THE MICROSCOPIC ANATOMY OF THE SKIN AND EXTERNAL EAR OF FELIS DOMESTICUS

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James H. Strickland

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THE MICROSCOPIC ANATOMY OF THE SKIN AND EXTERNAL EAR OF FELIS DOMESTICUS

by

James H. Strickland

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INTRODUCTION

This investigation resulted from a lack of sufficient information on the normal histology of cat skin and a request from the department of Surgery and Medicine for reliable data on the histology of the external auditory meatus of the cat. The field of dermatopathology relies on knowledge of the normal, and with the various pathological involvements of the skin and external ear canal of cats, it is hoped that this work will serve as a reference.

GENERAL REVIEW OF LITERATURE

Relatively little work has been done on the histology of cat skin. According to Speed (1941), Backmund (1904) worked on the embryology of the sweat glands in the cat, and Teger (1906) reported active sweat glands in the external auditory meatus. Stoss (1906) was one of the first to discuss the histology of cat skin. Frei (1928) studied the histology of the cat foot pad, while Thuringer (1939) studied the epidermal mitotic index of this same area. Trimarchi (1929) reported on the sebaceous and sudoriferous glands in the nasal vestibule of domestic carnivores. Varićak (1941) devoted part of his study of domestic animal skin to that of the cat. Montagna (1949) described the glands in the external auditory canal, and in 1952 reported on the epidermis. Tekada (1951) also studied the skin of the external auditory canal of the cat and other domestic animals, and Senturia and Liebmann (1956) studied the factors which may contribute to external ear infections of the cat. Trautmann and Fiebiger (1957) gave a detailed description of carnivore skin including some specific information on the cat. Daniel and Prichard (1956) described the arteriovenous anastomoses in the cat and eight other animals. They found an S shaped anastomosis less complex and smaller than in most animals studied. Kuntz and

Hamilton (1938) found afferent fibers associated with smaller blood vessels, lamellated end organs in the forelimb and foot pad, and a subepidermal plexus made up of slender nerve strands. Winkelmann (1957) described the sensory end organ of the hairless skin of the cat. Trautmann and Fiebiger (1957) found Pacinian corpuscles in the prepuce of the cat. Kamamura (1957) reported the cytochemical effect of pilocarpine administration on cat sweat glands, and described two different types of cells, a superficial and a basal cell composing the secretory unit of the plantar foot pad. Dukes (1955) and Marzulli and Callahan (1957) studied the sweat capacity of the cat.

Epidermis

Frei (1928) found that the foot pads of the cat have a thick epidermis with a superficial horny layer. Wavy lines separate the cornified cells in the stratun corneum and the epidermis is pierced by excretory ducts. According to Frei "foot pads that possess functional glands," do not have typically arranged cornified cells. Stoss (1906) reported six epidermal strata in the external border of the nasal septum of the cat. Thuringer (1939) found 2.37 dividing cells per thousand in the cat foot pad. Varicak (1941) observed that the epidermis of the cat resembles that of man, but the superficial translucent layer seldom occurs, while the stratum lucidum is usually present.

Montagna (1952) noted all epidermal layers in the cat digital pads.

Dermis

Stoss (1906) observed dense, tough connective tissue fibers in the cat dermis. Frei (1928) reported that the foot pads of the cat are similar to those of the dog, and are composed of four rounded pads. The thumb pad is the weakest, and is absent from the hind feet. He found closely arranged extremely vascular, short papillae, a less developed stratum reticulare, and a well developed subcutis. Trautmann and Fiebiger (1957) described thick layers of fat in the foot pads of carnivores.

Hair Follicle

Trautmann and Fiebiger (1957) found bundles of hair projecting from common follicular openings in carnivores. According to these authors three cover hairs composed of one larger main hair and two smaller hairs usually constitute a group and in the carnivore each group is surrounded by six to twelve lanugo or wool hairs. Stoss (1906) and Trautmann and Fiebiger (1957) described nontrabecular annular sinuses associated with the large tactile hairs of the cat. These sinuses are smooth walled with a cushion-like thickening.

Sebaceous Glands

Trautmann and Fiebiger (1957) found sebaceous glands in all body areas of carnivores except the foot pads and planum nasale. They reported a ring of sebaceous glands opening into the tactile hair follices and large sebaceous glands, "the supracaudal organ," on the dorsal surface of the cat tail. Stoss (1906) reported many sebaceous glands on the back, chest, and abdomen of the cat, and found two to three lobulated sebaceous glands emptying into a single hair follicle. He also observed large sebaceous glands in the upper jaw, prepuce, and proximal dorsal end of the cat tail, but generally small glands were present in other body areas. Trautmann and Fiebiger (1957) reported sebaceous glands independent of hair follicles in the prepuce, external auditory meatus, and tarsal glands of the eye lids in domestic animals. Montagna (1949) described large clusters of sebaceous glands in the external auditory meatus and stated that these may or may not be associated with lanugo hair follicles. He also reported that sebaceous glands exhibit considerable mitoses particularly at the periphery of the acini, and contain a moderate amount of stored lipoids. Trautmann and Fiebiger (1957) observed sebaceous glands in the teat of the cat, mare, and bitch.

Sweat Glands

Frei (1928) found sweat glands in the foot pads of carnivores, and Dukes (1955) stated that active sweat

glands are confined to the foot pads in the cat, dog, pig, and ox. Trautmann and Fiebiger (1957) stated that the prepuce of domestic animals contains prominent tubular glands. According to these authors well developed sebaceous and tubular skin glands are found in the scrotal skin of all domestic animals except the boar, in which they are scarce and small. Marzulli and Callahan (1957) in testing the capacity of certain laboratory animals to sweat observed that the cat did not sweat in hairy skin areas. They observed an apocrine type of active tubular sweat gland only in the foot pads of the cat, dog, and rat and in the palms of the monkey. Stoss (1906) found that sweat glands are well developed on the lips, plantar pad, ball of the toe and anus of the cat, but are difficult to demonstrate in the remaining areas. According to Habel (1958), Ellenberger and associates reported sweat glands in almost all skin areas, even extending to the level of the papillae of cover hairs. Stoss (1906) found that the sweat glands reach as far as the root of the hair follicle, and that the secretory ducts are narrow and undulating making up one-third of the total length of the ducts. Trautmann and Fiebiger (1957) described coiled secretory tubules in the cat, and Stoss (1906) reported a tapered excretory duct opening into the hair follicle and onto the surface of the foot pad. Stoss concluded that all hair follicles have adjacent sweat glands which empty into their respective follicle, while

lanugo hairs possess no such glands. According to Speed (1941), Backmund (1904) concluded that the sweat glands of the upper and lower jaw have a special shape and that fetal hair has a sweat gland but no free openings. Trautmann and Fiebiger (1957) described apocrine and sebaceous glands in the anal sac of the cat and tubular and alveolar glands in the excretory duct of the anal sac.

According to Speed (1941), Teger (1906) observed active sweat glands in the external auditory meatus of the cat. Montagna (1949) working on the cat found both coiled dilated tubular sudoriparous glands and sebaceous glands opening either into the upper portion of the hair follicle or directly onto the surface of the external auditory meatus.

MATERIAL AND METHODS

A total of twenty domestic cats including eight mature animals, five females and three noncastrated males, one incomplete immature female, and one immature male were used for this study. Supplemental sections were secured from ten other cats. The animals were obtained from the departments of Physiology and Pharmacology, Surgery and Medicine, and Anatomy and were sacrificed with a lethal dose of sodium pentothal. Sections approximately one-half inch square were taken from twenty-seven body areas as indicated in Figures A and B. Since Frei (1928) found all the foot pads to be similar, the metacarpal pad was taken as a representative example. The tissues were fixed in formalin-alchol-acetic acid (Lavdowsky's mixture, Guyer-1949), and embedded in "Tissuemat,"[1] according to the methods of Johnson et al. (1943). Longitudinal and frontal sections were prepared with a modified hematoxylin and eosin (Malewitz and Smith 1955), Weigerts and Van Gieson's connective tissue stain, Wright's blood stain for mast cells (Belanger et al. 1957), and Yang's (1952) method for pigment determination. Measurements of skin thickness were made in ten representative body areas. The epidermis was measured in microns

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[1] "Tissuemat"--Fisher Scientific Company, Pittsburgh, Pennsylvania.

and sketched on graph paper by projection for future reference and general comparison. The units of graph paper were given values according to the calibration of the microscope. The dermis was measured in four respective fields at the highest and lowest points. The averages are given in Table I.

Figure A

BODY AREAS FROM WHICH TISSUES WERE TAKEN

3. Supraorbital region
4. Upper eyelid
5. Lower eyelid
6. Planum nasale
7. Upper lip
8. Lower lip
9. Dorsal neck
10. Thoracicolumbar region
11. Lateral body wall
12. Ventral abdomen
13. Tail root
14. Shoulder
15. Lateral foreleg
16. Lateral thigh
17. Lateral hindleg
18. Scrotum
19. Supracaudal gland
20. Teat (female)
21. Prepuce
22A. Anal sac
22B. Metacarpal pad

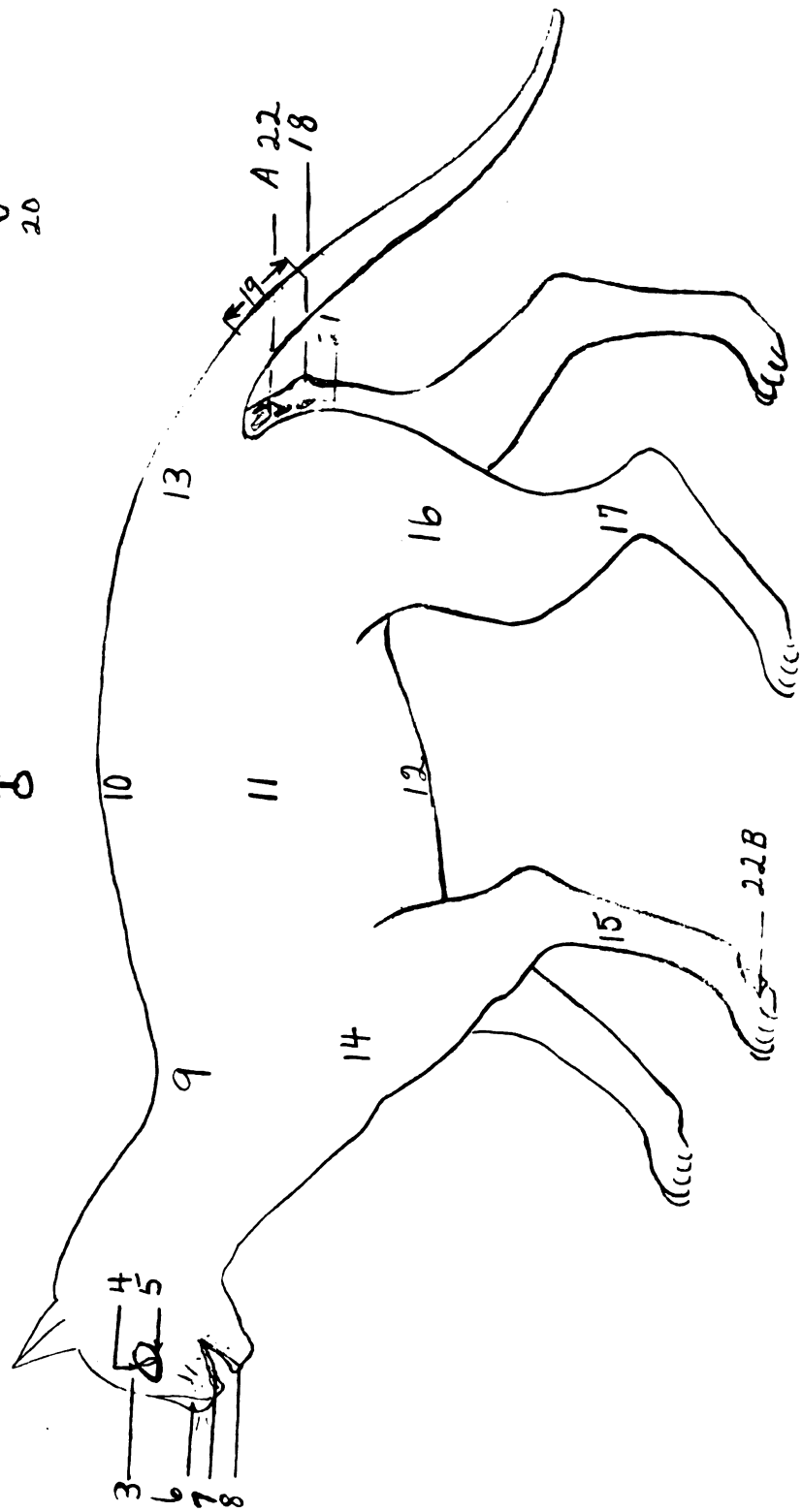


Figure A. Body Areas from Which Tissues Were Taken

Figure B

EAR AREAS FROM WHICH TISSUES WERE TAKEN

1. Apex of pinna
2. Scapha of pinna
23-1. Auditory longitudinal meatus--medial wall
23-2. Auditory longitudinal meatus--lateral wall
24-1. Upper one-third of meatus--level 1
24-2. Upper one-third of meatus--level 2
25. Middle meatus--level 1
26. Lower section near tympanic membrane--level 2
27-1. Lower middle meatus--level 2
27-2. Lower one-third of meatus--level 1

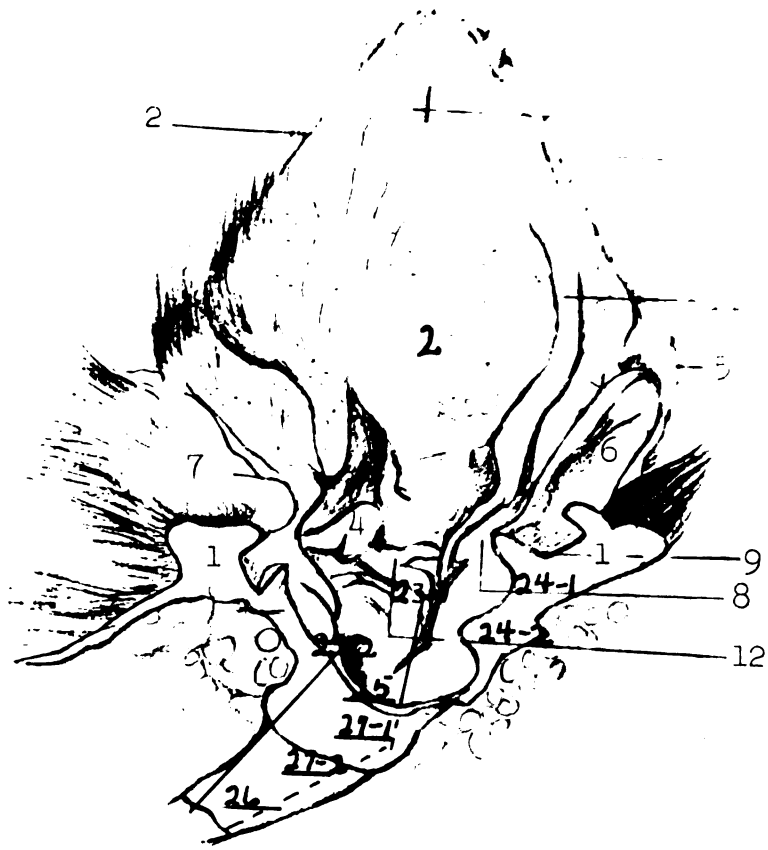
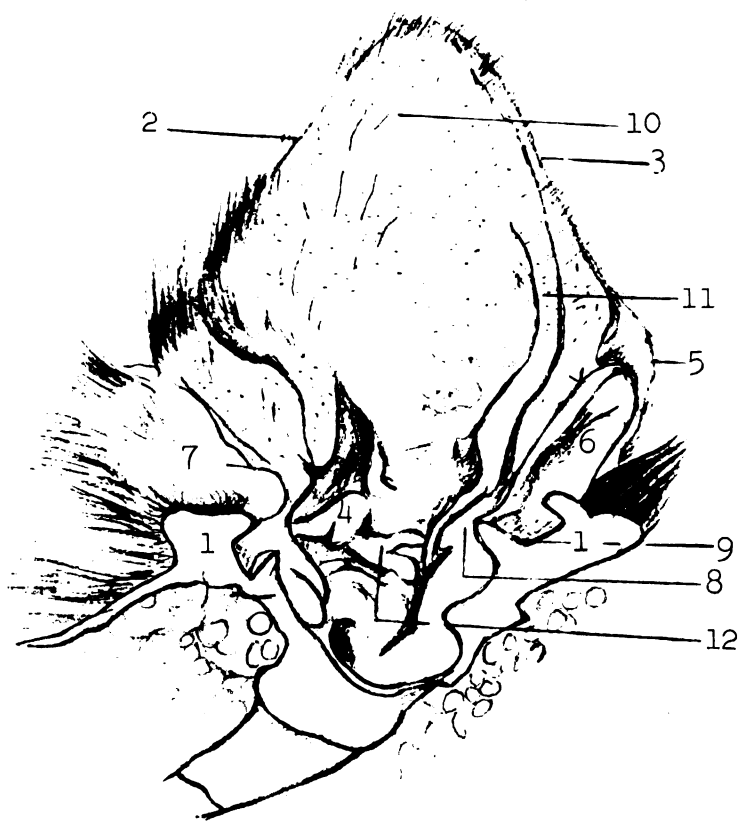


Figure B. Anterolateral view of cat's ear

1. Cut edge of tragus
2. Rostral border
3. Caudal border
4. Anthelix (tubercle of)
5. Posterior auricular sulcus
6. Antitragus
7. Anterior auricular sulcus
8. Plica antitragica
9. Incisure intertragica
10. Scapha
11. Longitudinal ear folds
12. Transverse folds

Left Ear
3k
3k-1
3k-2
3k-3
3k-4
3k-5
3k-6



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10. Scapha
11. Longitudinal ear folds
12. Transverse folds

RESULTS AND DISCUSSION

I. GENERAL

From a comparative viewpoint most investigators have assumed the skin of the cat to be similar to the skin of the dog. This is essentially true but certain apparent differences will be pointed out in the following discussion. Due to certain area limitations and specialization, the ten general body regions shown in Table I were selected as most typical for an over-all picture.

The thickest areas are found on the dorsal neck, lumbar, and sacral regions. The thinnest areas are on the lateral sides of the lower hind leg, thigh, and lower fore-leg. Generally the thickness decreases from dorsal to ventral on the trunk, and from proximal to distal on both front and hind limbs. The maximum skin thickness is 1905 microns in the dorsal neck region and a minimum of 374 microns on the lower lateral side of the hind leg.

The epidermis is thin in all hairy areas, usually measuring between twenty and thirty microns, with a range from twelve to forty-five microns. According to Lovell and Getty (1957), the average epidermal thickness in the hairy skin of mongrel dogs is thirty to forty microns. Webb and Calhoun (1954) reported the thinnest epidermis in

mongrel dogs to be 26.5 microns in the sternal region. In the present investigation twenty-five microns is considered an average epidermal thickness in the cat. One may assume that the epidermis in mongrel dogs is generally thicker than that of the cat in the hairy skin areas. The epidermis of the prepuce, scrotum, and similar specialized areas of the cat ranged from seventeen to sixty microns, while similar areas in mongrel dogs measured sixty-seven to ninety microns (Webb and Calhoun 1954).

Small hairless knoblike enlargements in the hairy skin area of mongrel dogs have been referred to as epidermal papillae by Lovell and Getty (1957). Since both the dermis and epidermis are involved in this structure the term integumentary papillae seems more appropriate (Plate I). The epidermis of these integumentary papillae in the cat is thicker than the epidermis of most hairy areas. Occasional epidermal thickness to 100 microns may be seen in the anal sac lumen. The thickest epidermis is found in the digital pads and planum nasale and measures 900 microns compared to 1,800 microns seen in mongrel dogs (Lovell and Getty 1957).

The epidermis of the planum nasale exhibits prominent ridges which form the basis for the nose print technique similar to human finger printing methods (Plate IX).

