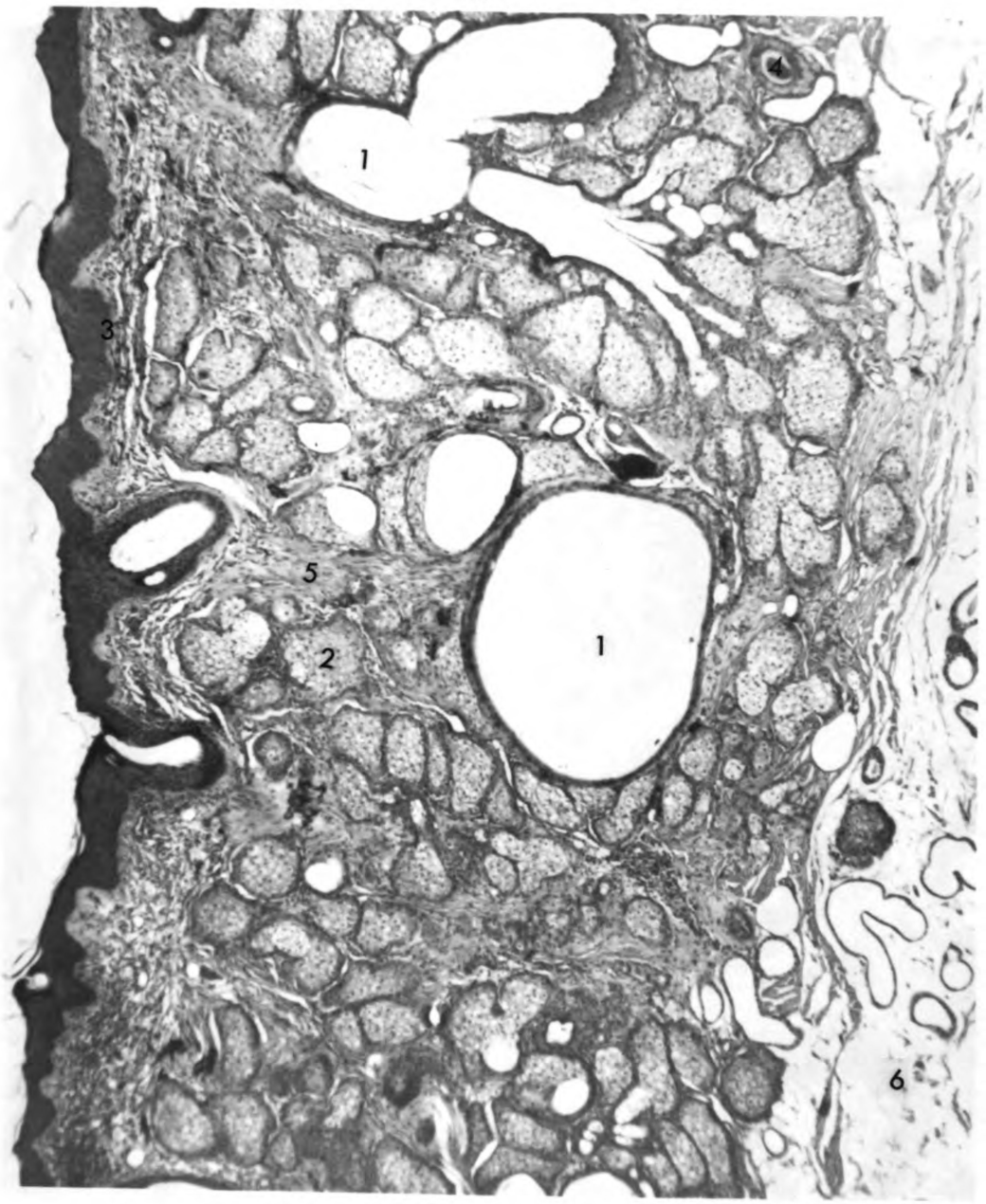

PLATE XVIII

Vertical section of infraorbital pouch gland. 1. large saccular sweat glands; 2. infraorbital (lacrimal) pouch gland of modified multilobulated sebaceous gland; 3. flattened dermal papillae; 4. wool follicle; 5. arrector pili muscle; 6. subcutaneous adipose tissue.
H. and E. stain. 58X

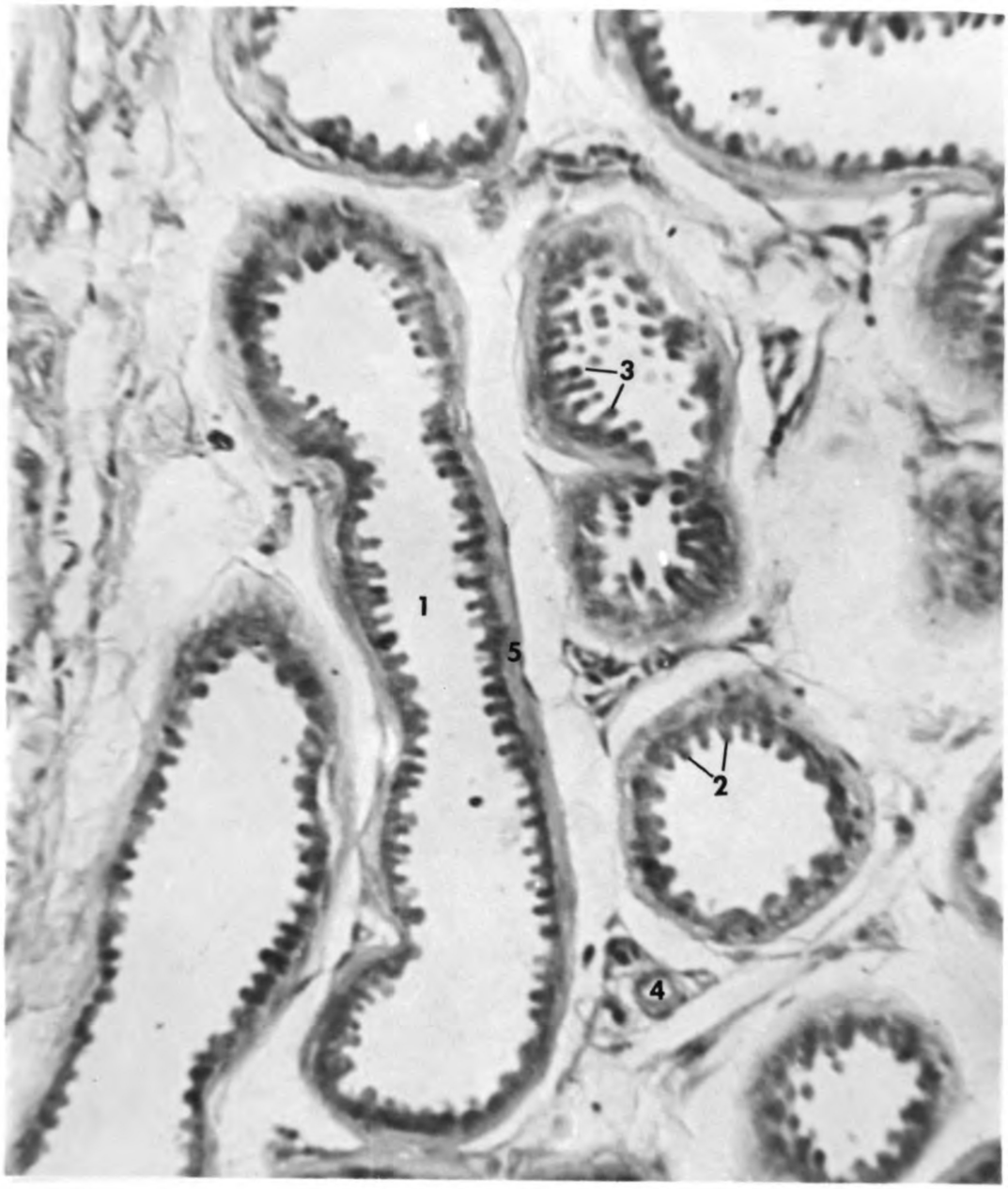

PLATE XIX

Horizontal section of active apocrine sweat gland (interdigital gland). 1. lumen of secretory portion of sweat gland; 2. active glandular cells; 3. apical projections; 4. capillary; 5. myo-epithelial cells.
Pinkus stain. 384X