TABLE I. MEASUREMENT OF THE DERMIS AND EPIDERMIS OF THE HAIRY SKIN AREA*

Animal		Supraorbital	Dorsal Neck	Dorsal Lumbar	Flank	Ventral Abdomen	Tail Root	Shoulder	Lateral Foreleg	Lateral Thigh	Lateral Hindleg	Animal Average
A--M	E**	20	20	25	23	22	20	20	30	21	18	21.9
mature	D	837	1240	889	650	730	617	568	693	655	415	729.4
B--F	E	34	32	25	25	25	25	30	23	32	22	26.9
	D	1128	1825	1275	828	1170	903	588	862	918	600	1009.7
C--F	E	22	35	35	35	20	22	20	24	21	25	25.9
	D	1262	1805	1605	828	1204	980	832	885	644	531	1057.6
D--F	E	22	30	24	25	18	18	24	18	20	20	21.9
	D	1127	1575	1141	1070	651	1151	943	875	653	570	975.6
E--M	E	25	30	27	25	30	25	25	35	30	24	27.6
	D	1162	1875	1280	1143	890	1025	893	843	800	471	1038.2
F--F	E	23	28	35	35	35	20	29	24	20	30	27.9
	D	1168	1462	1433	1140	960	1063	1181	725	722	812	1066.6
H--F	E	18	20	20	26	20	17	19	18	16	19	19.3
	D	1160	1727	1651	725	775	1075	893	762	711	442	992.1
N--M	E	27	28	20	20	16	23	20	25	23	24	22.6
	D	1537	1529	1181	758	668	1405	868	657	620	350	957.3
R--M	E	24	22	28	24	22	28	35	35	20	25	26.3
	D	1127	1850	1275	700	550	1502	1293	765	687	700	1044.9
Average***		24.3	28.1	26.1	26.7	22.7	22.2	25	25.2	24	23.6	24.5
		1208	1706	1302.6	899	808.5	1137.6	936.2	796.7	719.3	559.5	1007.3

*Each figure represents an average of four measurements of the dermis and epidermis in microns.
**E=epithelium, D=dermis, M=male, F=female.
***Average includes only mature animals B through R.

II. SPECIFIC EPIDERMAL LAYERS

The nonhairy skin of the cat consists of five distinct epidermal layers: stratum corneum, stratum lucidum, stratum granulosum, stratum spinosum, and stratum cylindricum. In hairy skin areas, the stratum lucidum is not usually found.

Stratum Corneum

The stratum corneum is present in most body areas. This is in contrast to the findings of Varićak (1941), who stated that the superficial translucent stratum corneum is usually absent. In hairy skin, it varies from three to twenty microns. In certain areas such as the integumentary papillae, the stratum corneum may be thicker. It is best developed in the digital pads and planum nasale and ranges from fifteen to thirty-five microns. In the anal sac gland and lip, the stratum corneum is well developed, although not as thick and prominent as in the metacarpal pad and planum nasale. In the external auditory meatus the stratum corneum and related layers may become hyperplastic and contribute to a change in the general morphology of the skin of that area. It increases in thickness and in certain instances covers the openings of sebaceous and ceruminous glands that open upon the surface. The epidermal thickness may increase as much as three to four times forming interpapillary pegs. The cells of the epidermis appear to migrate into the dermis and invest the sebaceous and ceruminous glands (Plate II).

The Stratum Lucidum

The stratum lucidum is best developed in the metacarpal pad where the thickness ranges from twenty-eight to forty microns. It is less developed in the planum nasale and anal sac and is absent from almost all hairy skin areas. It is not present in the external auditory meatus. These findings are directly opposed to those of Varićak (1941) who stated that the stratum lucidum is generally present in most body area

Stratum Granulosum

The stratum granulosum consists of one or two layers and is present in most of the hairy and nonhairy skin areas. The thickest stratum granulosum is in the metacarpal pad and consists of 4 to 8 cell layers. In the planum nasale there are usually 3 to 4 layers of cells, which contain dark cytoplasmic granules (Plate IX). These granules are very prominent in the teat and scrotum.

Stratum Spinosum

The stratum spinosum is present in all sections of hairy and nonhairy skin. In hairy skin, it averages from 1 to 2 layers. Where there are integumentary papillae with a thick cornified epidermis, as many as 5 layers are not uncommon. The tonofibrils (intercellular bridges) are not as prominent in the hairy as in the nonhairy skin (Plate X). In the nonhairy metacarpal pads, planum nasale,

and the less hairy hyperplastic external auditory meatus the stratum spinosum contains the greatest number of layers. As many as 38 cell layers are sometimes observed (Plates II, V, and IX). The stratum spinosum of the teat, scrotum, prepuce and portions of the external auditory canal exhibit a loose nonuniform layer.

Stratum Cylindricum

The stratum cylindricum is present in all sections studied and is composed of one layer of cells, which usually is oriented perpendicular to the epidermis. Few mitotic figures are present. These cells stain slightly darker than the cells of the other epidermal layers and generally appear tall and columnar in shape. This is not always true in the external auditory canal, teat, and scrotum, where the epidermis may be less stratified.

III. PIGMENT

The pigment concentration varies considerably according to the body area in the cat. With reference to the ten hairy skin areas illustrated in Figure 4 (areas 3 and 9 to 17), there is little relationship of pigment to hair color. In the hairy areas the skin is usually devoid of pigment and the color of the hair coat is concentrated in the individual hairs. The darker skin of the lip, digital pads, and planum nasale

usually contains large amounts of pigment in the epidermis and little or no pigment in the dermis. A small amount of pigment is seen in the epidermis of the external auditory canal, and ear pinna. Specialized areas such as the prepuce, scrotum, anal sac, and teat exhibit pigment in the epidermis. Chromatophores are occasionally observed in the dermis of the scrotum.

IV. DERMIS

The dermis is composed of collagenous, elastic, and reticular fibers, nerve components, and blood vessels. Nerve structures resembling those described by Winkelmann (1957) are present in the lip, planum nasale, and metacarpal pads. Plate X shows a special nerve ending in the cat lip, and Plate XI illustrates a Pacinian corpuscle in the deep portion of the metacarpal pad. Large nerve trunks are observed crossing the blood sinuses in tactile hairs. Large and small nerve trunks are seen throughout the dermis in the hairy skin, and are usually associated with blood vessels.

Hairy Skin Area

The hairy skin is usually characterized by a very indefinite division between the stratum papillare and the stratum reticulare. The stratum papillare is composed of fine collagenous fibers which usually are parallel to the epidermis (Plate III). These fibers appear more uniform

than those of the stratum reticulare. The elastic fibers of this layer form a fine interlacing network, but occasionally single fibers are present. The fibers of the papillary layer appear to interlace near the dermal-epidermal junction. These observations agree with those of Dick (1947) and Odland (1950)..

The stratum reticulare is characterized by large densely arranged collagenous fibers which are approximately three times larger than the fibers of the stratum papillare. These form large bundles extending in all directions (Plate IV). These fibers encircle hair follicles throughout the reticular layer, and usually disappear at the junction with the subcutis giving way to adipose tissue. The elastic fibers increase in number, extend in all directions and also encircle the hair follicles. Elastic fibers appear to adhere to the side of collagenous fibers in the reticular layer and are increasingly abundant near the attachment of the arrector pili muscle. In areas where the skin is most flexible, such as the dorsal neck, scapular region and lateral upper forelimb, collagenous bundles are smaller and more loosely arrange.

Areas With Little or No Hair

The nonhairy areas are the planum nasale and the metacarpal pad. The lip and external auditory meatus have little or no hair present. Since the dermal strata vary, depending on the area, a regional discussion seems more appropriate.

External auditory meatus. Both dermal layers are present in the external auditory canal with the fiber contour determined by folds in the skin and the number of sebaceous and ceruminous glands. The skin of the external auditory meatus exhibits large and small folds in the outer and middle divisions. Small elastic and collagenous fibers surround the sebaceous and ceruminous glands immediately beneath the epidermis (Plate VII). This layer is referred to as the stratum papillare in keeping with the size of fibers and description of skin in other areas, but in hyperplasia a more definite papillary layer is formed (Plate II). The fibers beneath the papillary layer are large and resemble the reticular layer in other areas, with the exception of being extremely dense. These fibers fuse with the perichondrium of the elastic cartilage. The elastic fibers of the lower meatus appear larger, more numerous, and extend parallel to the epidermis. The folded areas usually possess a fat-laden central portion as illustrated in Plate VI, which occasionally contains ceruminous glands. These folds have more surface area resulting in less crowding of the dermal elements.

Metacarpal pad. The dermis has very prominent dermal papillae and interpapillary epithelial pegs which expand with weight. The dermis is characterized by a definite division between the stratum papillare and stratum reticulare. Frei (1928) reported that short dermal papillae

contained a large amount of blood vessels. In this investigation no significant differences were noted in any of the papillae studied (Plate V). The finding of closely arranged papillae and a less developed stratum reticulare agrees with the observation of Frei (1928). The subcutis is composed of thick bands of collagenous fibers and abundant smaller elastic fibers which interweave and enclose the panniculus adiposus (Plates V and VIII). Plate VIII shows the junction between the subcutis and hairy dermis of the foot pad. Large number of elastic fibers separate the two areas. The arrangement of these layers concurs with the description of carnivores by Trautmann and Fiebiger (1957).

Planum nasale. The planum nasale has a thick well developed stratum reticulare. The fibers appear unusually large as compared with the small fibers of the stratum papillare (Plate IX). The fibers form a very distinct papillary body. Nerve structures resembling those described by Winkelmann (1957) are present.

Lip. The dermis of the lip is composed of very little connective tissue as compared with other less hairy skin structures. Plates XIV, XVI, and XIX illustrate the sparse amount of connective tissue in relation to the other dermal elements. The connective tissue fibers are prominent only immediately beneath the epidermis. No distinctive stratum papillare and stratum reticulare are observed.

Special Skin Areas

Teat, scrotum, prepuce, and eyelid. The connective tissue fibers of the teat are very dense as compared with other skin areas. A distinct stratum papillare and stratum reticulareare present (Plate XXII). The numerous elastic and collagenous fibers run both parallel and horizontal to the epidermus. The dermis of the prepuce and scrotum is composed of a coarse fiber network. No distinctive stratum papillare or stratum reticulare are present in the scrotum but the parietal layer of the prepuce exhibits a papillary body. The connective tissue of the eyelid is composed of many collagenous and elastic fibers (Plate XVII). The contour of these fibers is interrupted by the eye lashes and tarsal glands. No distinctive dermal layers are observed but the fibers near the epidermis of the eye lashes appear smaller than the fibers of the deeper layers. This observation agrees with that of Trautmann and Fiebiger (1957) on the eyelid in domestic animals.

V. HAIR

The hair of the cat is arranged in clusters of two, three, four, and five groups around a large central guard hair with two and three being more common on the dorsal aspect of the body (Plates III and IV). Clusters of four and five when present usually occur in the ventral and lower extremities. Table II illustrates the distribution of hair

TABLE II. HAIR GROUP DENSITY PER SQUARE MILLIMETER IN OBLIQUE SKIN SECTIONS*

	A--M	B--F	C--F	D--F	E--M	F--F	H--F	N--M	R--M	Average B-R
Dorsal Neck	Immature 11	13	12	11	11	11	11	9	9	10.8
Dorsal Lumbar	12	9	10	9	9	9	11	9	8	9.2
Flank	13	12	14	11	13	12	12	13	11	12.1
Ventral Abdomen	15	13	13	11	13	13	12	11	11	12.1
Tail Root	10	10	10	11	13	12	9	11	9	11.9
Shoulder	17	14	15	17	14	15	16	13	14	14.6
Lateral Foreleg	16	16	17	17	16	17	15	18	17	16.5
Lateral Thigh	17	17	17	19	17	18	16	15	10	16.1
Lateral Hindleg	27	17	17	17	19	18	13	16	15	16.5
Animal Average	15.3	13.5	13.8	13.7	13.8	14.	12.7	12.7	11.7	

* Each figure represents an average of five counts.

in the nine body areas. While there are too few animals to form any definite conclusion, these data suggest that the hair might be less dense in males than in females. Each lateral group usually contains three primary hairs surrounded by six to twelve lanugo hairs (Plate III). These findings agree with the description given by Trautmann and Fiebiger (1957) for carnivores. From twelve to twenty hairs are seen diverging from a common opening. On oblique sections of the dorsal aspect of the hairy skin areas there are eight or nine groups of hairs per square millimeter. Toward the ventral surface and the lower extremities this number increases to twelve or sixteen groups per square millimeter. The hair arrangement is essentially the same over the entire body with the exception of the dorsal supracaudal area of the tail where the array is less complex (Plate XII). These hairs of the tail appear larger than those of other areas of the skin. The supracaudal area does not extend the entire dorsal length of the tail but is restricted to a small central area as indicated on Figure A. This is similar to the supracaudal area in the dog, described by Lovell and Getty (1957).

Follicular Folds

Follicular folds first described by Goldsberry (1955) in the cow are present in the upper portion of the guard hair follicle only (Plate XIII). The folds appear to be undulations of the stratum corneum. Cells resembling the stratum spinosum

are observed beneath this layer. Goldsberry (1955) reported from ten to twenty-five follicular folds in the cow. From five to ten folds are observed in the follicle of the cat. Because of the opening of the sebaceous glands into the hair follicle just proximal to these folds, it is possible they bear some relation to the expulsion of oil to the surface. Future research may show that these folds are present in, and have specific numbers and characteristics for each species of mammal.

Tactile Hairs

The tactile or large sinus hairs (vibrissae) contain a cushion like thickening of connective tissue surrounding a large smooth walled annular blood sinus. This sinus is usually filled with blood and measures approximately 900 microns in diameter (Plates XIV and XIX). Striated muscle fibers are associated with tactile hairs (Plate XVI).

Mm. Arrectores Pilorum

The arrectores pilorum are bundles of smooth muscle present in all sections of the hairy skin. They are most highly developed on the dorsal lumbar, sacral, and tail regions. They measure as much as 150 to 220 microns in diameter at the base of the attachment to the follicle (Table III). These muscles may be seen branching as they approach the epidermis (Plate XV). The smallest muscles are found in the lateral fore and hindleg. The muscle attaches to

the lower portion of the guard hair follicle and appears to extend to the adjacent hair clusters.

TABLE III. ARRECTORES PILORUM MUSCLES*

Dorsal Neck 29-40	Tail Root 40-80
Dorsal Lumbar 150-200	Shoulder 20-45
Supracaudal Area 150-220	Lateral Foreleg 25-30
Flank 25-60	Lateral Thigh 30-60
Ventral Abdomen 25-35	Lateral Hindleg 25-30

*Range of size in microns at the base of attachment to the follicle.

VI. SEBACEOUS GLANDS

The sebaceous glands show a characteristic simple alveolar structure. Differences in size of these glands are very striking in certain areas.

Hairy Skin Areas

The diameter of sebaceous glands in the general hairy skin area ranged from 20 to 75 microns. These empty into the upper portion of the hair follicles around which they are clustered. This is in agreement with Stoss (1906) who found two to three lobulated sebaceous glands surrounding the follicle throughout general body areas. Plate IV illustrates the general size and arrangement of sebaceous glands throughout the hairy skin area.

Areas With Little or No Hair

Metacarpal pad. No sebaceous glands are found in the metacarpal pad. This is similar to the dog as described by Lovell and Getty (1957) and Webb and Calhoun (1954).

External auditory meatus. There are generally large clusters of sebaceous glands in the outer third of the meatus, where the cartilage has infringed on the dermis to form ridges or tubercles resulting in more surface area (Plate VI). No mitotic figures are observed contrary to the report by Montagna (1949). The number of sebaceous glands depends on their location in the meatus. In the outer third there are one to two large clusters per square millimeter in the areas with ridges and tubercles. In the middle meatus, this number is slightly increased, and distinctive crowding is seen in the lower third of the canal nearest the tympanic membrane. Although the largest sebaceous clusters in the external auditory canal measure approximately 300 microns in diameter, a variety of sizes may occur. A similar description was given by Montagna (1949) in the cat, and in the dog by Nielsen (1953).

Upper and lower lip. The sebaceous glands of the lip are large measuring 500 to 800 microns. The larger glands have a somewhat elongated shape (Plates XVI and XIV). The lip also has smaller sebaceous glands associated with the tactile hairs. They are approximately the same size as the sebaceous glands of the hairy skin and are located around the upper portion of the large hair (Plate XIX).

Special Skin Areas

Supracaudal organ. The sebaceous glands of the supracaudal organ are approximately 700 microns in diameter. These are large oval clusters located on the proximal dorsal aspect of the tail. These sebaceous glands usually stain slightly darker than the sebaceous glands in other areas (Plate XII). All other areas of the tail exhibit small sebaceous glands similar to those of other hairy skin.

The upper and lower eyelids. The sebaceous glands of the upper eyelid are larger and more highly developed than those of the lower lid. In the upper eyelid the tarsal glands (Meibomian glands) are arranged in a linear series along the posterior portion. They are oval shaped clusters measuring 450 microns in diameter (Plate XVII).

Prepuce. The sebaceous glands of the prepuce are usually large, ranging in diameter from 100 to 200 microns. They are usually associated with hair follicles in this area.

Teat. The sebaceous glands of the teat are few and occur in isolated groups resembling the sebaceous glands of the hairy skin area in size. Sebaceous glands previously were reported in the teat by Trautmann and Fiebiger (1957).

Scrotum. The sebaceous glands of the scrotum although more dense and slightly smaller, resemble those of the prepuce.

VII. SWEAT GLANDS

In this investigation sweat glands are found in all sections studied with the exception of the planum nasale. Although an intensive search of this area has been made for glands which might be the source of the moisture usually present on the surface, none are seen. This agrees with the work of Lovell and Getty (1957) and Webb and Calhoun (1954) on mongrel dogs. Sweat glands of the cat exhibit two physiological types. They are saccular and coiled apocrine glands occurring over the general body areas and coiled merocrine glands of the metacarpal pads. These resemble those described by Stoss (1906) and Trautmann and Fiebiger (1957) but there is some controversy as to their distribution. In contrast to the above findings, Trautmann and Fiebiger (1957) reported "poorly developed glands of the cat are present only" in the oral region, anus, lower jaw, and foot pads.

Saccular Apocrine

Both small and large saccular apocrine sweat glands occur in the cat. In the hairy skin areas the glands are generally small, with a sac shaped secretory portion. The excretory unit opens into the upper portion of the hair follicle in agreement with Stoss (1906) (Plate XX). These glands are composed of low cuboidal epithelium, a reticular tissue framework and a thin layer of smooth muscle. With

reference to sweat capacity, Marzulli and Callahan (1957) found that the cat did not sweat in any area except the foot pad. It appears that the small sweat glands of the hairy skin area function very little or are completely non-functional. The secretory unit of these glands measures between fifteen and thirty-five microns in diameter. The excretory portion can not always be followed but it is much smaller than the secretory unit. The sweat glands occasionally pierce the arrector pili muscles as illustrated in Plate IV.

The larger saccular sweat glands are found in the supracaudal organ and scrotum ranging from 45 to 110 microns in diameter (Plates XII and XVIII). The larger saccular apocrine glands are essentially the same as the smaller glands except for taller epithelium.

Coiled Apocrine

Large coiled apocrine sweat glands occur in the upper and lower lip, eyelids, anal sac, and prepuce. Saccular apocrine glands are usually found in combination with the coiled glands in most of these sections (Plates XXI and XVII). These glands are large resembling the saccular glands of the supracaudal organ and scrotum. In the upper and lower lip the glands are so extensively coiled that Backmund in 1904 (Speed 1941) concluded that these glands had a special shape. In contrast to these findings in the cat, Webb and Calhoun (1954) reported only coiled apocrine sweat

glands in the lip of mongrel dogs. The sweat glands of the eyelids are less coiled than those of the lips. Nielsen (1953) described large coiled apocrine sweat glands over the entire skin of various breeds of dogs and Webb and Calhoun (1954) reported similar findings in mongrel dogs. In the cat the glands of the general body area are comparatively small and are usually saccular. One may assume that the sweat glands of dogs and cats are generally the same in structure but may differ in certain regions of the body. The large sweat glands of the prepuce are associated with the hair follicles. These glands have tall columnar cells, each bearing a very distinct apex protruding into the lumen of the glands. Similar morphological observations were reported by Nielsen (1953) for the glands of canine skin.

Coiled Merocrine

Small merocrine sweat glands are situated in the subcutaneous fatty tissue of the metacarpal pads (Plate V). These glands are extensively coiled and are similar to those reported for the foot pad of the canine by Nielsen (1953). Merocrine sweat glands were found only in the foot pad in contrast to the apocrine type in all other sections of the skin.

VIII. CERUMINOUS GLANDS

The ceruminous glands are found throughout the external auditory meatus and open upon the surface of the canal or into hair follicles. These glands increase in number in the lower third of the meatus. They are coiled dilated tubular glands similar in structure but larger than sweat glands, measuring sixty-five to eighty-five microns (Plate VII). The epithelium is tall columnar. The ceruminous glands are more numerous than the sweat glands. A similar condition was described by Nielsen (1953) in the canine. Under pathological conditions the ceruminous glands may increase in size five to six times and become filled with cellular debris (Plate II).

IX. SPECIAL BODY AREAS

Teat

The teat of the cat is composed of a hairless external surface with a moderate epidermal thickness, and epidermal pegs. The dermis possesses an abundant amount of collagenous and elastic fibers with dermal papillae. The fiber arrangement is both parallel and horizontal to the epidermis. Situated within these fibers are bundles of smooth muscles and clusters of sebaceous glands. There are seldom more than three or four milk ducts present in any one histological

section but the cat teat may contain as many as seven (Plate XXII).

Prepuce

The prepuce is covered with a thin layer of stratified squamous epithelium resembling that of other body areas. The epithelium lining the prepuce is composed of a layer of stratified squamous epithelium which is usually thicker than that of the general body area, and forms epidermal pegs. The dermal portion is comprised of a large amount of collagenous and elastic fibers and skeletal muscle. Trautmann and Fiebiger (1957) observed skeletal muscle in all domestic animals except the horse and cat. The sebaceous and sweat glands are large and associated with the hair follicles.

Scrotum

The epithelium of the scrotum is less cornified than that of other body areas. The cell layers appear loose and irregular in shape compared to the epidermis in other areas. The connective tissue is very coarse with little distinction between papillary and reticular layers. The sweat and sebaceous glands are large and are associated with the hair follicles (Plate XVIII).

The Anal Sac and Associated Glands

The anal sac is a small spherical structure found lateroventrad to the anus. It is a sacculation of skin

into which sebaceous and coiled apocrine sweat glands open. The large columnar lined sweat glands surround the stratified squamous epithelial lined sac (Plate XXl), and secrete fluid into the lumen. The sebaceous glands form a large cluster and empty into the sac. The underlying connective tissue contains collagenous and elastic fibers which extend parallel to the epidermis and includes some skeletal muscle. A similar description of the anal sac of the dog was given by Nielsen (1953), and Montagna and Parks (1948).

Ear Pinna

The ear pinna is composed of a central core of elastic cartilage and skeletal muscle covered on both sides by a layer of skin. The skin is very thin, has dense connective tissue characterized by a very indefinite division between the fibers of the stratum reticulare. The skin increases in thickness from the tip of the pinna to the opening of the external auditory canal. The skin of both surfaces contains sweat and sebaceous glands with short, crowded, excretory and secretory units due to the presence of the cartilaginous septum. The hair distribution on the convex side is usually dense similar to other hairy skin areas. The concave surface has very sparse and fine hair except toward the rostral border. Occasionally, single follicles are observed resembling those of the external auditory canal.

SUMMARY AND CONCLUSION

Skin specimens were studied from twenty-seven body areas including the external auditory canal. Five mature females, three noncastrated mature males, one incomplete female, and one immature male were studied. Selected skin sections were taken from ten other cats.

Hairy Skin Area

The thickest areas are the dorsal neck, lumbar, and sacral regions. The thinnest areas are the lateral hindleg, thigh, and lower foreleg. The skin thickness decreases from dorsal to ventral and proximal to distal, with the maximum being 1905 and minimum 374 microns. The epidermis in the hairy skin averages 20 to 30 microns. Microscopic hairless integumentary papillae are found in the hairy skin.

Areas with Little or No Hair

The thickest epidermis 900 microns is observed in the metacarpal pad, although that of the planum nasale and lip are well developed. Specialized epidermal areas usually rangefrom 17 to 60 microns but an occasional thickness of 100 microns is observed in the anal sac lumen.

Sex and Age Differences

The only sex difference is observed in the fat layer of the skin. This layer in females appears better developed

than in males. The skin of the one immature cat is thinner and possesses a greater amount of connective tissue. These tissue fibers are smaller and appear more dense than the mature specimens. The microscopic hair population in oblique sections is more dense per square millimeter in the immature animal than the mature specimens.

Specific Epidermal Layers

The epidermis of the cat skin is usually composed of four layers, the stratum lucidum being absent from most hairy skin. The stratum corneum is usually present in all areas measuring 3 to 20 microns in hairy skin and 15 to 35 microns in nonhairy skin. This layer may become thickened in the external auditory meatus contributing to an abnormal condition. The stratum lucidum is usually absent in all hairy skin, ear canal, and lip, but is present in the anal sac, foot pads, and planum nasale. The stratum granulosum consisting of one or two layers is present in most body areas. The thickest layer is found in the metacarpal pad with 4 to 8 layers and the planum nasale with 3 to 4 layers. The teat and scrotum exhibit very prominent cytoplasmic granules in this layer. The stratum spinosum is always present showing the greatest variation in the number of cell layers. These layers range from one to two in hairy skin to as many as 38 in the nonhairy foot pad. Tonofibrils are more prominent in thick nonhairy than in hairy areas. The stratum cylindricum is

composed of one layer of darker staining cells. Few mitotic figures are present. These cells usually appear tall columnar but variations in shape may occur where the epidermis is less stratified. Epidermal pegging is present in the lip, planum nasale, metacarpal pad, teat, and prepuce.

Pigment

The skin pigment is concentrated in the epidermal layers in areas with little or no hair and in individual hairs in the hairy skin. No pigment is found in the dermis or epidermis in the hairy skin, but is found in the epidermis of the teat, scrotum, prepuce, and anal sac. Occasional chromatophores are observed in the dermis of the scrotum.

Dermis

Hairy skin. The papillary layer is composed of fine collagenous fibers which usually run parallel to the epidermis and appear more uniform than the fibers of the stratum reticulare. Elastic fibers form a fine interlacing network with single fibers occasionally observed. The stratum reticulare possesses dense collagenous fibers approximately three times larger than fibers of the stratum papillare. These fibers form bundles, encircle hair follicles and extend in all directions. Elastic fibers increase, anastomose and occasionally appear to adhere to the sides of large collagenous fibers. Elastic

fibers are more abundant where arrector pili muscles attach and where the skin is more flexible. No dermal papillae are observed in the hairy skin areas. The pinna is characterized by two thin skinned surfaces separated by an elastic cartilage support.

Areas with little or no hair. The external auditory meatus exhibits both layers of the dermis but the fiber arrangement may be altered by the size and number of glands present in the three divisions of the external auditory canal. The stratum papillare shows the same general morphology as in other areas. The fibers are small and extend in the same manner as described in the hairy skin. The stratum reticulare becomes very dense as it fuses with the perichondrium of the elastic cartilage. Elastic fibers appear larger and more numerous in the lower third of the meatus. Few fibers are observed in sections showing hyperplasia. The metacarpal pad has a papillary layer with closely arranged prominent dermal papillae, and a less developed reticular layer is present. Thick collagenous and elastic fibers comprise the well developed subcutis.

The planum nasale has thick well developed collagenous and elastic fibers. The fibers of the papillary layer are very small forming a distinct papillary body. The stratum reticulare is composed of unusually large fibers as compared with the papillary layer. Specialized nerve structures are present in the lip, planum nasale, and metacarpal pad. The lip has very sparse connective tissue.

Hair

The hair of the cat occurs in clusters of two, three, four, or five groups bunched around a central guard hair. Groups of two and three are most common on the dorsal, back, and tail region; and four and five on the ventral surface and lower extremities. Twelve to twenty hairs diverge from a common opening. Hair group density is less per millimeter on the dorsal surface and increases in density toward the ventral surfaces and lower extremities. Follicular folds first described by Goldsberry (1955) are present only in the upper portion of the guard hair follicle.

Mm. Arrectores Pilorum

These muscles are the most highly developed on the dorsal lumbar, sacral, and tail regions. This seems to be correlated with the elevation of hair in these regions. In skin where little or no hair elevation occurs the muscles are less developed as on the dorsal neck, ventral abdomen, and lower extremities.

Sebaceous Glands

Hairy skin areas. Sebaceous glands ranging from 20 to 75 microns in diameter form clusters and empty into the upper portion of the hair follicle in the general body areas. In the glands of the supracaudal organ are exceptionally large measuring approximately 800 microns.

Areas with little or no hair. The sebaceous glands of the lip are also large measuring 500 to 800 microns. The

glands of the lip are usually elongated while the supracaudal glands are oval. Small sebaceous glands are associated with the tactile hairs. No sebaceous glands are found in the planum nasale or metacarpal pads. Sebaceous glands of the external auditory meatus and upper eyelid measure from 200 to 450 microns in diameter. The tarsal glands are usually consistent in size but the glands of the external auditory meatus vary in size. Sebaceous glands of 100 to 200 microns in diameter are associated with hair follicles in the prepuce and scrotum. Sebaceous glands of the external auditory meatus, teat, and the tarsal glands may occur independently of hair follicles.

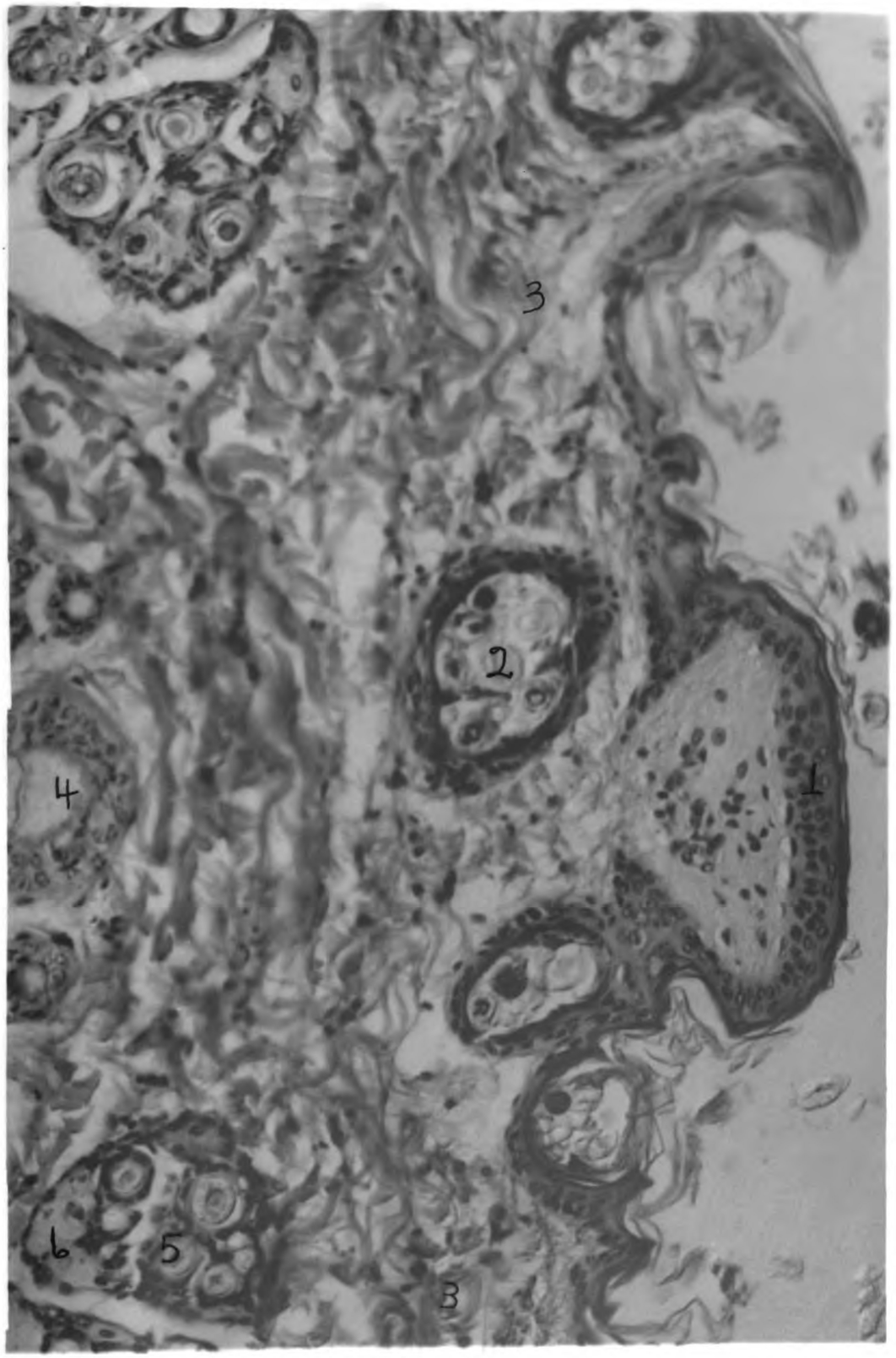
Sweat Glands

Sweat glands are found in all sections studied with the exception of the planum nasale. They exhibit two physiological types (1) saccular and coiled apocrine glands occurring over the general body areas, and (2) coiled merocrine glands of the metacarpal pad. Both large and small saccular glands occur in the hairy skin areas, supracaudal organ, and scrotum. Both saccular and coiled apocrine glands are found in the upper and lower lip, eyelids, anal sac, and prepuce. Ceruminous glands are found throughout the external auditory meatus.

PLATE I

Oblique section through an integumentary papillae in the hairy skin. H. and E. 280X.

1. Integumentary papillae.
2. Numerous follicles per group.
3. Indefinite stratum papillae and stratum reticulare.
4. Large guard or central hair.
5. Lateral and lanugo hairs.
6. Sebaceous glands.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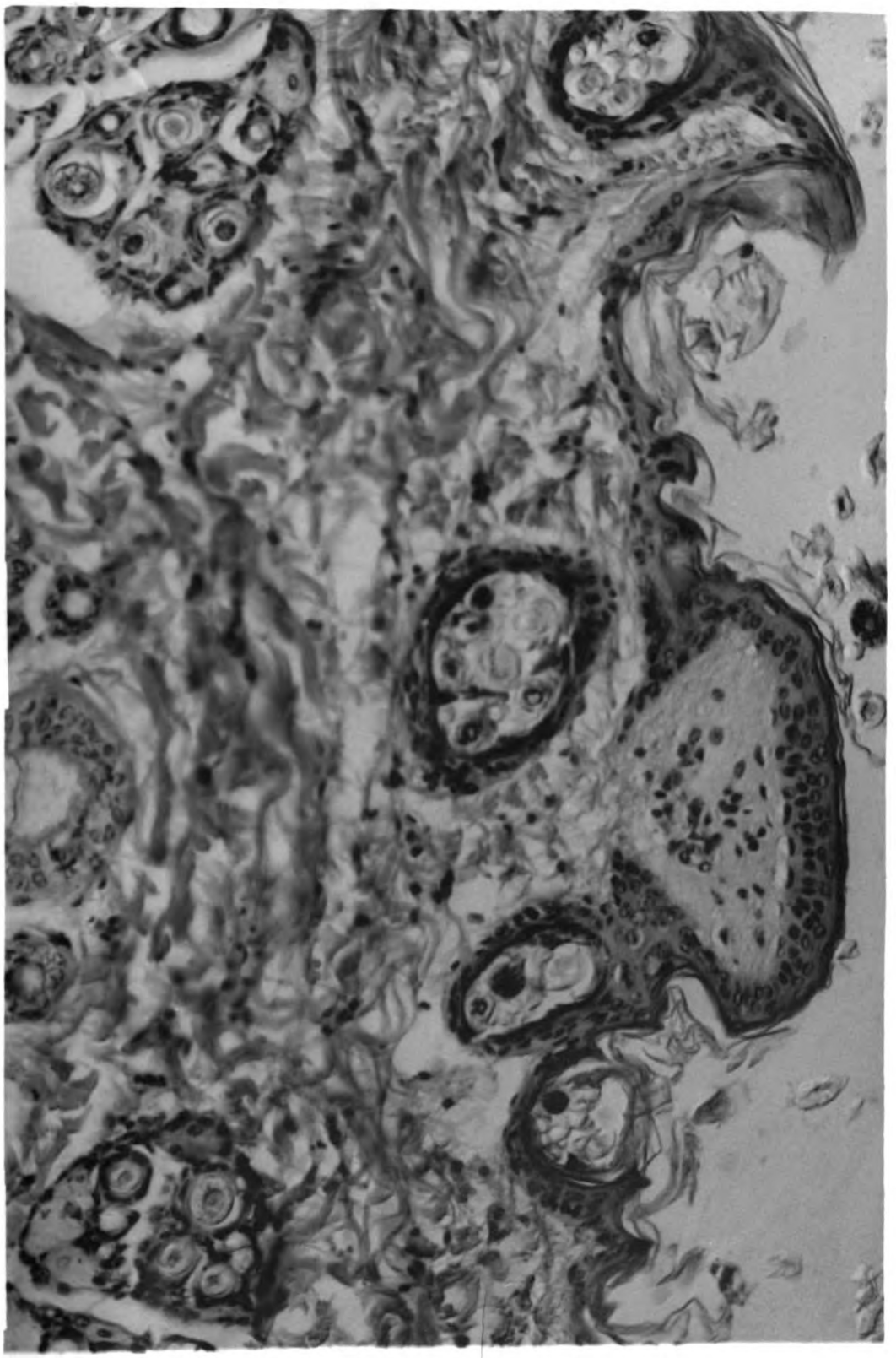

PLATE II

Section from lower third of external auditory meatus showing hyperplastic epidermis, distended ceruminous glands, calcium deposits, and degenerate sebaceous glands. Plate VII shows the normal in the same area. H. and E. 250X.

1. Stratum spinosum.
2. Degenerate sebaceous glands.
3. Modified ceruminous glands.
4. Calcium deposits.
5. Stratum cornium.

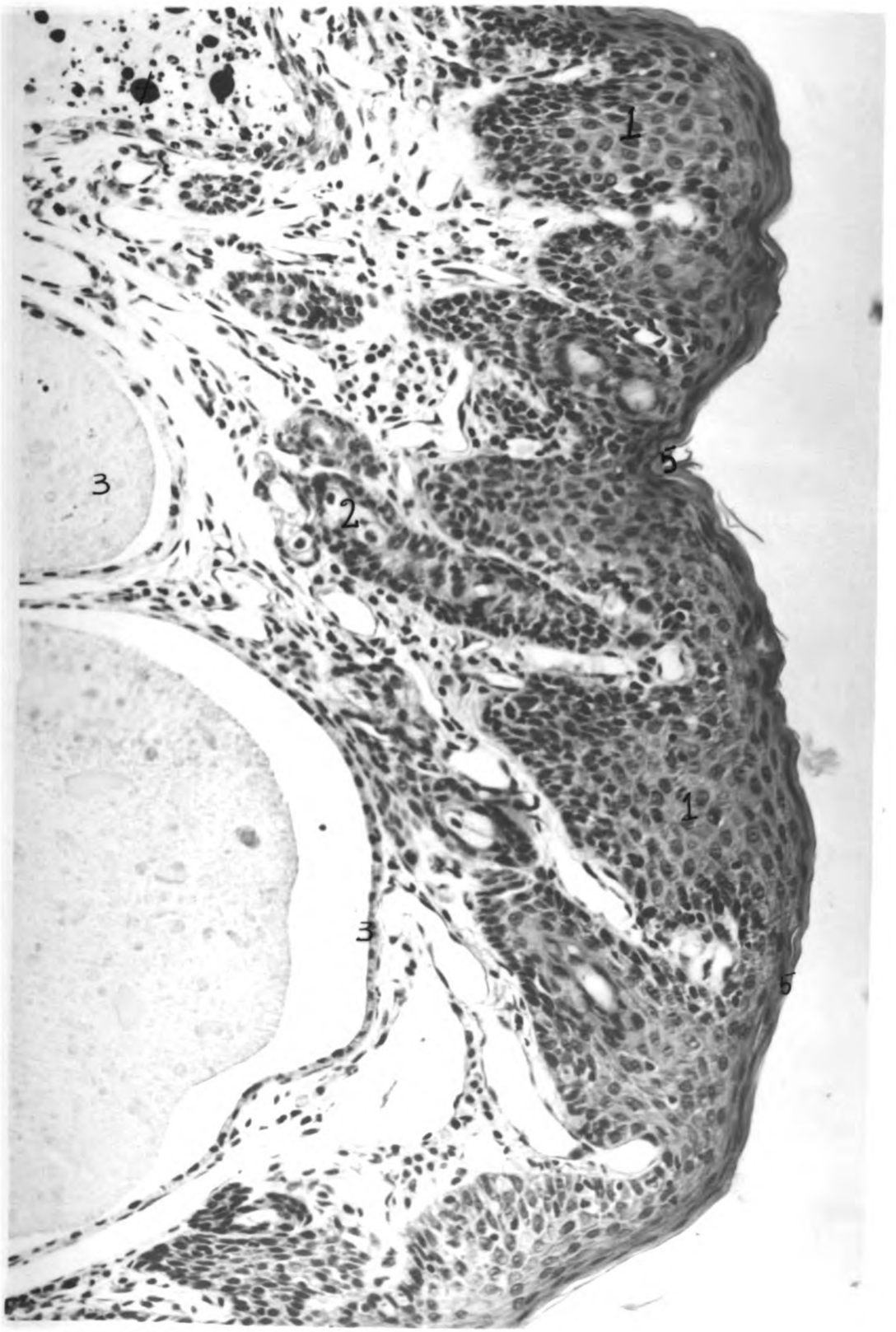
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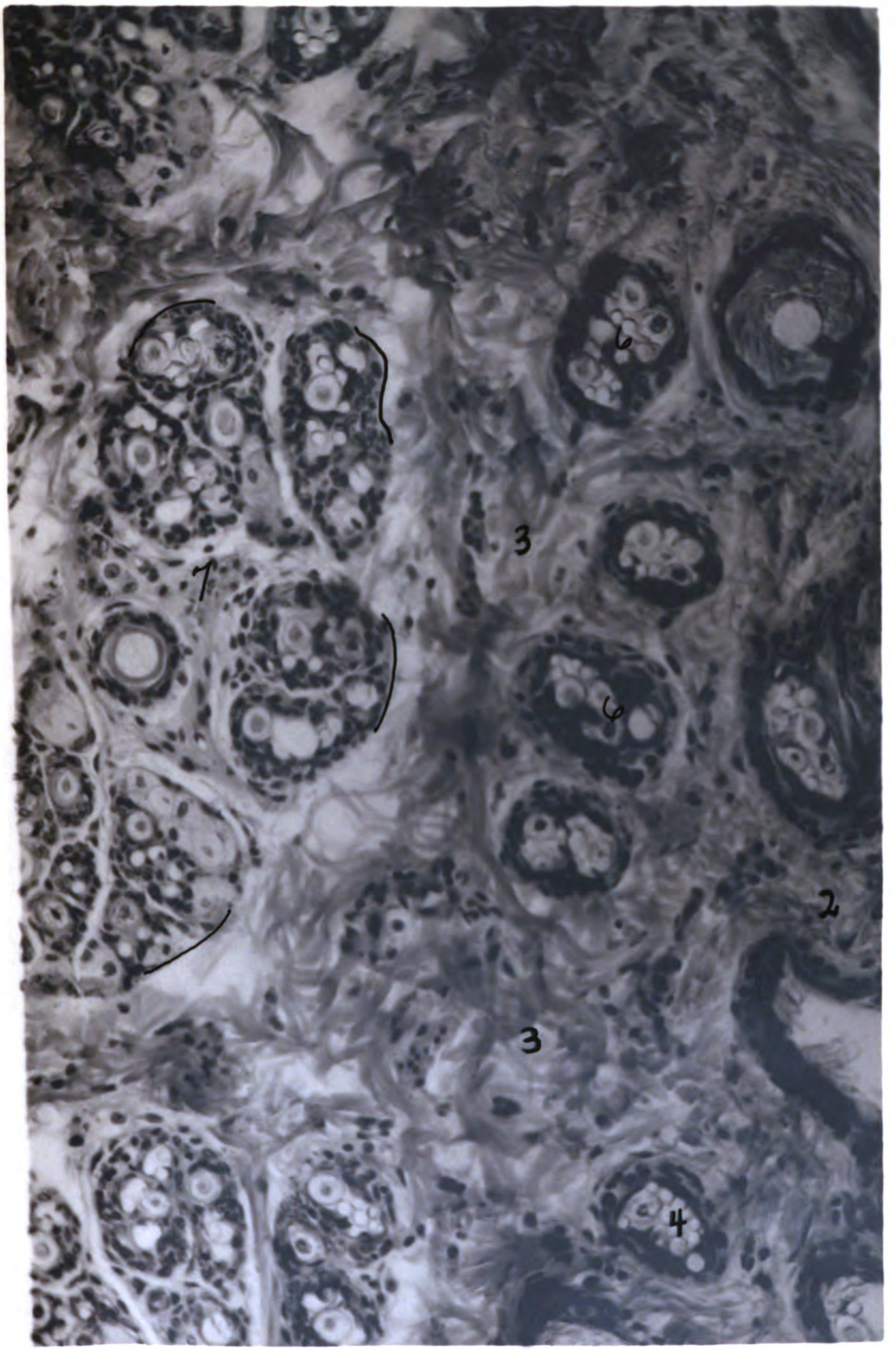
PLATE III