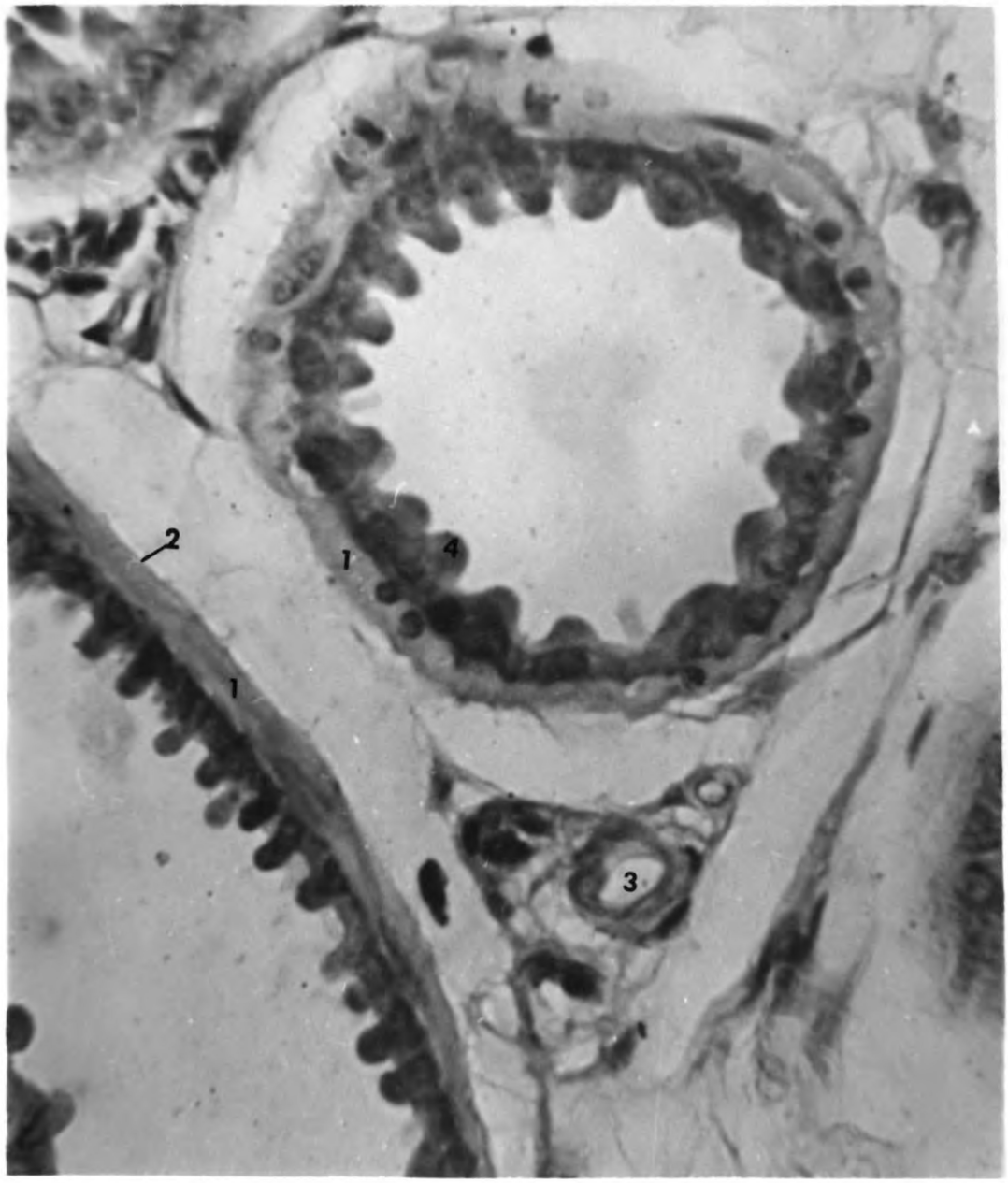

PLATE XX

Horizontal section of active apocrine sweat gland (interdigital gland). 1. myoepithelial cells (transverse and longitudinal cut); 2. basement membrane; 3. capillary; 4. columnar cell with lobed process.
Pinkus stain. 960X

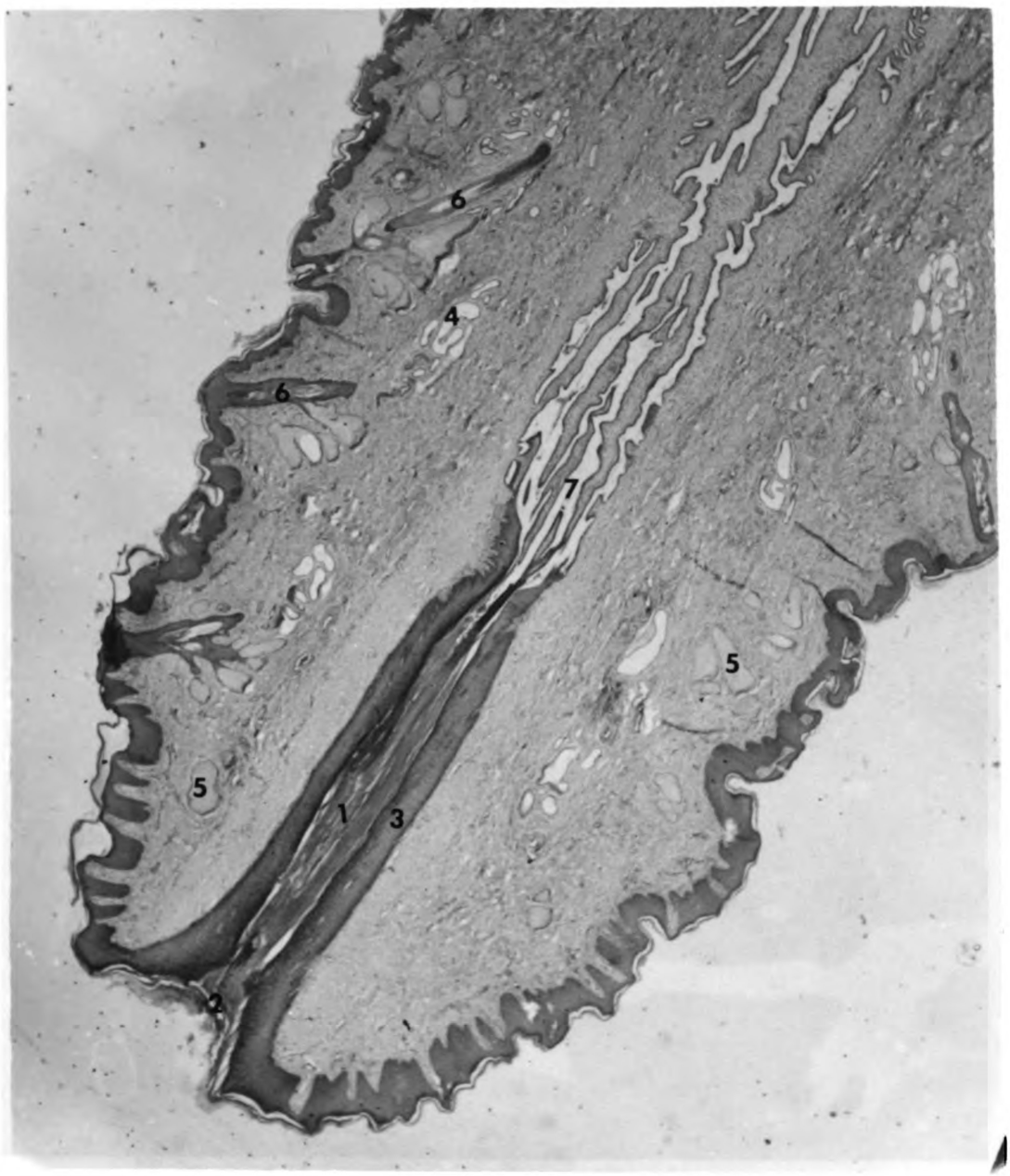

PLATE XXI

Vertical section of teat. 1. teat canal; 2. keratin; 3. stratified squamous epithelium; 4. saccular sweat glands; 5. sebaceous glands; 6. wool follicles; 7. lactiferous duct.
H. and E. stain. 16X