A section from the dense hairy skin area of the lateral lower leg. H. and E. 280X.

1. Epidermis.
2. Stratum papillare.
3. Stratum reticulare.
4. Lanugo hair.
5. Large connective tissue fibers.
6. Typical hair group showing three primary hairs and twelve lanugo hairs.
7. Four to five groups around a central guard hair.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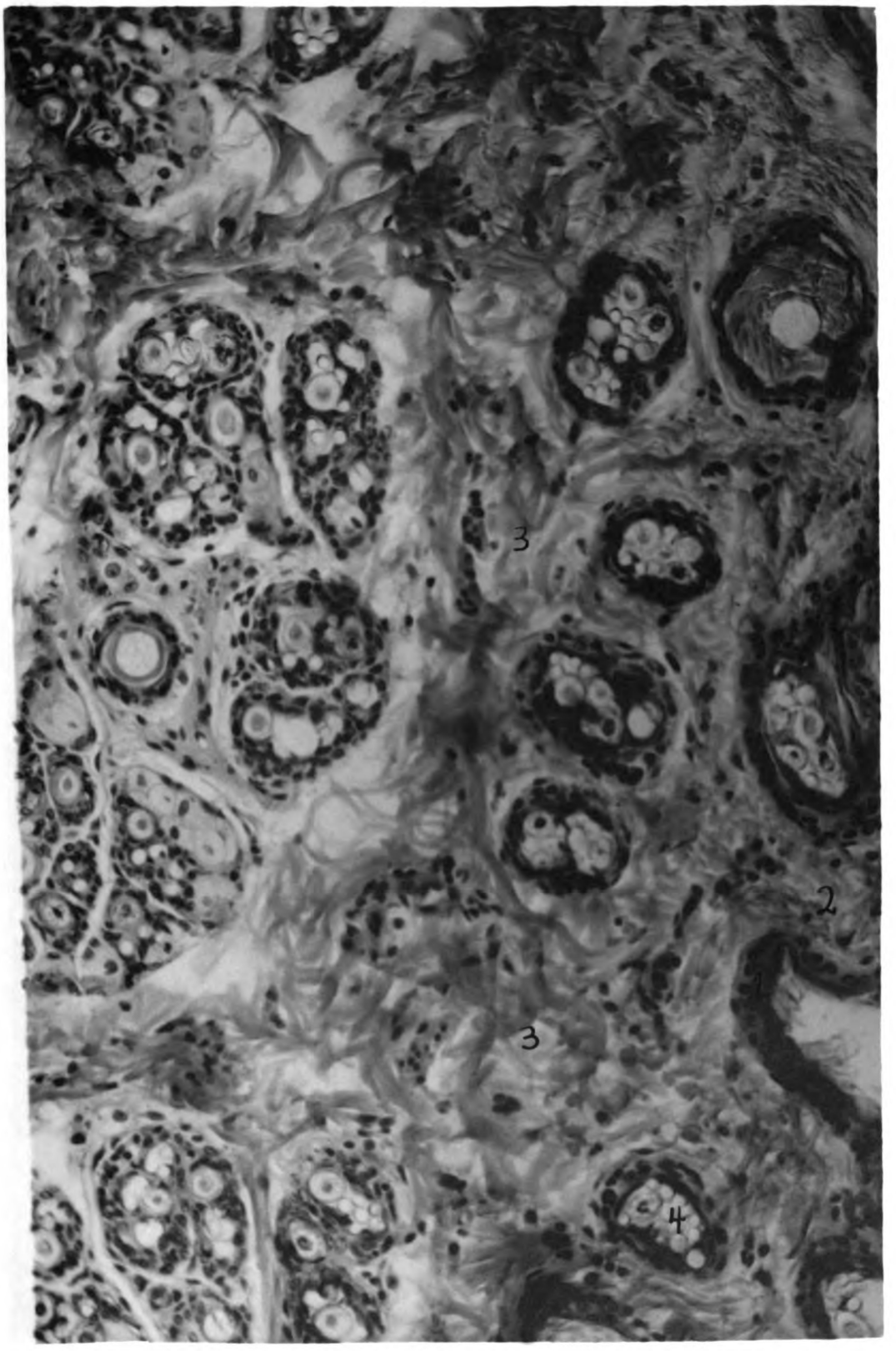
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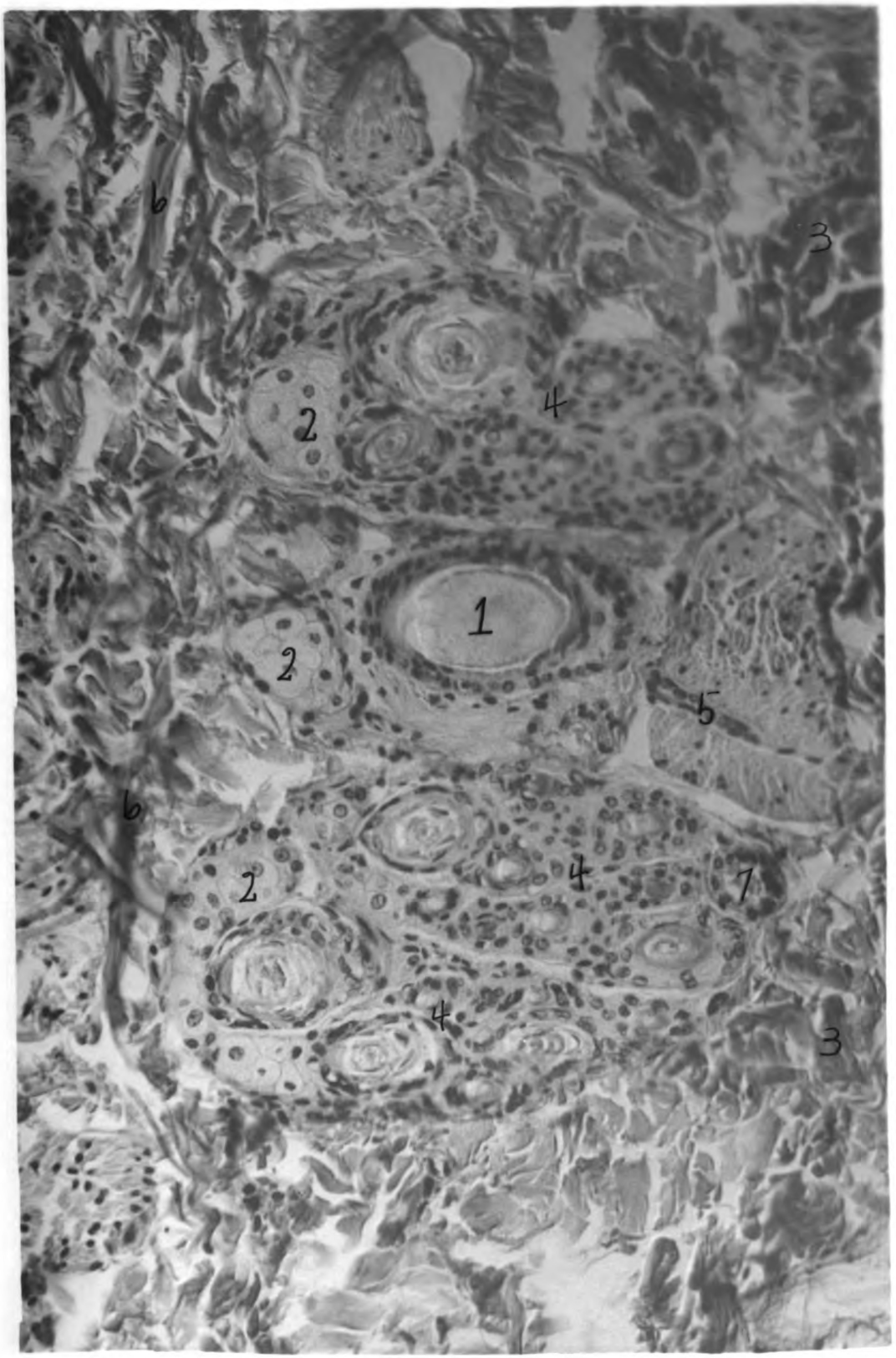
PLATE IV

Section through the dorsal lumbar region representative of the hairy skin of the entire back. Note the size of the sebaceous glands, also sweat gland traversing the arrector pili muscle. H. and E. 360X.

1. Large guard hair flanked by two clusters or groups.
2. Sebaceous glands.
3. Large bundles of collagenous fibers in the stratum reticulare.
4. Lateral follicle groups.
5. Sweat gland extending through the arrector pili muscle.
6. Collagenous fibers parallel to the epidermis.
7. Sweat duct at the edge of a lateral group.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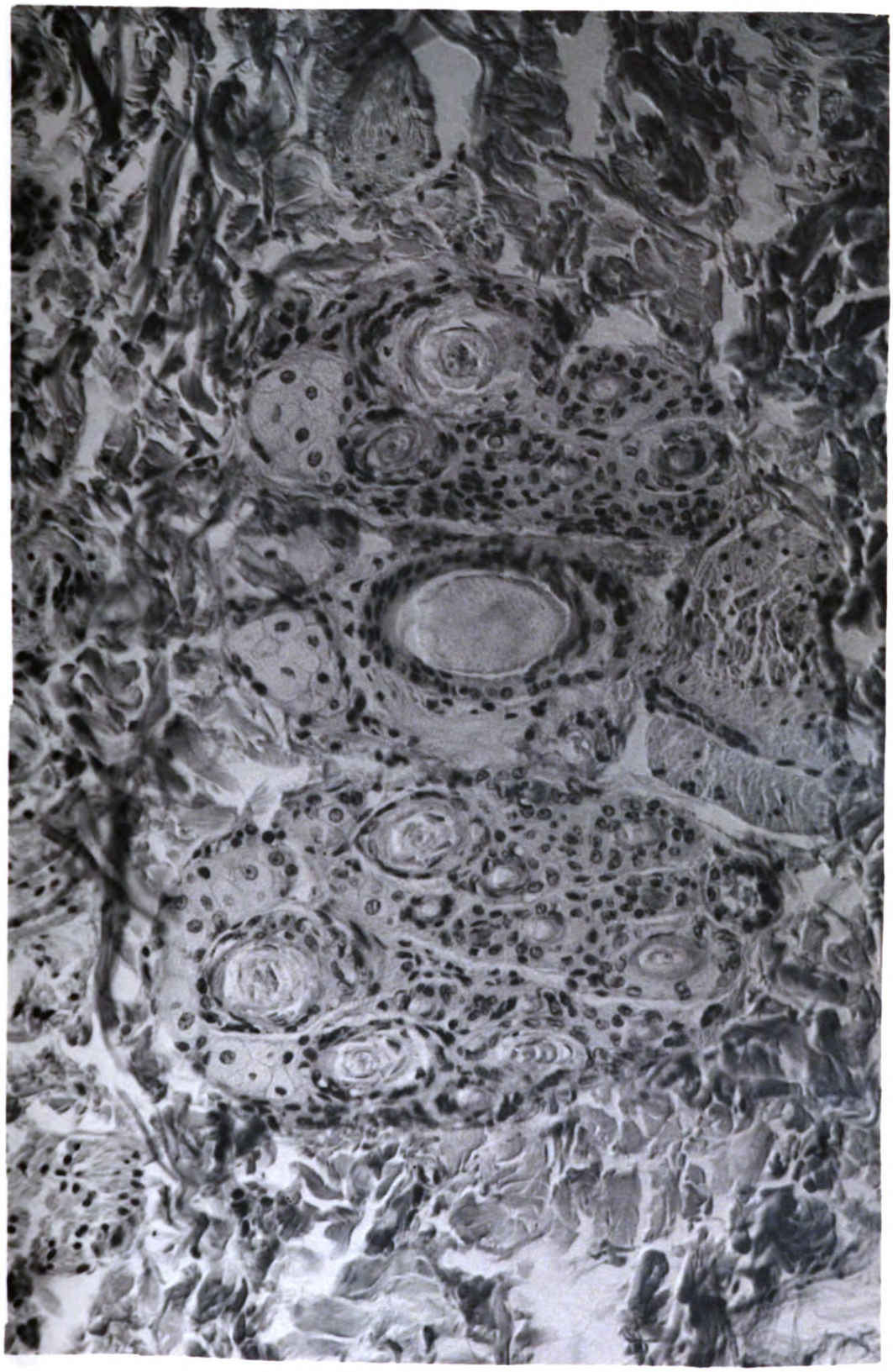
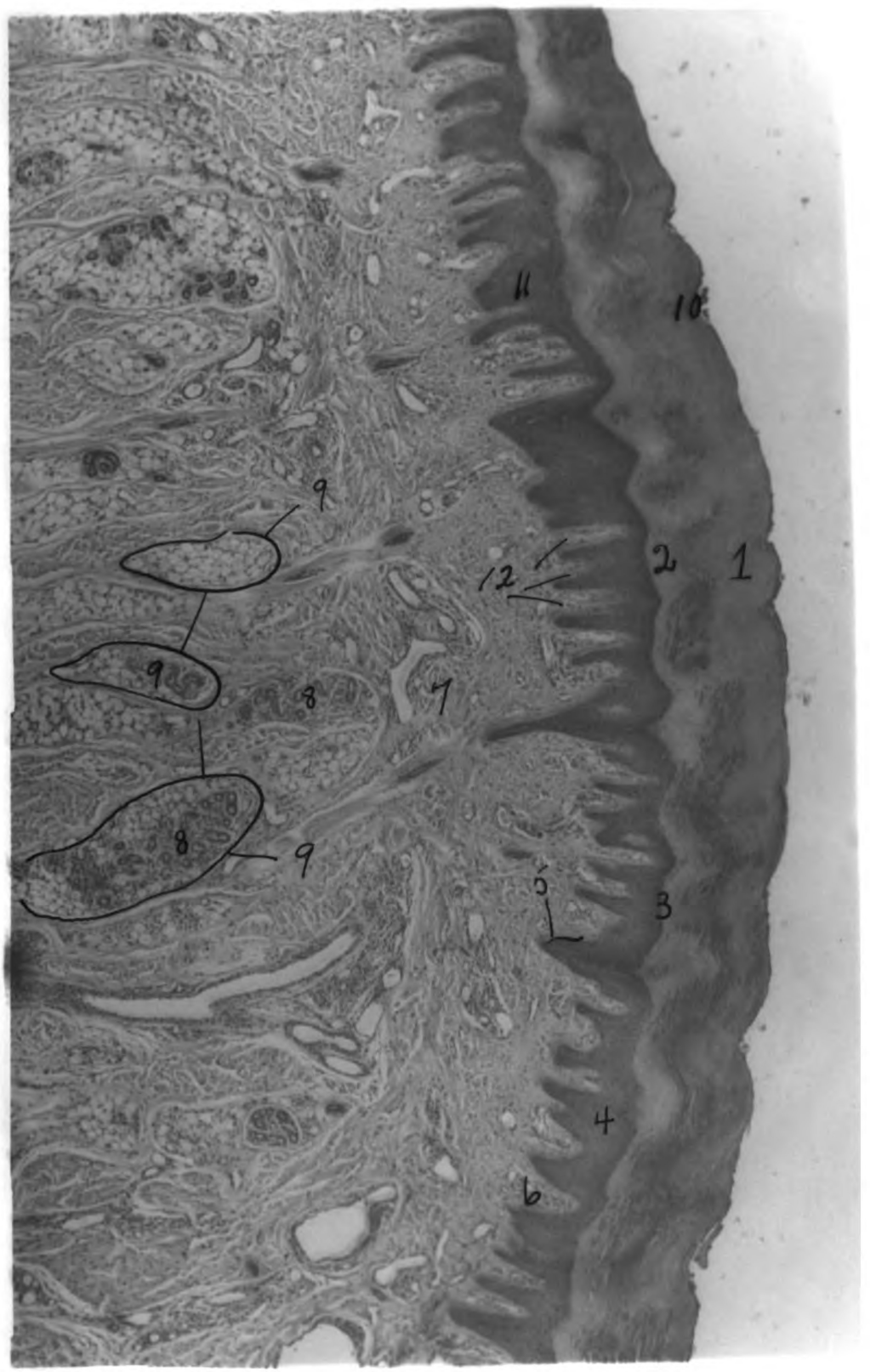


PLATE V

Section through the metacarpal pad. H. and E. 11X.

1. Stratum corneum.
2. Stratum lucidum.
3. Stratum granulosum.
4. Stratum spinosum.
5. Stratum cylindricum.
6. Stratum papillare.
7. Stratum reticulare.
8. Merocrine sweat glands.
9. Panniculus adiposus.
10. Sweat gland ducts opening upon the surface of foot pad.
11. Interpapillary or epidermal pegs.
12. Dermal papillae.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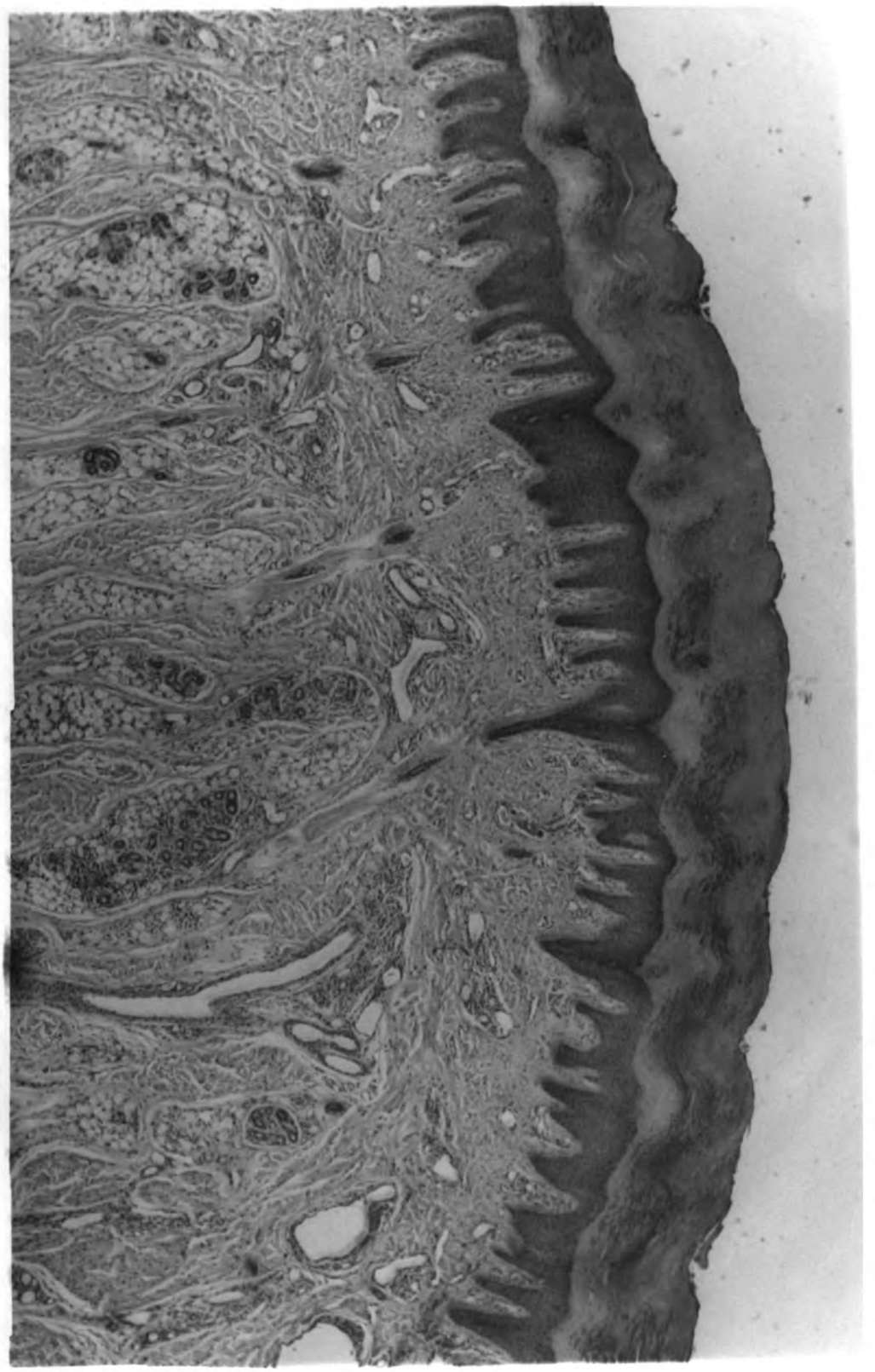

PLATE VI

Section of a tubercle in anthelix showing the large less densely arranged sebaceous glands and fat-laden central portion representative of all ear folds. Compare density of sebaceous glands with Plate VII.

H. and E. 183X.

1. Sebaceous glands.
2. Adipose tissue.
3. Collagenous and elastic fibers.


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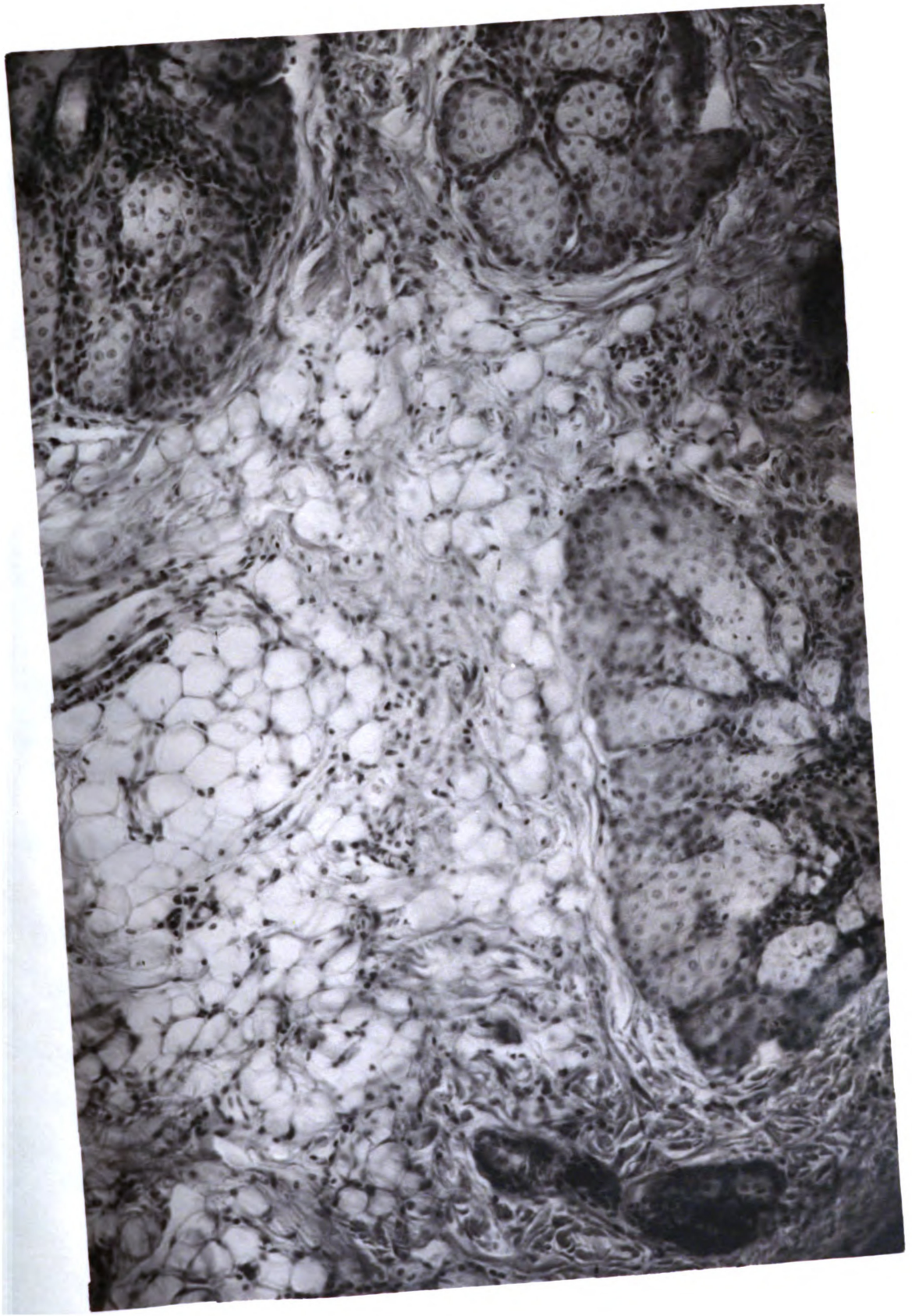

PLATE VII

Section through the lower third of the external auditory meatus showing the normal condition of the area as compared with Plate II in the same region. Note the difference in the thickness of epidermis, sebaceous glands, and the ceruminous glands. H. and E. 242X.

1. Epidermis
2. Sebaceous glands.
3. Ceruminous glands.
4. Sebaceous glands opening upon surface of external auditory meatus.


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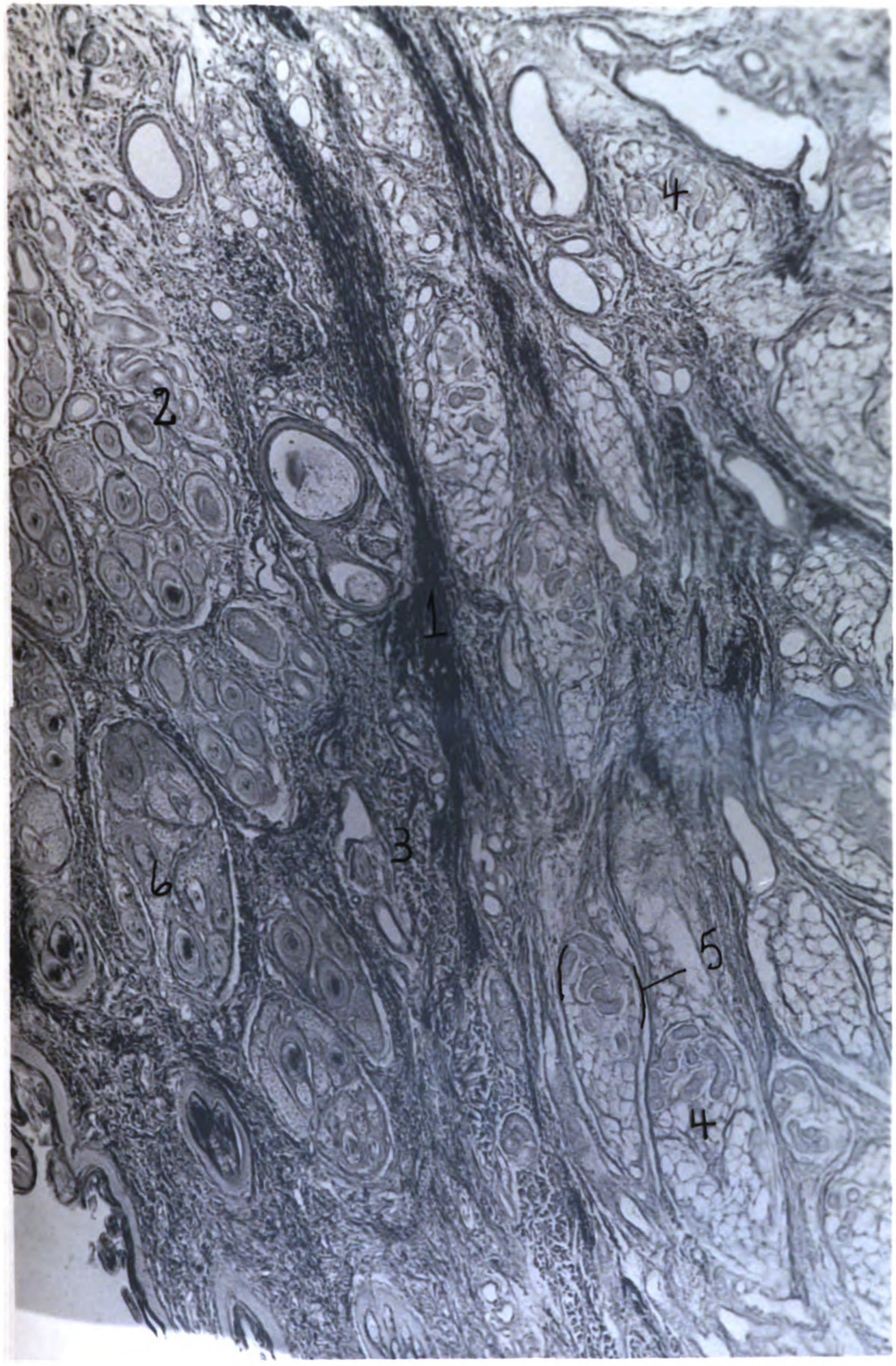
PLATE VIII

Section of the metacarpal pad showing the junction of the hairy and nonhairy subcutis, and distribution of elastic tissue. Weigert's and Van Gieson's connective tissue stain. 256X.

1. Elastic tissue (black).
2. Apocrine sweat glands.
3. Dermis of hairy and nonhairy junction.
4. Coiled merocrine sweat glands.
5. Panniculus adiposus.
6. Groups of hair follicles.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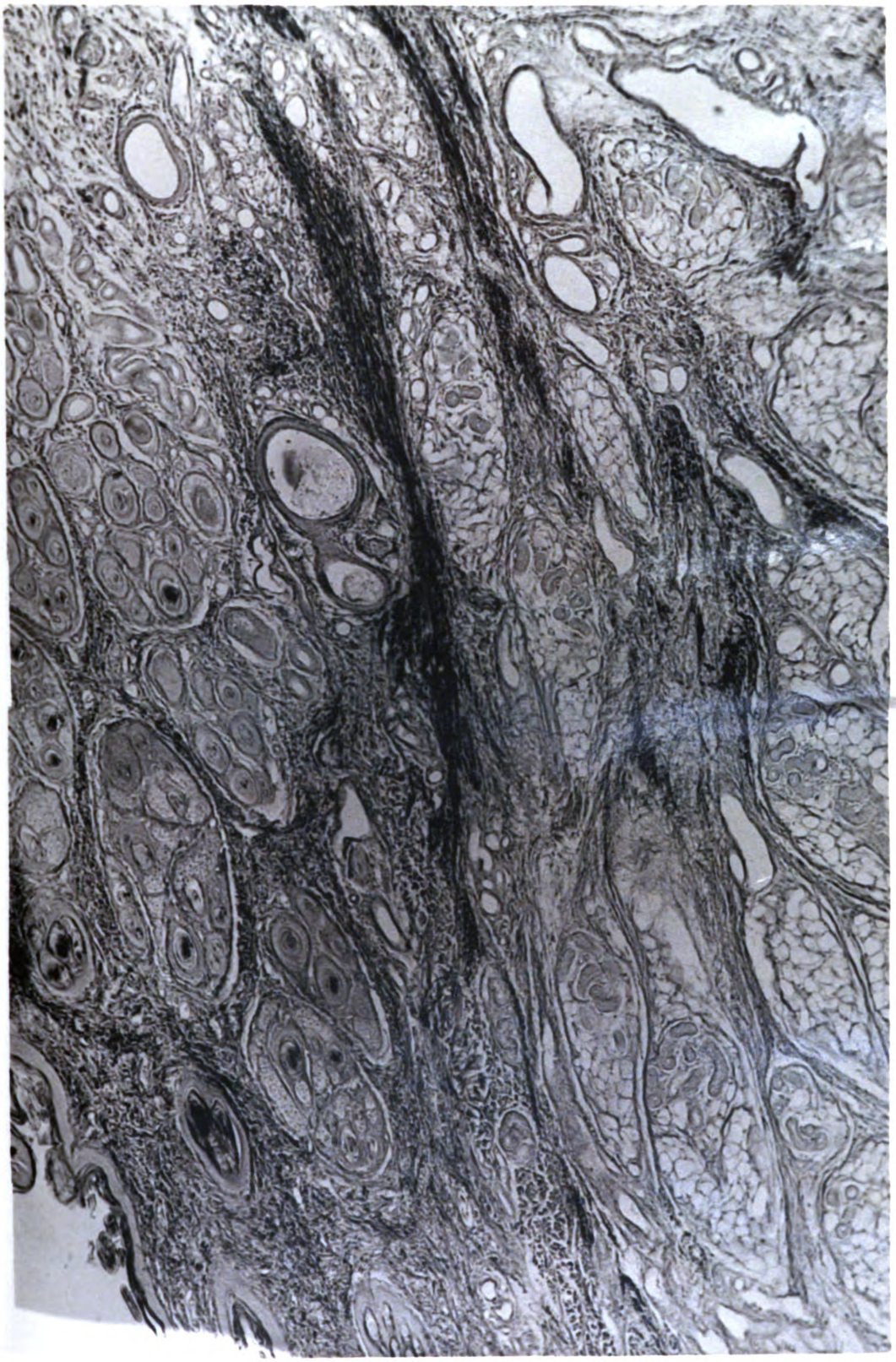

PLATE IX

Section through the nose print area of the planum nasale. Weigert Van Gieson stain, 220X.

1. Stratum corneum.
2. Stratum spinosum.
3. Large collagenous fibers of the reticular layer.
4. Stratum papillare.
5. Stratum granulosum with prominent cytoplasmic granules.

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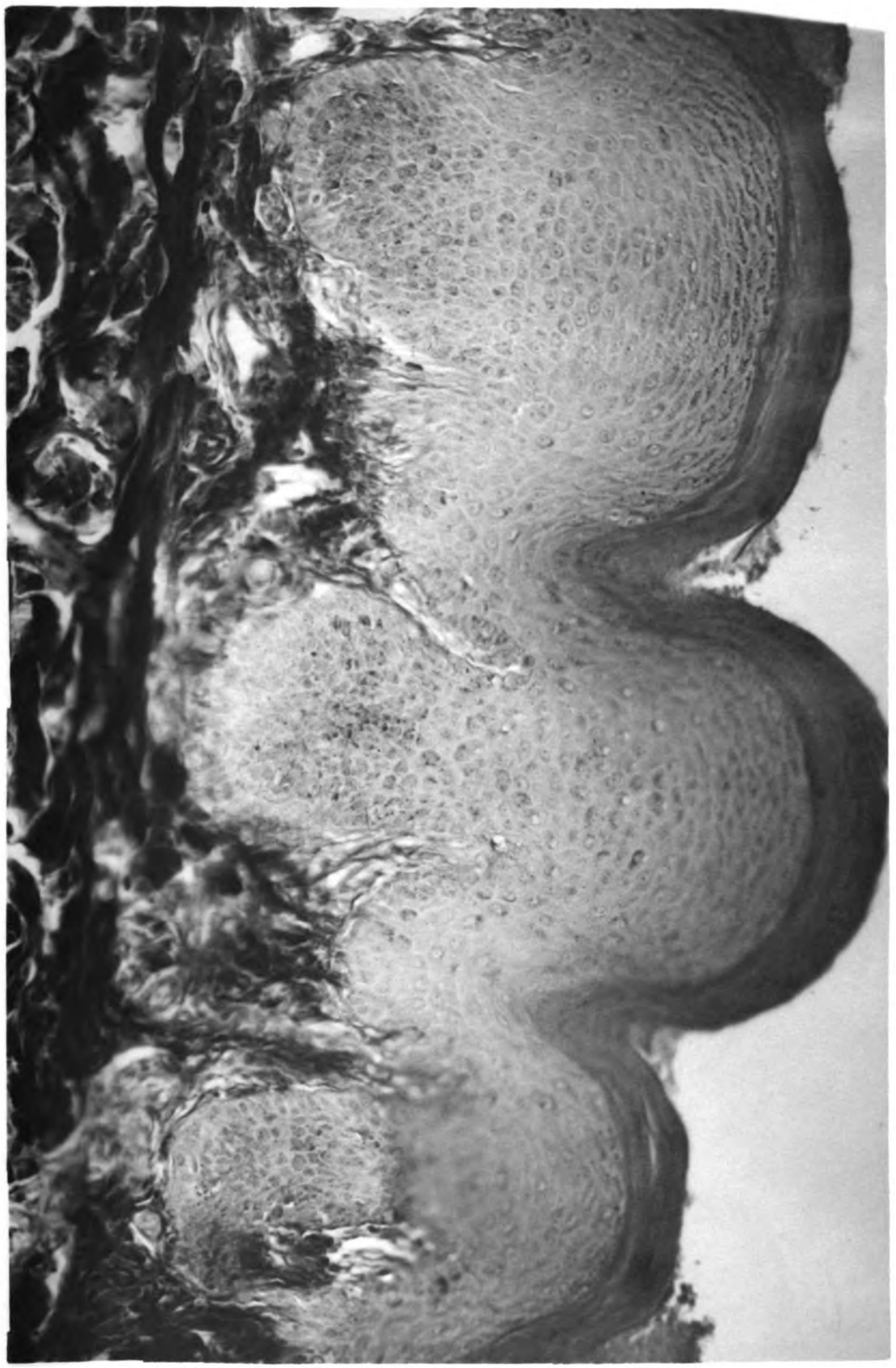
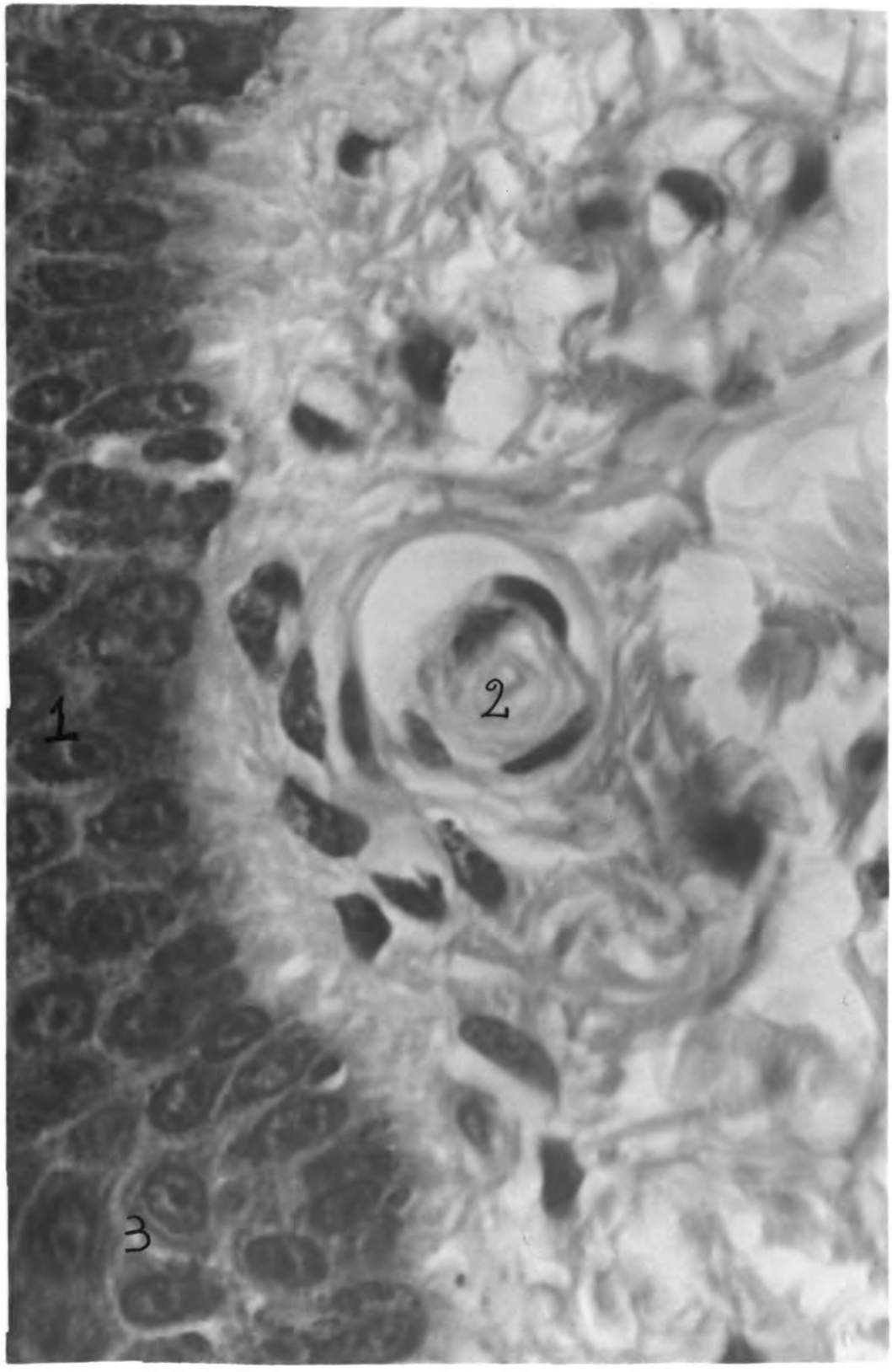


PLATE X

Special nerve ending in the lip of the cat. H. and. E. 1533X.