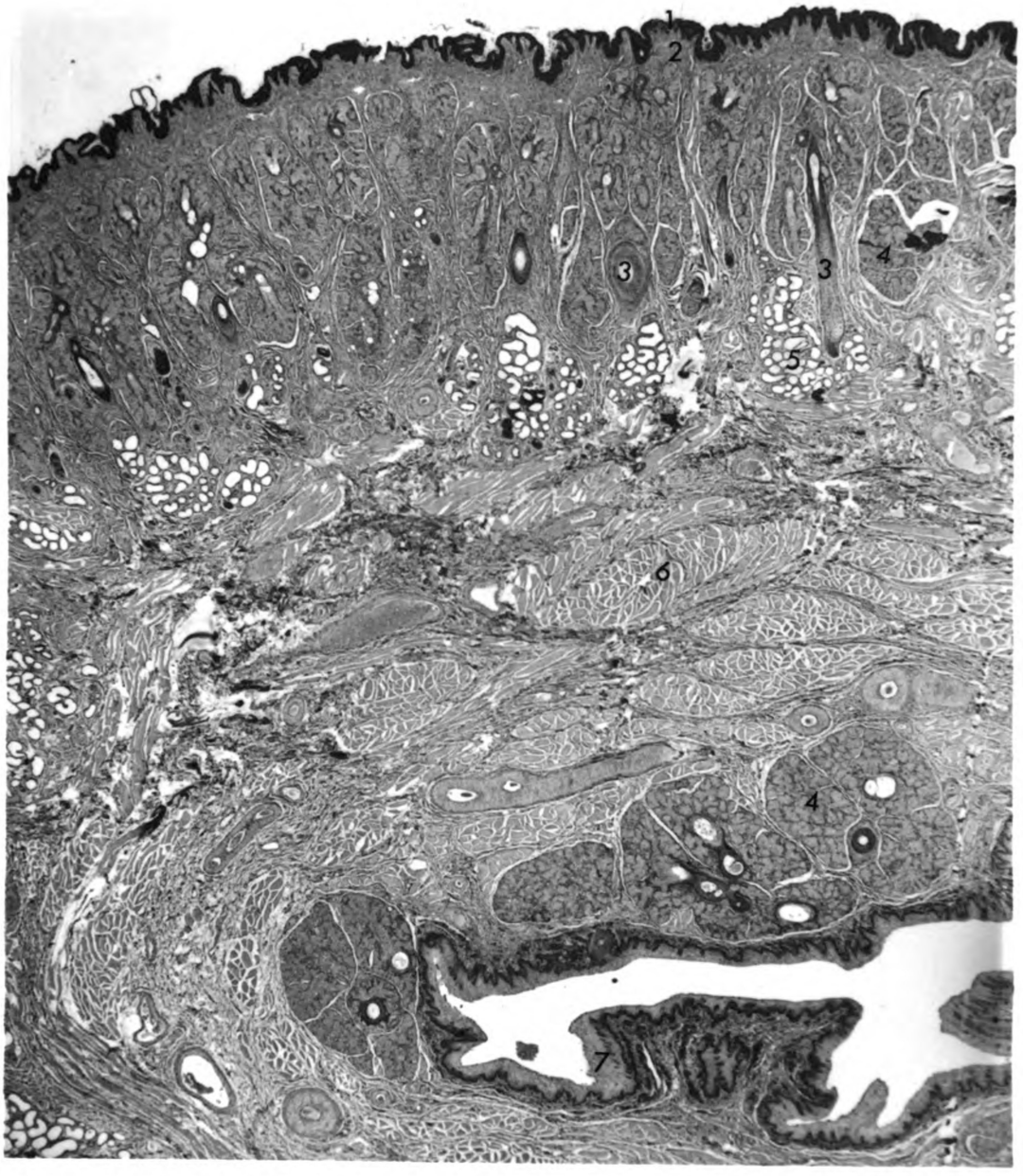

PLATE XXII

Vertical section of prepuce showing columnar arrangement of sweat gland. 1. epidermis; 2. dermis; 3. wool follicles; 4. sebaceous glands; 5. sweat glands; 6. skeletal muscle; 7. stratified squamous epithelium lining lumen of prepuce. H. and E. stain. 40X