1. Epithelium.
2. Nerve ending.
3. Intercellular bridges.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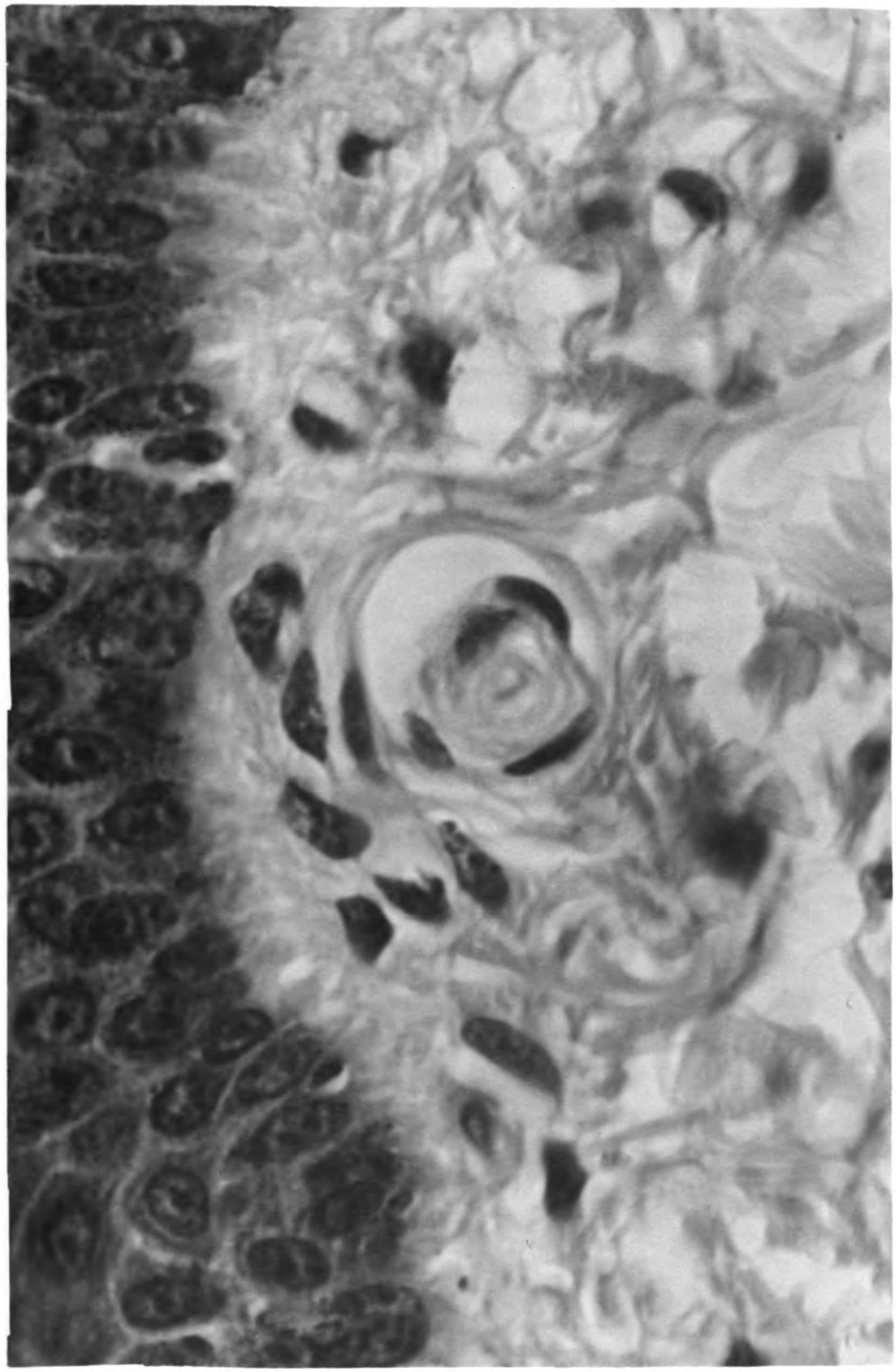
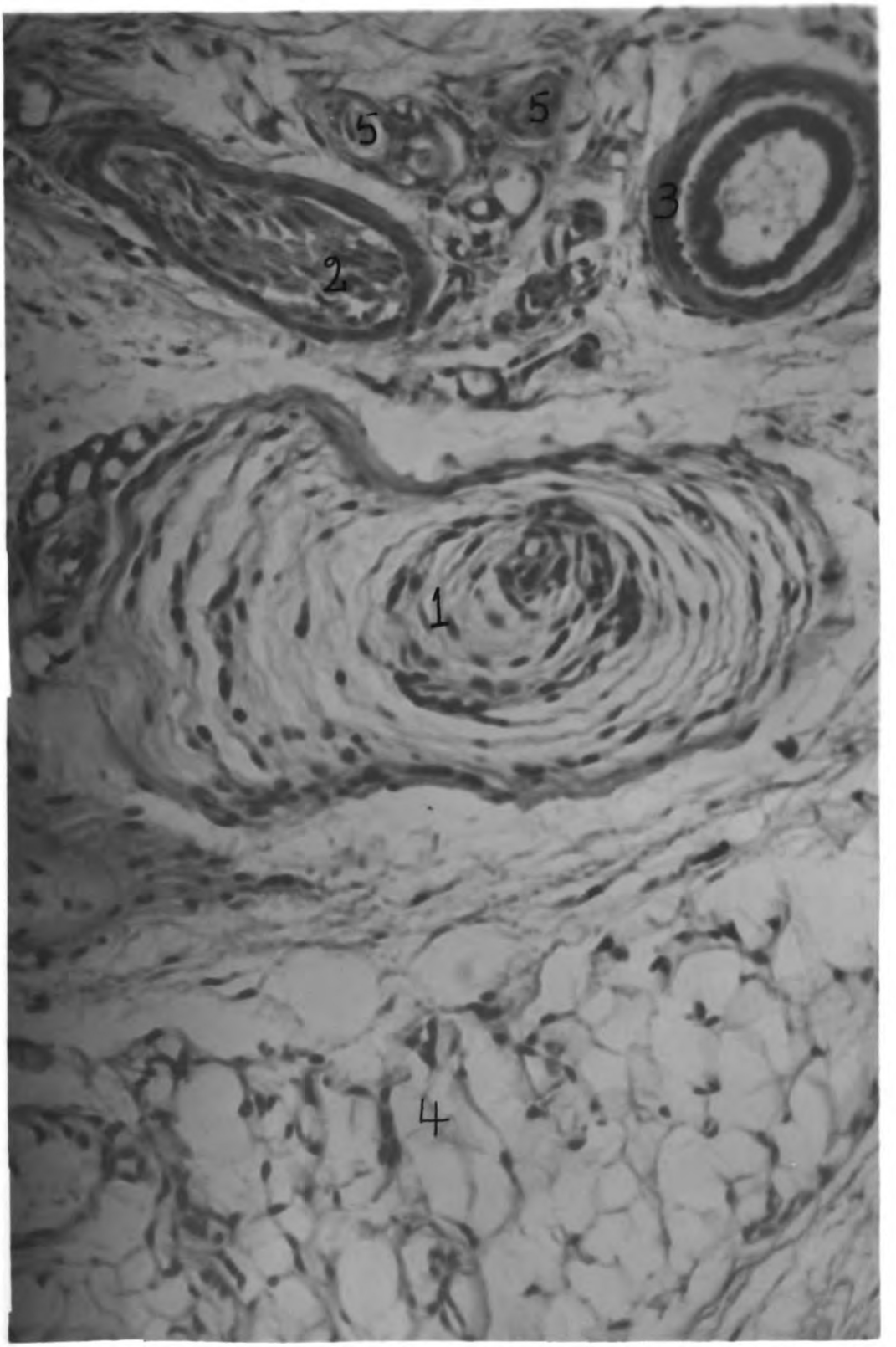


PLATE XI

Section from subcutis of foot pad showing a large Pacinian corpuscle, large nerve trunk, blood vessels and special nerve ending resembling those in Plate X. H. and E. 260X.

1. Pacinian corpuscle.
2. Nerve trunk.
3. Large blood vessel.
4. Adipose tissue.
5. Special nerve structure.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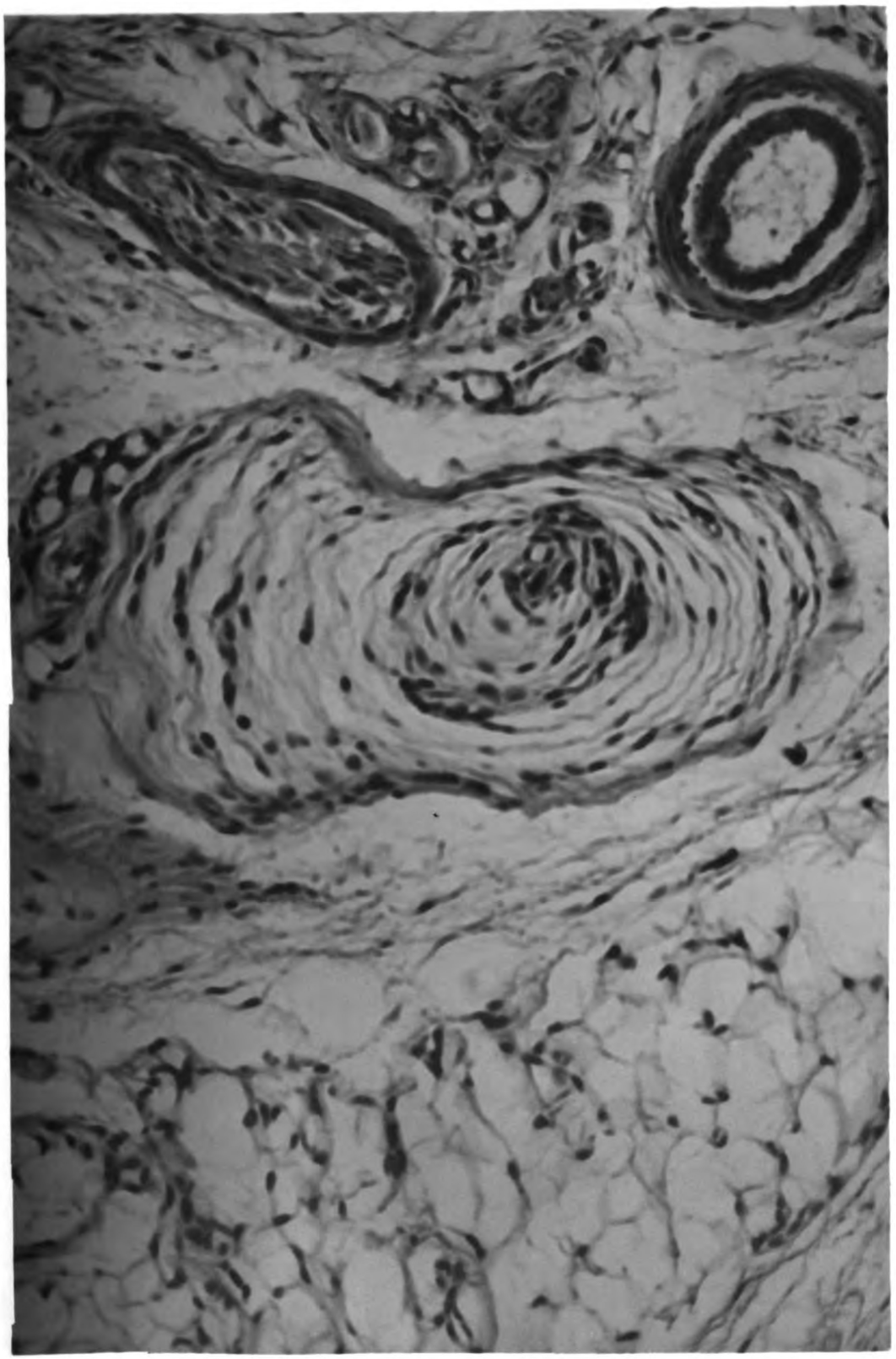

PLATE XII

A longitudinal section through the supracaudal gland area in the proximal dorsal portion of the tail.

H. and E. 13X.

1. Large well developed arrector pili muscle.
2. Large sebaceous glands.
3. Large saccular sweat gland.
4. Large hairs.


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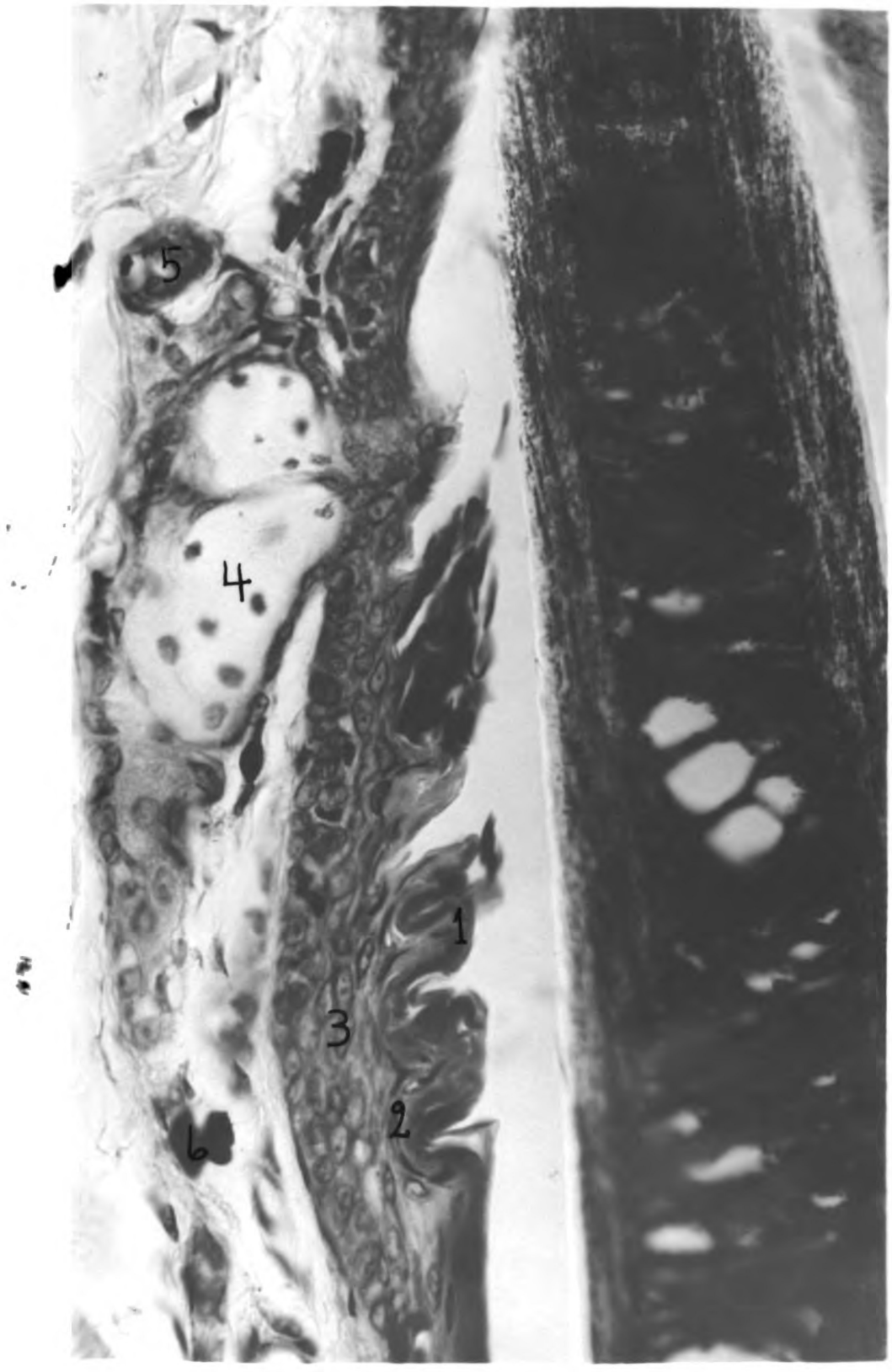
PLATE XIII

Section of guard hairs showing the follicular folds.

Wright's blood stain modified for tissue, 465X

1. Undulations of the stratum corneum showing follicular folds.
2. Granular layer.
3. Stratum spinosum.
4. Sebaceous gland.
5. Excretory duct of sweat gland.
6. Mast cells.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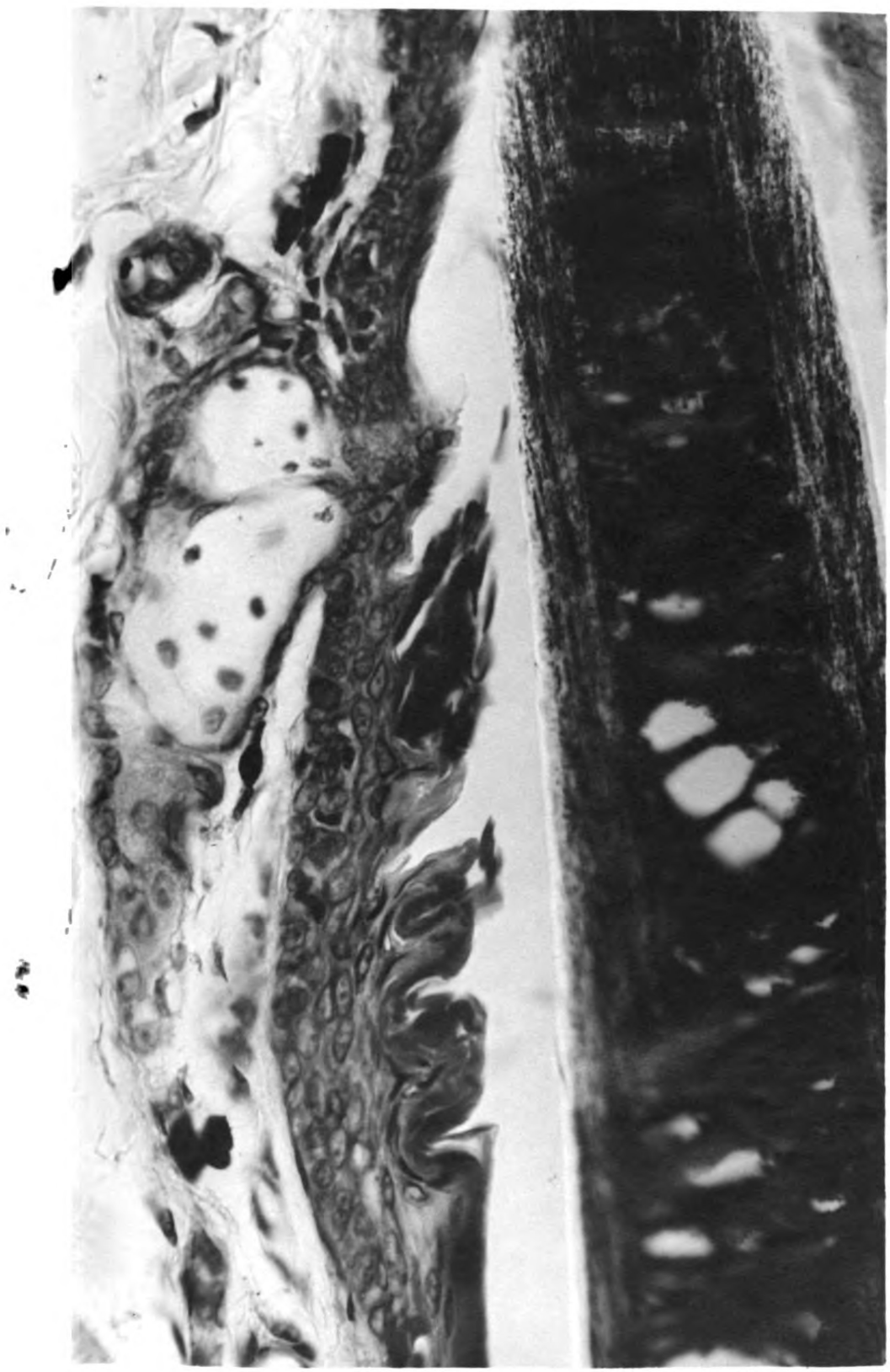

PLATE XIV

Oblique section through the lip. H. and E. 10X.

1. Large sebaceous glands.
2. Blood filled sinus.
3. Large tactile hair in the center of blood sinus.
4. Large sweat glands.
5. Note that the entire stratum reticulare portion of the lip is taken up by the large glands.
6. Smaller hair follicle.
7. Orbicularis muscles.

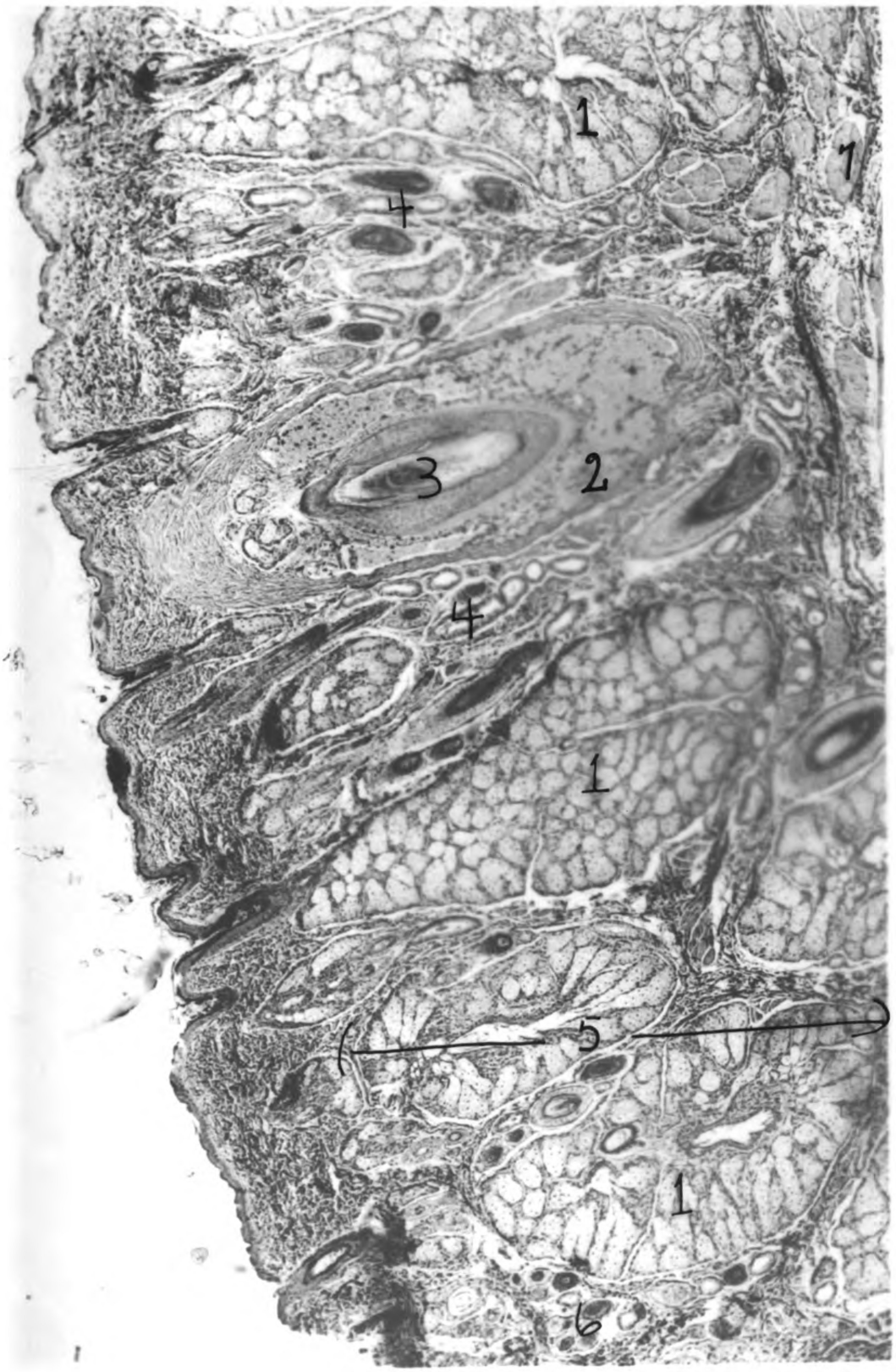
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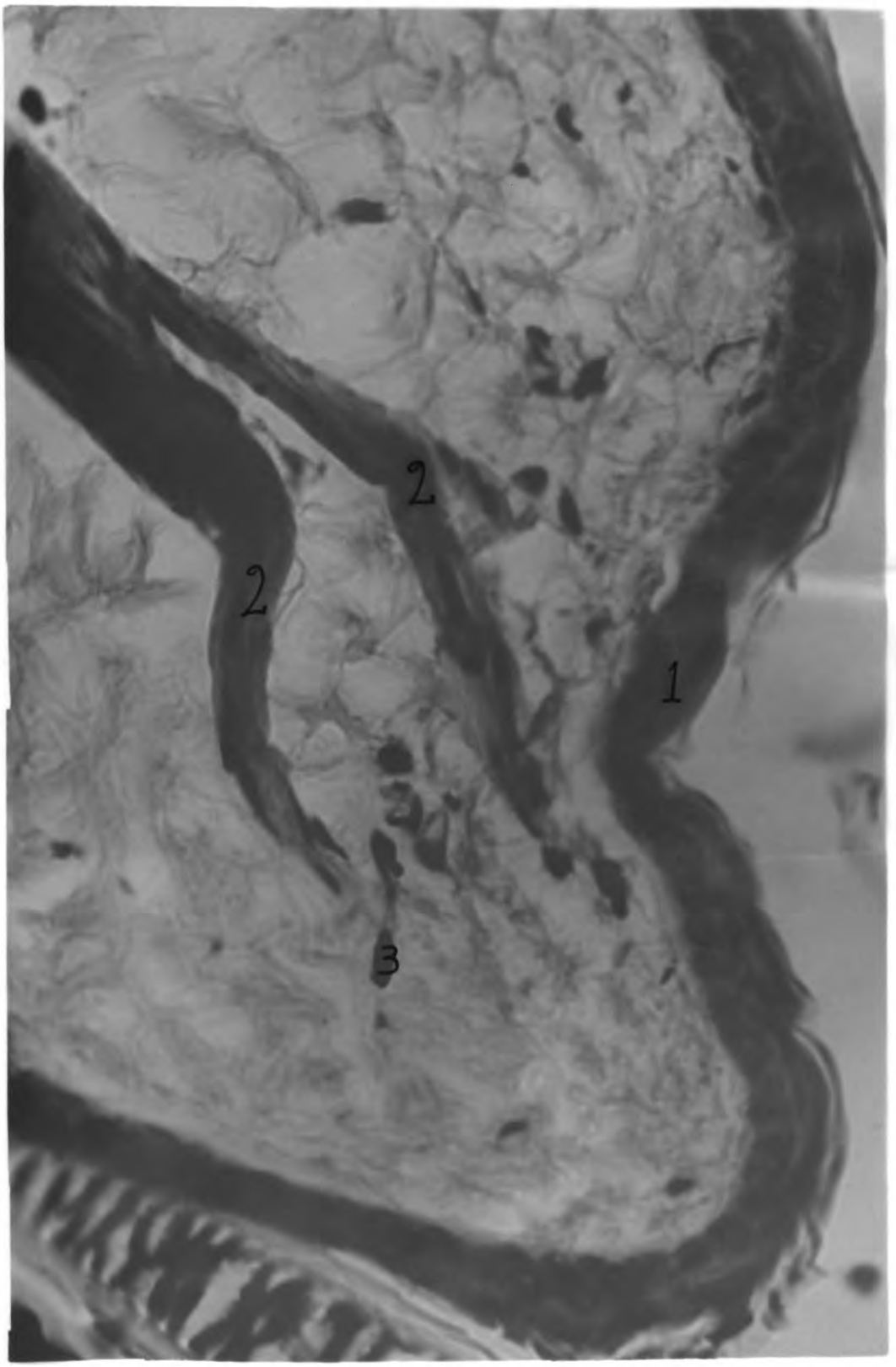
PLATE XV

Longitudinal section from the hairy skin showing branching arrector pili muscle. Wright's blood stain, 464X.

1. Epidermis.
2. Arrector pili muscle.
3. Mast cells.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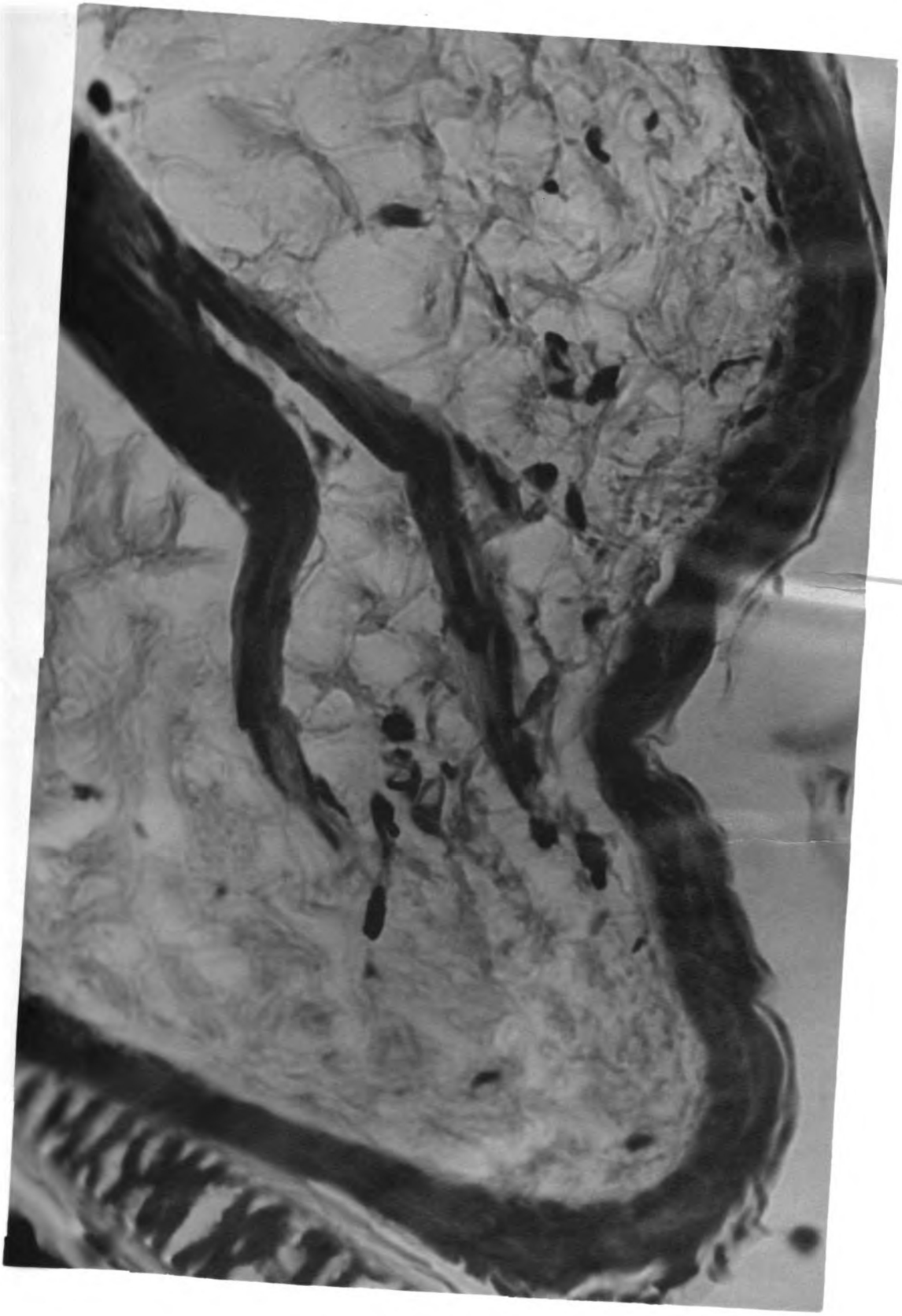
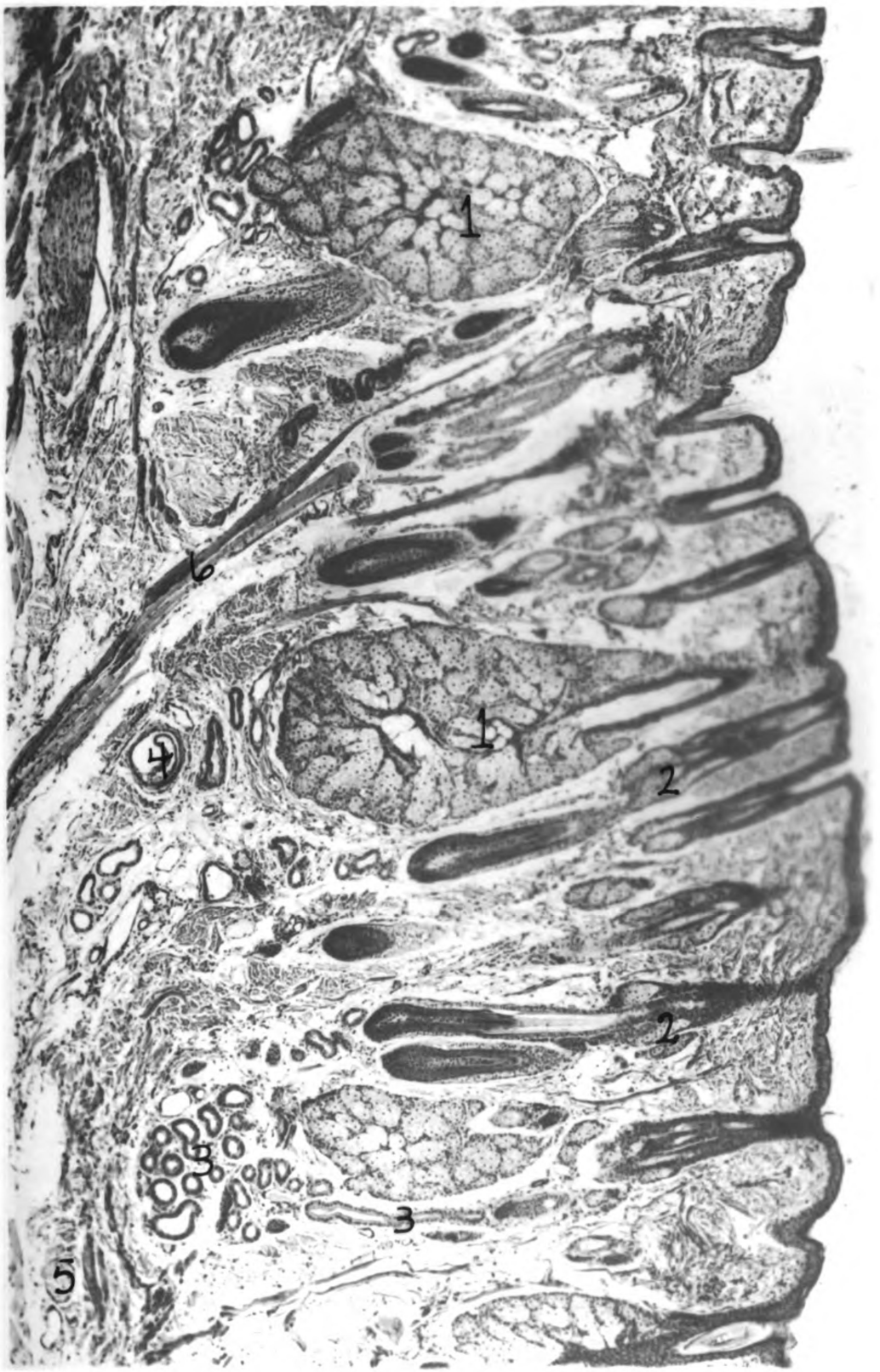


PLATE XVI

Longitudinal section through the lip, showing large sebaceous glands, coiled sweat glands. H. and E. 12X.