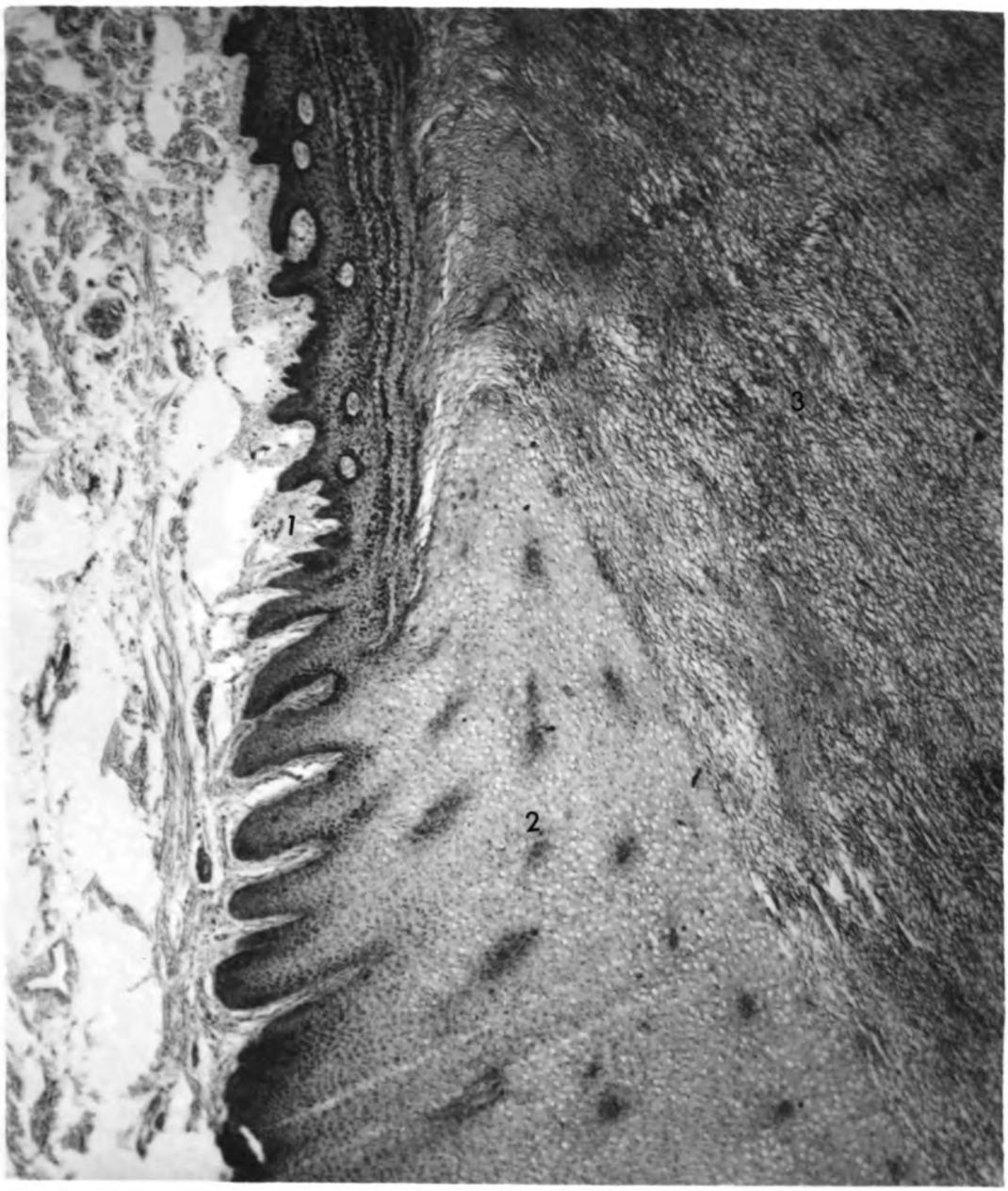

PLATE XXIII

Vertical section of ovine claw and skin junction. 1. compound dermal papilla; 2. stratum medium; 3. tubular and intertubular horn.
H. and E. stain. 40X

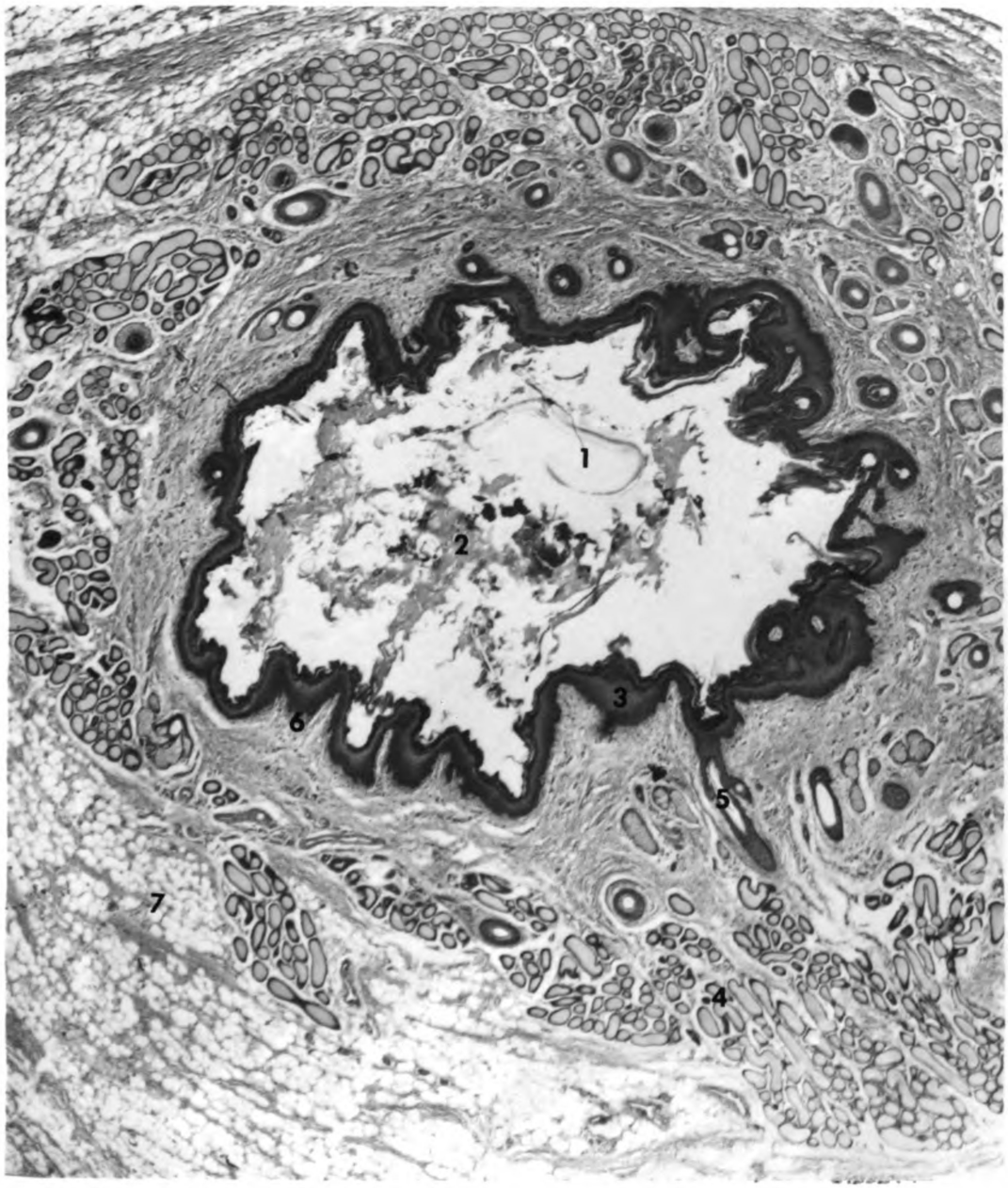

PLATE XXIV

Vertical section of interdigital pouch ("gland") of pelvic limb. 1. lumen of interdigital gland; 2. keratin fragments; 3. stratified squamous epithelium; 4. tubular sweat glands; 5. wool follicles; 6. flattened dermal papillae; 7. adipose tissue.
H. and E. stain. 20X

PLATE XXV

Vertical section of muzzle showing capillaries in dermal papillae. 1. compound epithelial peg; 2. dermal papillae; 3. capillary dividing to project branches into separate papillae.
Weigert's iron hematoxylin and VanGieson's stain. 307X

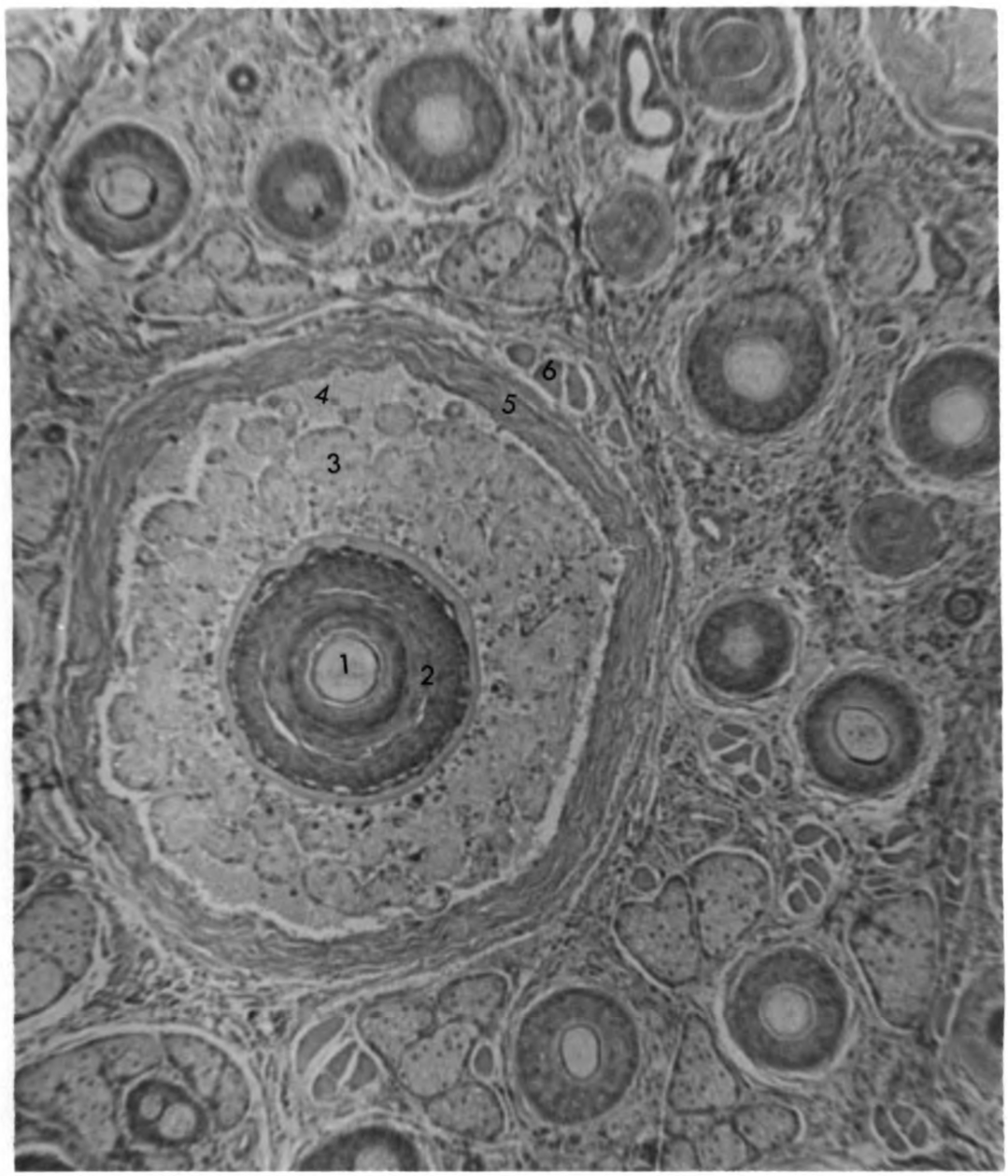

PLATE XXVI

Horizontal section of tactile hair follicle of muzzle. 1. tactile hair; 2. epithelial sheath; 3. inner connective tissue sheath; 4. blood; 5. outer connective tissue sheath; 6. skeletal muscle.
H. and E. stain. 96X

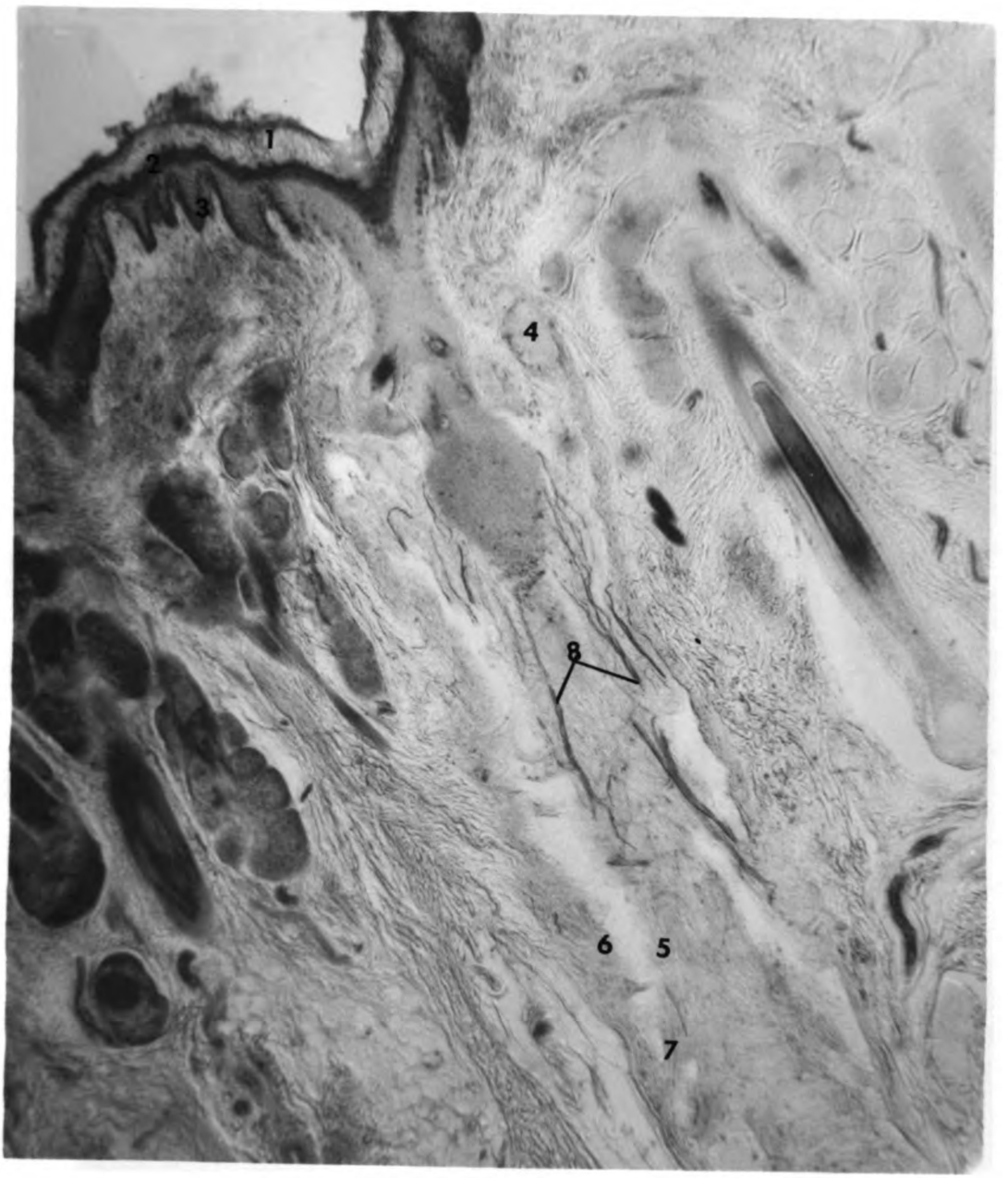

PLATE XXVII

Vertical section of tactile hair follicle of muzzle. 1. stratum corneum; 2. stratum granulosum; 3. compound papillae; 4. sebaceous gland of sinus hair; 5. inner layer of dermal sheath; 6. outer layer of dermal sheath; 7. blood sinus with trabeculae; 8. sensory nerves surrounding sinus hair. Modified Bielschowski-Gros Silver stain. 51X

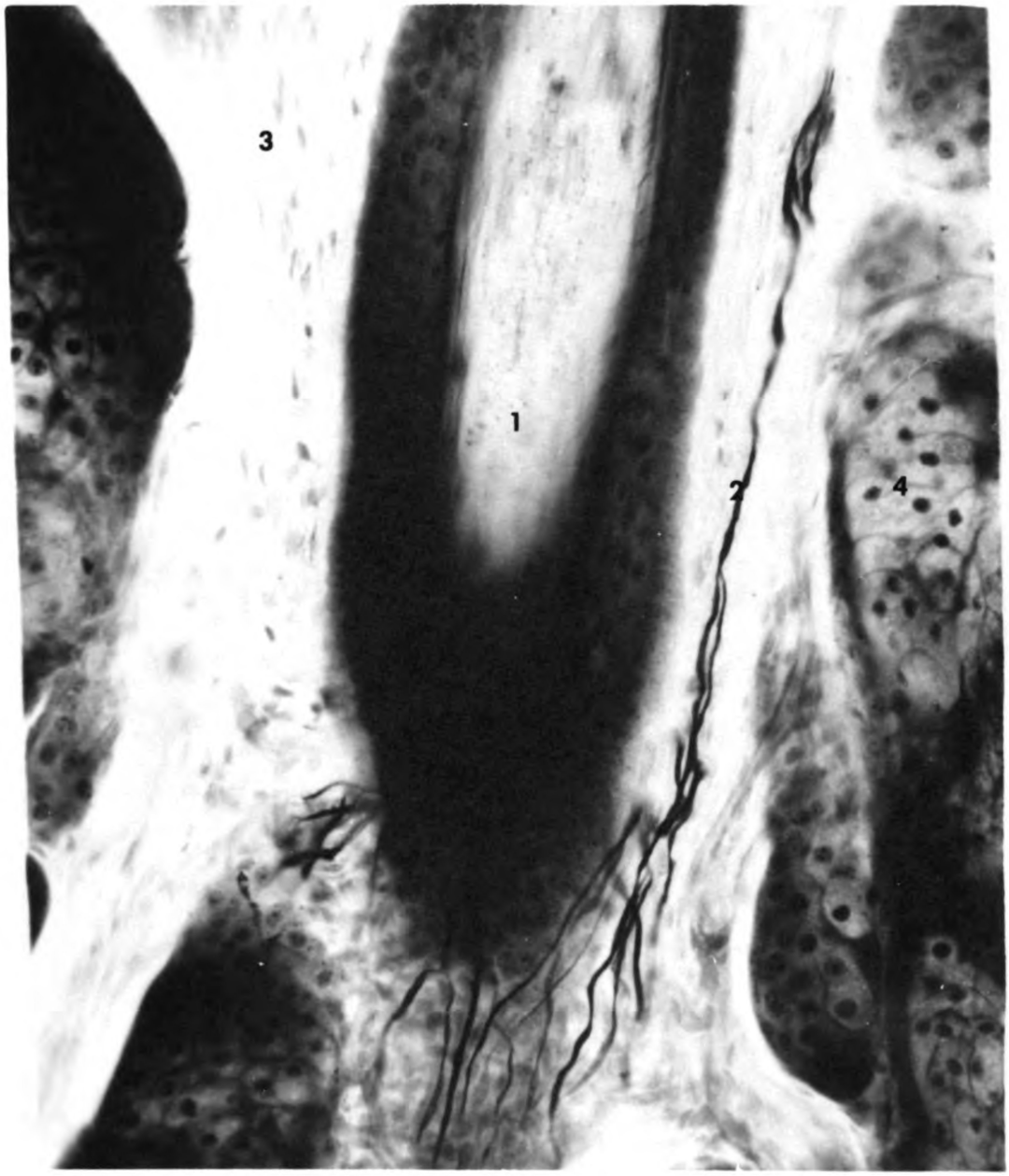

PLATE **XXVIII**

Vertical section of wool follicle showing relationship of nerve plexus to follicle. 1. hair root; 2. nerve fibers; 3. dermis; 4. sebaceous glands.
Modified Bielschowski-Gros Silver stain. 448X

PLATE XXIX

Vertical section of muzzle showing melanocytes of basal layer.
1. basal layer of muzzle epithelium; 2. melanocytes; 3. papillary layer of dermis.
Modified Bielschowski-Gros Silver stain. 512X

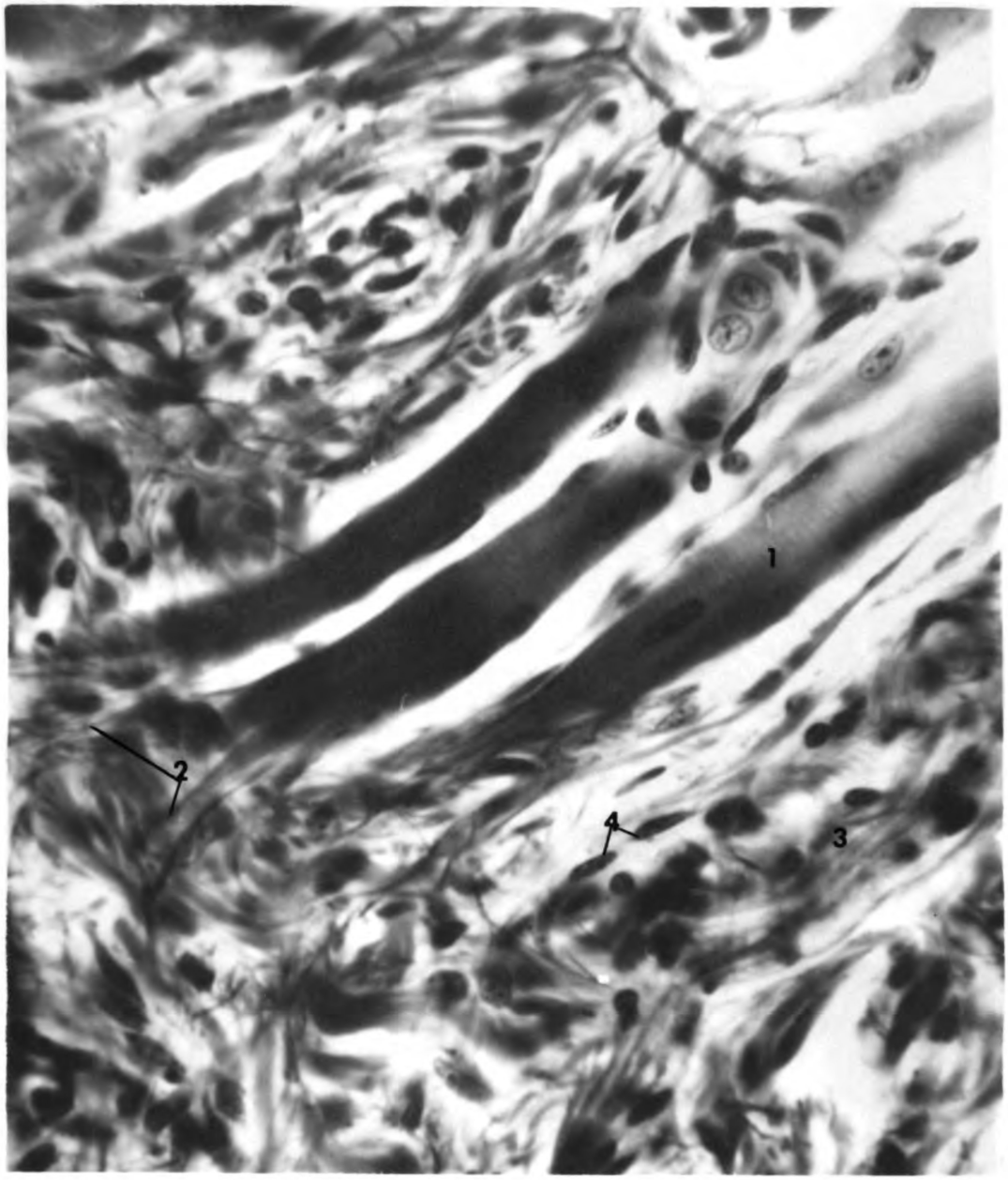

PLATE XXX

Vertical section of skin showing skeletal muscle fibers attached to elastic fibers in papillary layer of dermis (muzzle). 1. skeletal muscle fibers; 2. elastic fibers; 3. collagen fibers; 4. fibroblasts.
Weigert's iron hematoxylin and VanGieson's stain. 59X

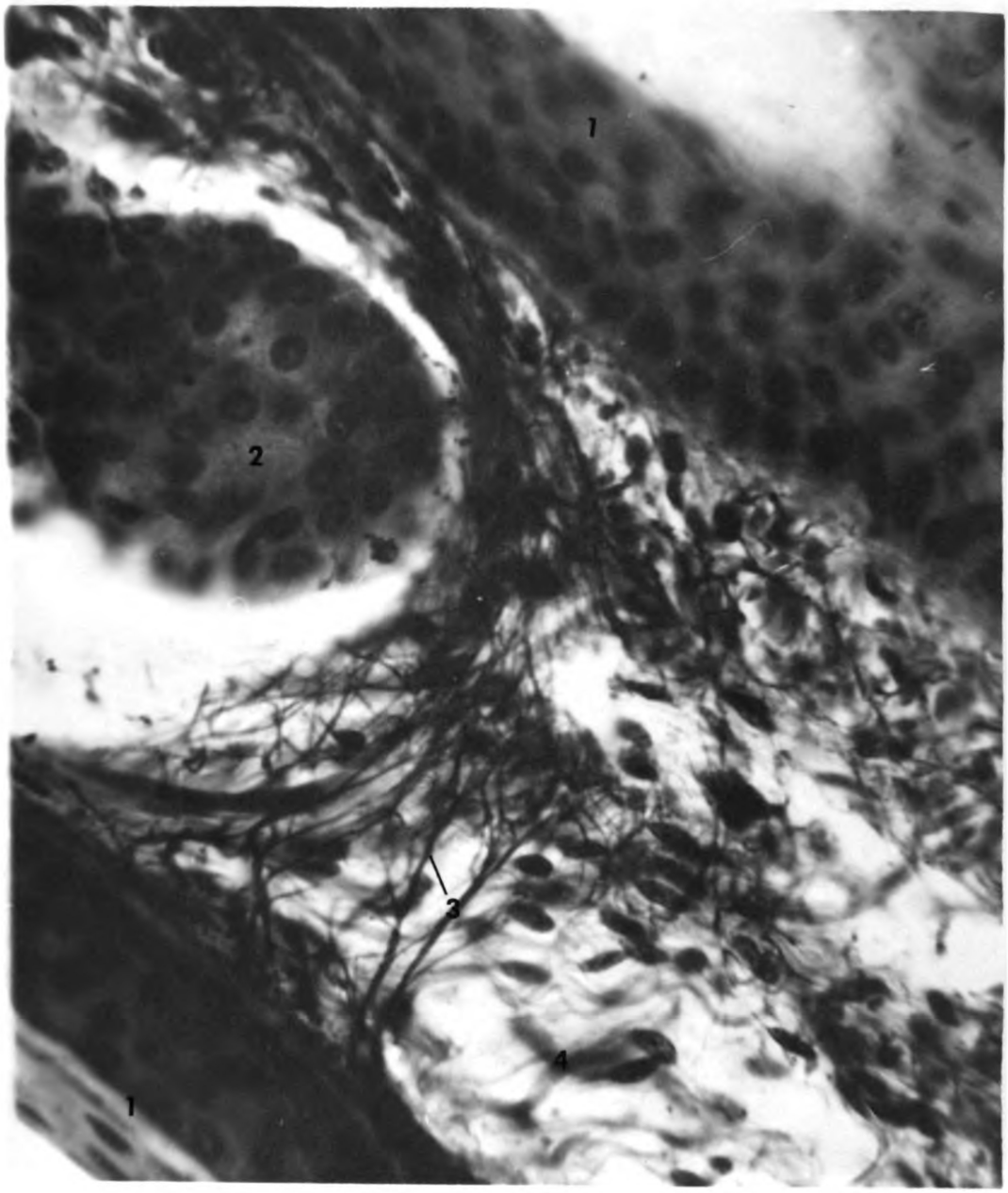

PLATE XXXI

Vertical section of skin showing elastic fibers connecting two wool follicles and a sebaceous gland. 1. wool follicles; 2. sebaceous gland; 3. elastic fibers; 4. collagen fibers. Weigert's iron hematoxylin and VanGieson's stain. 59X

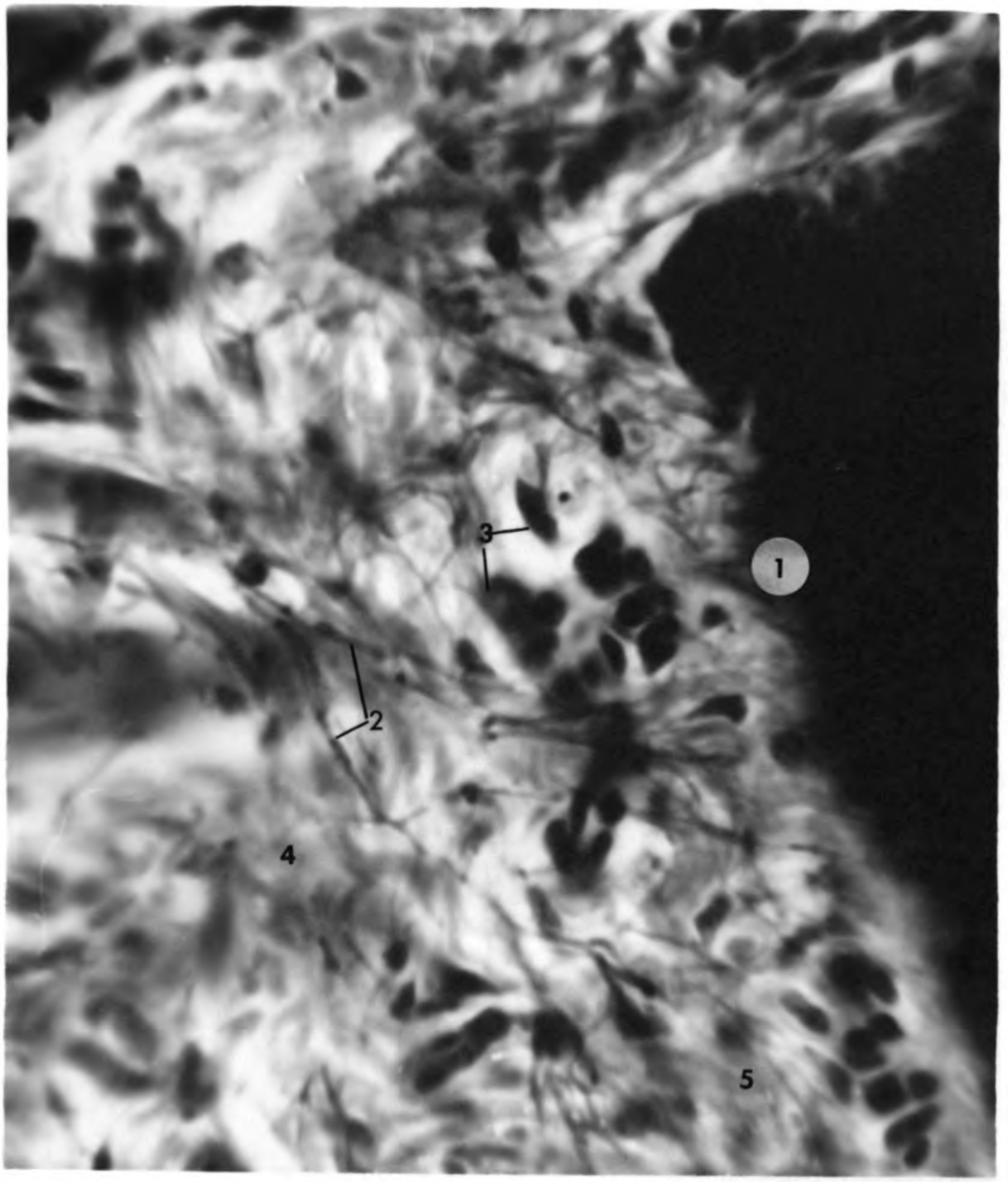

PLATE XXXII

Vertical section of muzzle showing elastic fibers at dermal-epidermal junction. 1. stratum basale of muzzle; 2. elastic fibers; 3. fibroblasts; 4. collagen fibers; 5. papillary layer of dermis.
Weigert's iron hematoxylin and VanGieson's stain. 770X

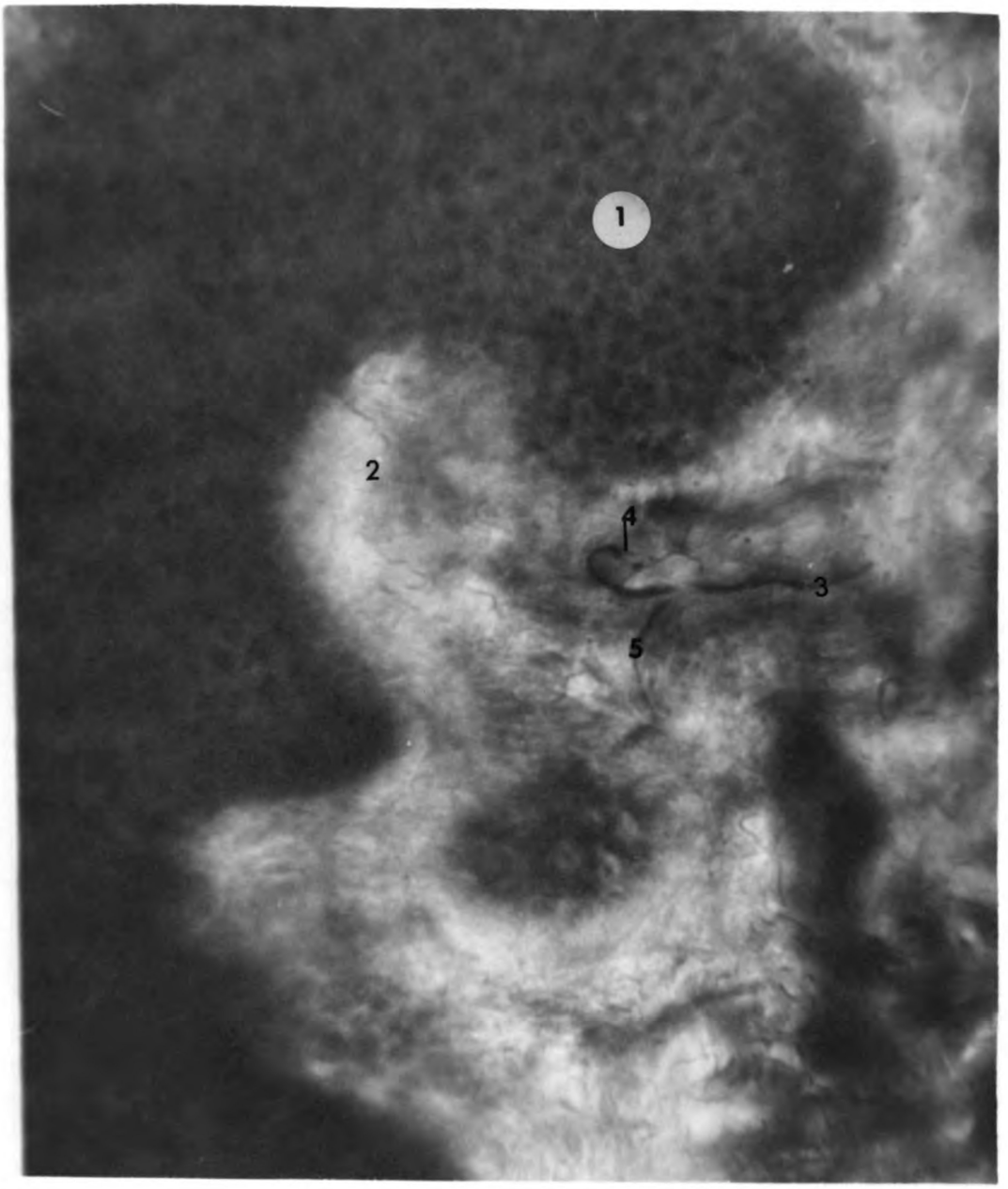

PLATE XXXIII

Vertical section of muzzle showing nerve process with end bulb and branching collateral. 1. stratum spinosum of muzzle; 2. dermal papillae; 3. nerve process; 4. encapsulated end bulb; 5. branch of nerve process.
Modified Bielschowski-Gros Silver stain. 384X

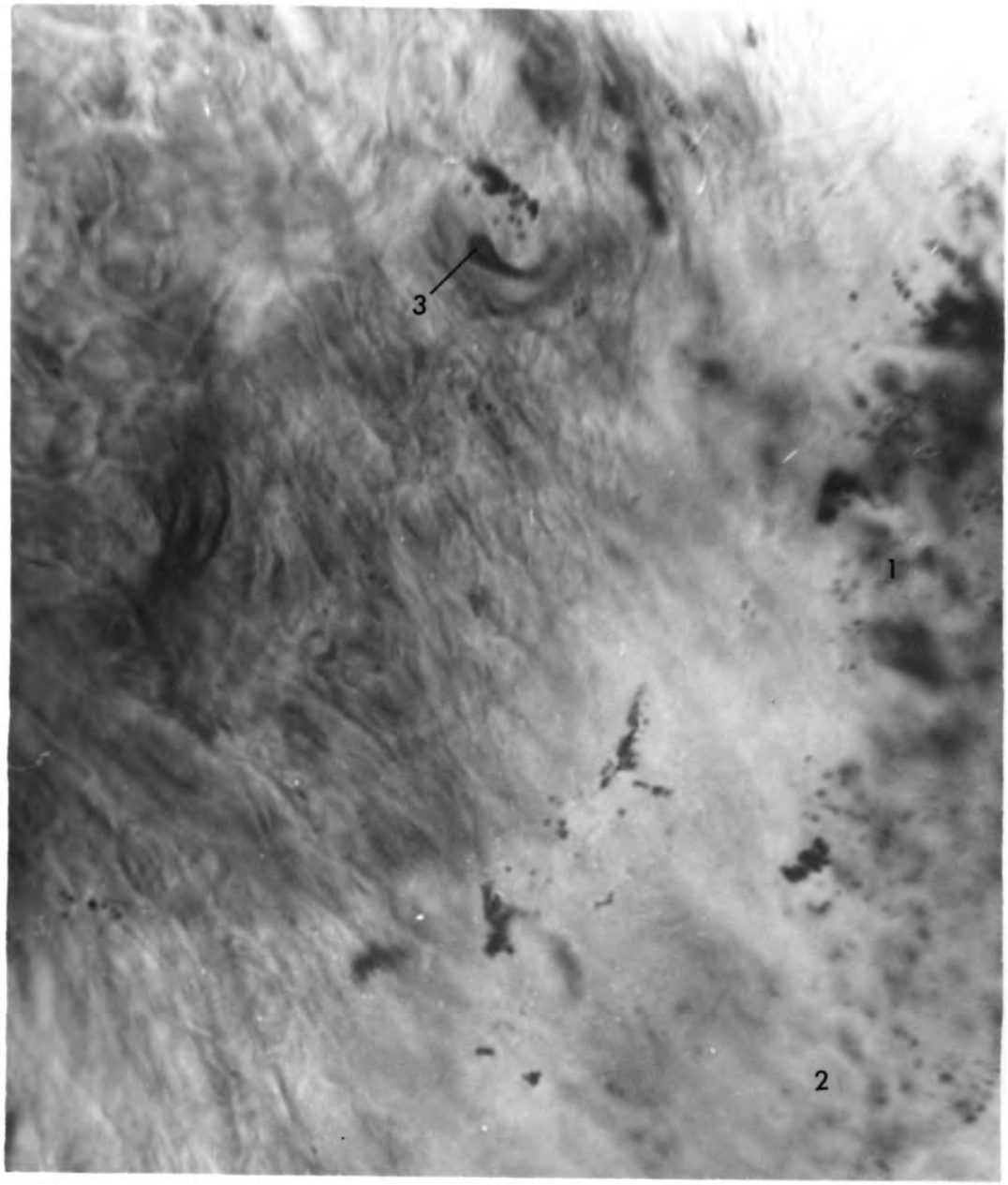

PLATE XXXIV

Vertical section of muzzle showing lamellated nerve end bulb.
1. stratum basale; 2. dermis; 3. nerve end bulb.
Modified Bielschowski-Gros Silver stain. 960X