1. Large sebaceous glands.
2. Small sebaceous glands.
3. Coiled sweat glands shown entering hair follicles.
4. Blood vessel.
5. Small nerve trunk.
6. Striated muscle fibers of tactile hairs not shown in this section.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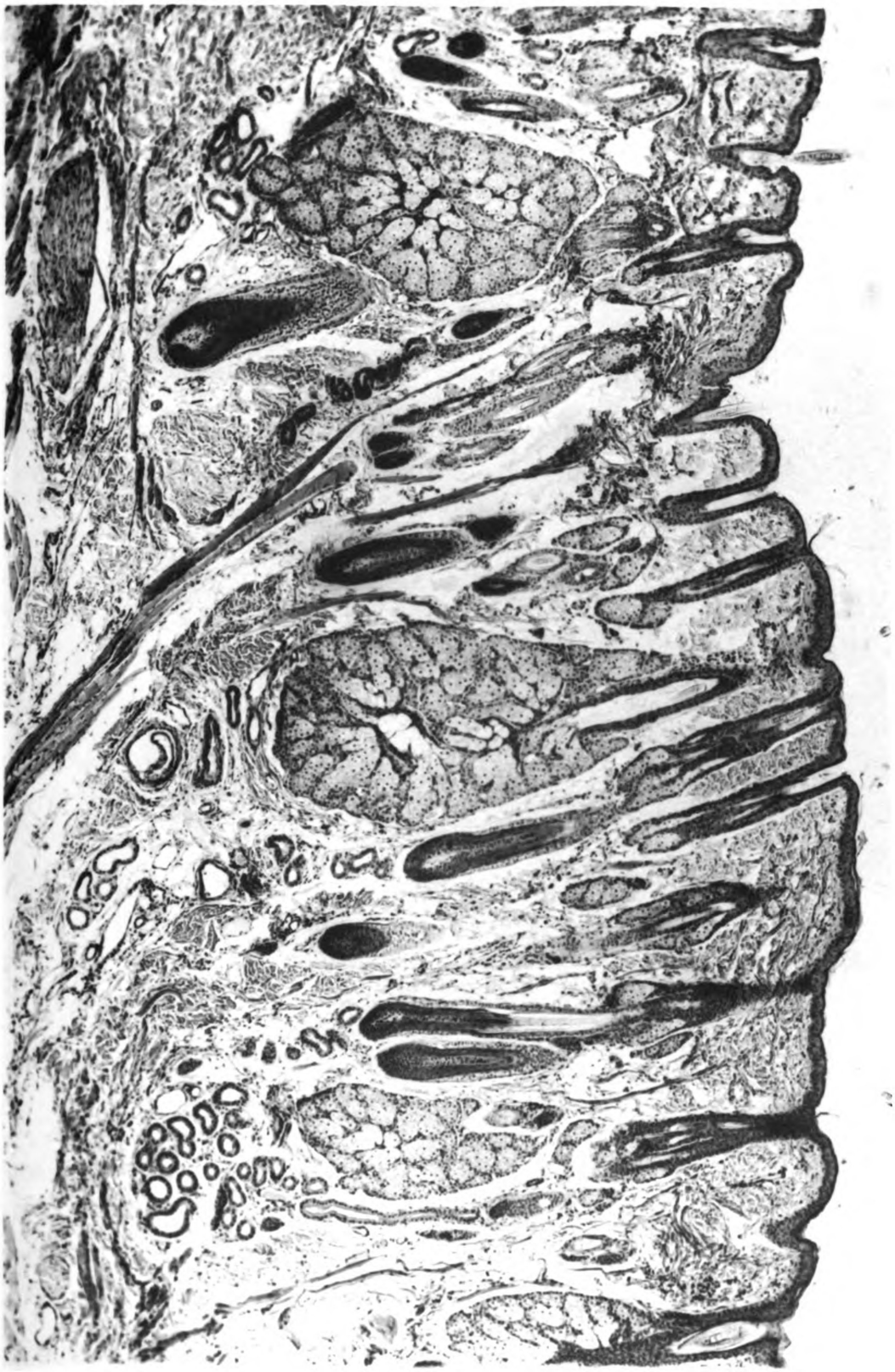
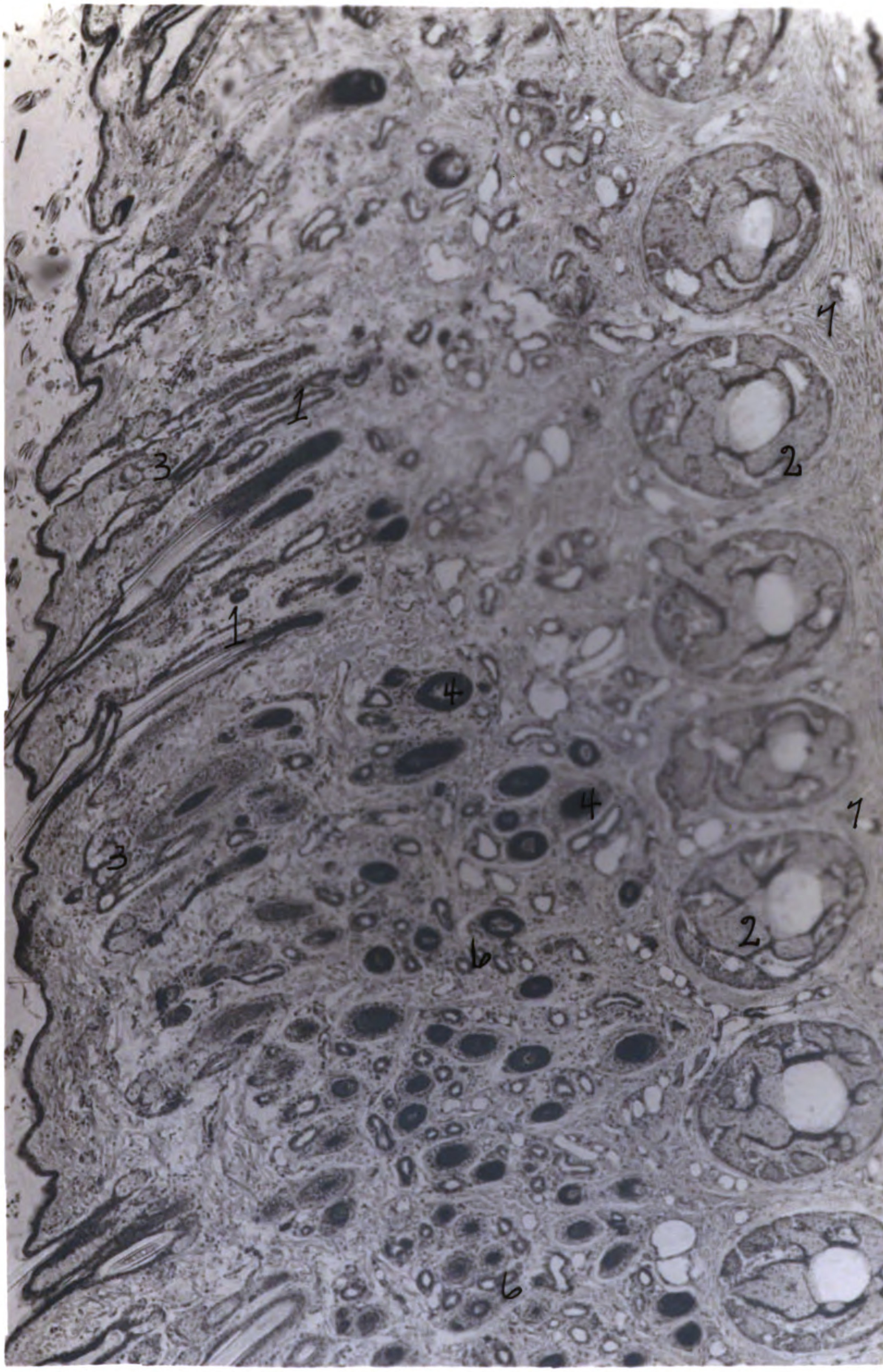


PLATE XVII

Longitudinal section through the upper eyelid showing interior border of the lid, linear series of tarsal glands, and saccular type sweat glands. H. and E. 8X.

1. Saccular apocrine sweat glands.
2. Tarsal glands.
3. Ring of sebaceous glands (upper portion of hair follicle).
4. Roots of hairs.
5. Large hairs of eyelids.
6. Coiled apocrine sweat glands.
7. Collagenous and elastic fibers.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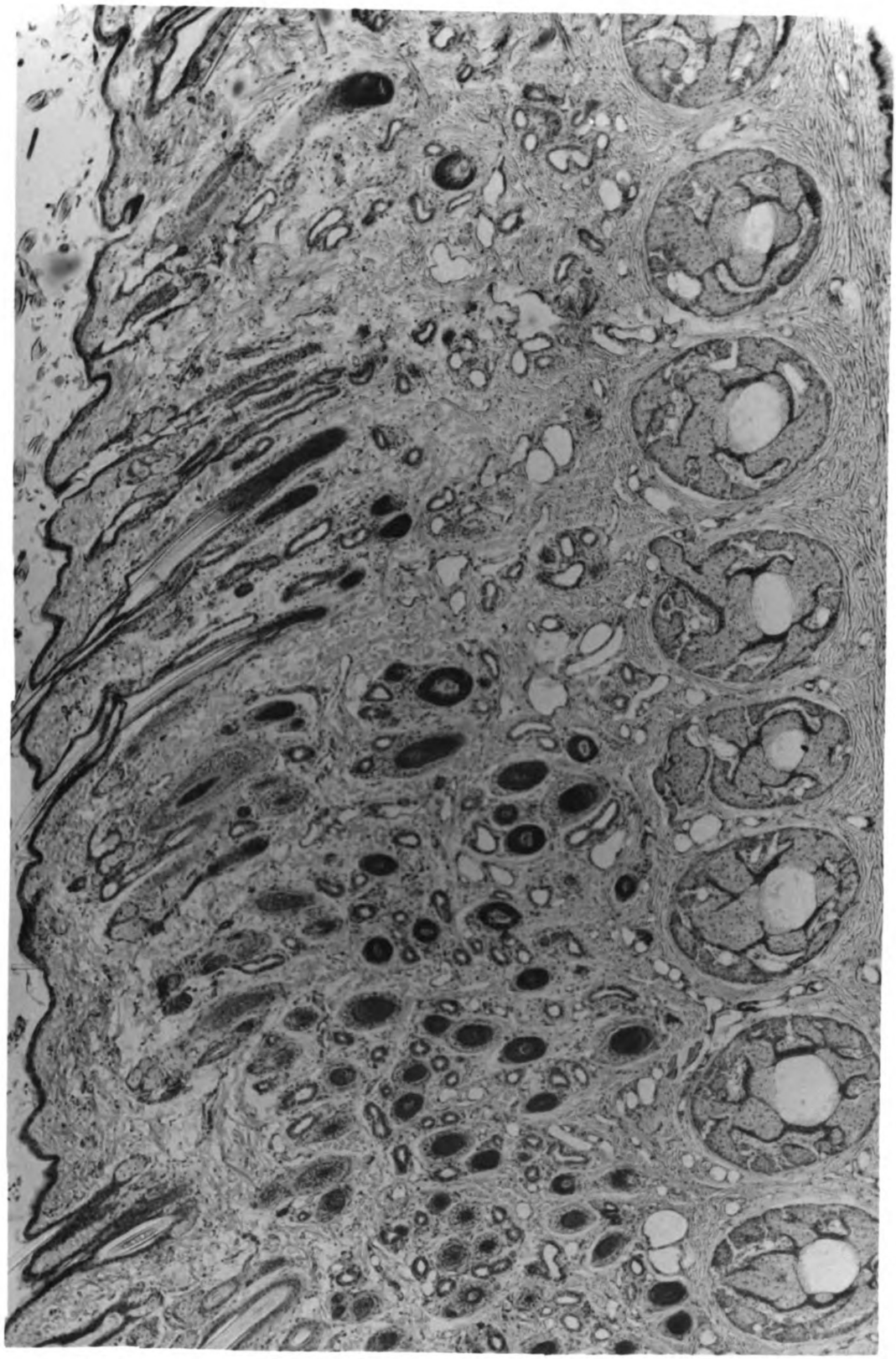
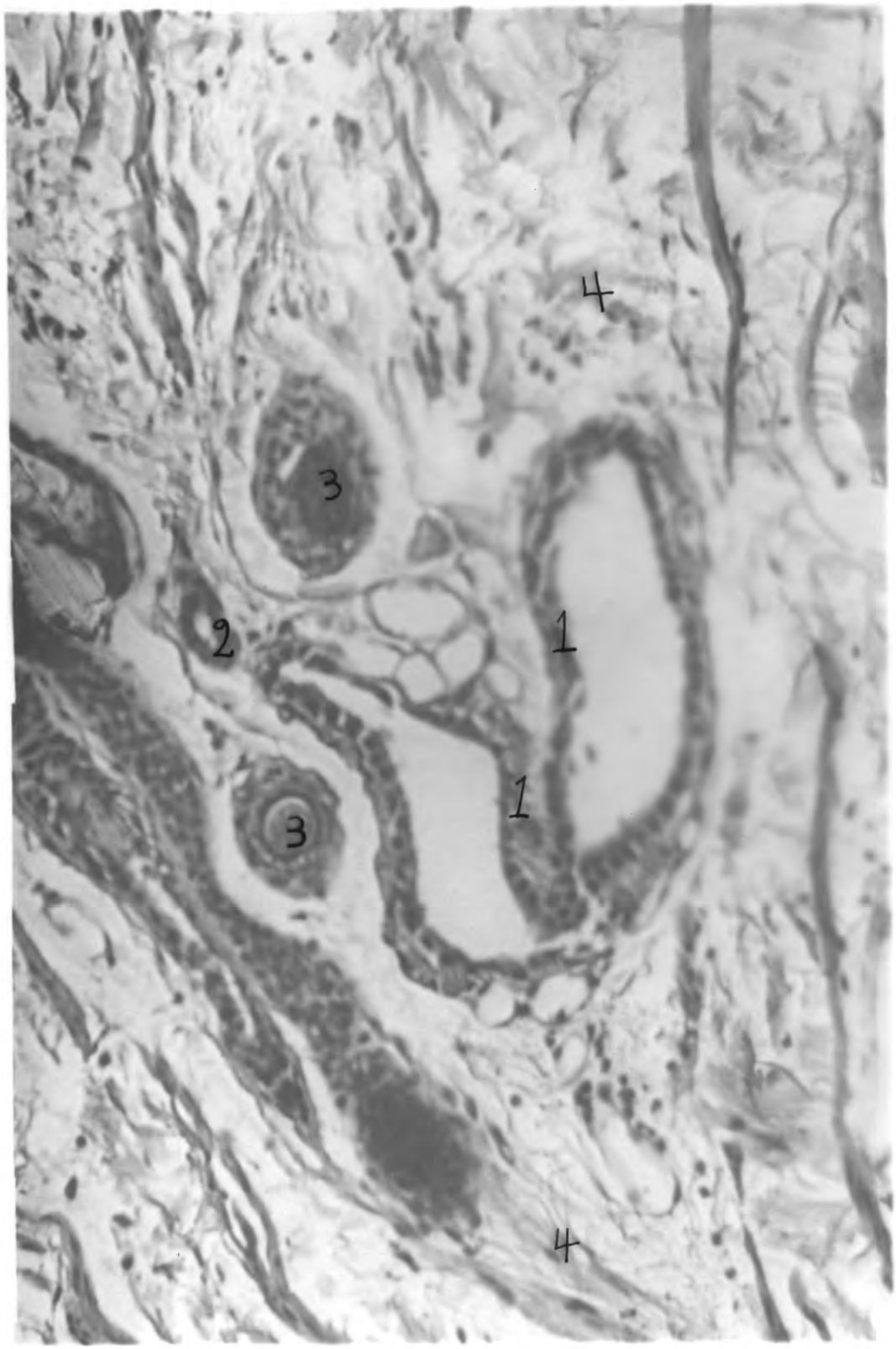


PLATE XVIII

Sweat glands of the scrotum. H. and E. 248X.

1. Large secretory unit of the sweat gland.
2. Excretory portion of the gland.
3. Hair follicle.
4. Loose connective tissue fibers.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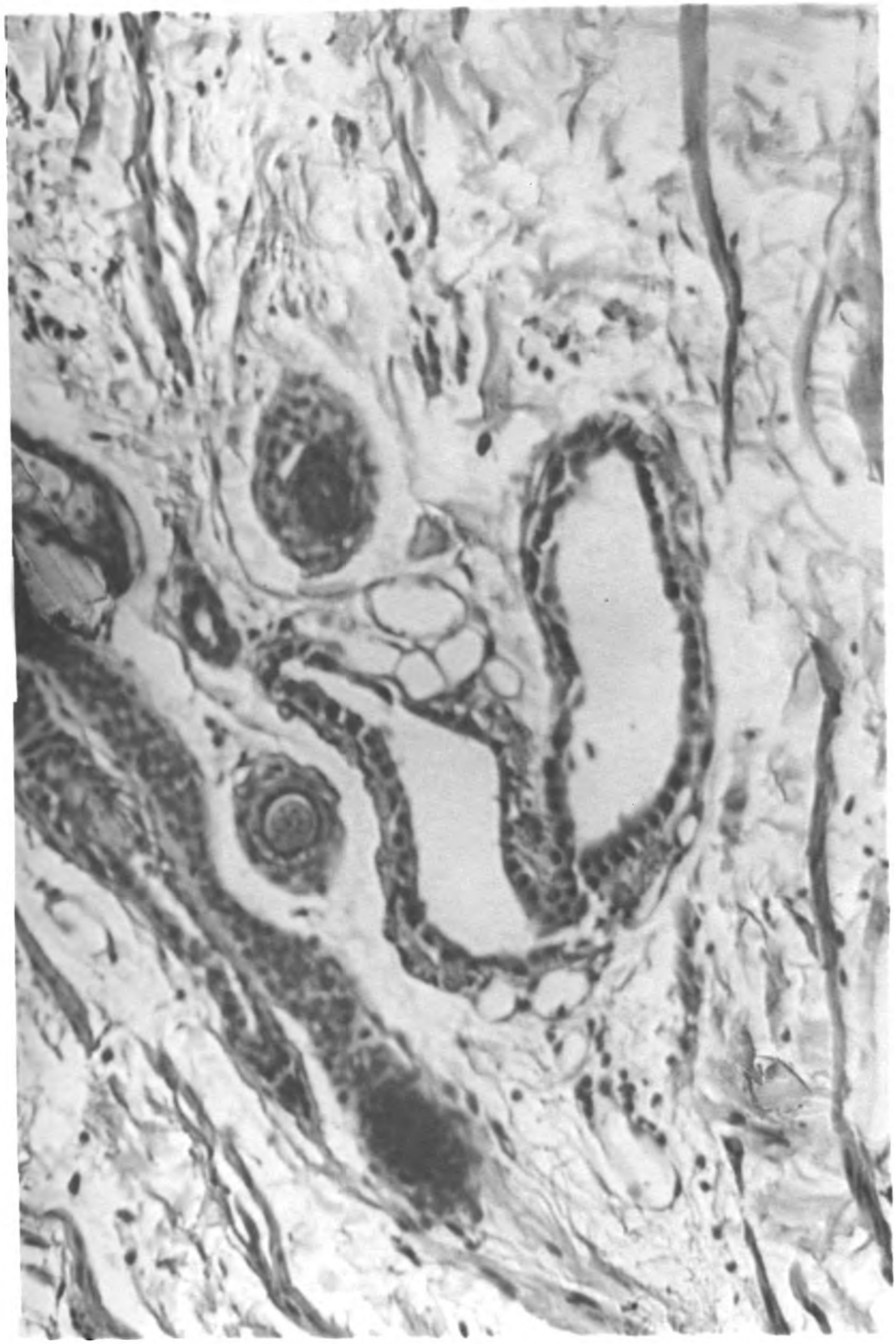
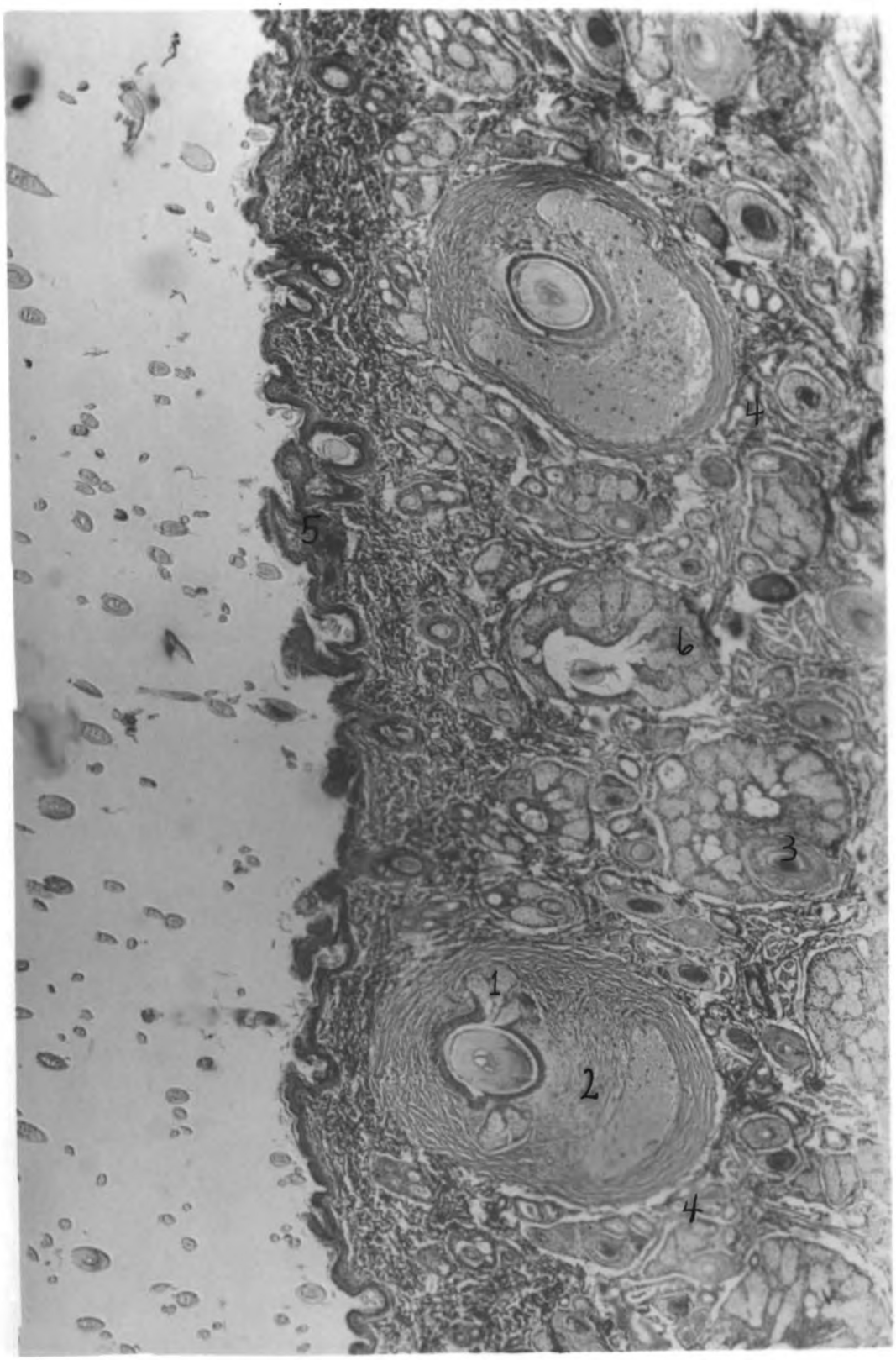


PLATE XIX

Frontal oblique section of tactile hairs showing small sebaceous glands at proximal portion, also showing different hair levels. H. and E. 10X.

1. Small sebaceous gland inside of connective tissue annular ring.
2. Increasing thickness of connective tissue near the proximal portion of hair as compared to other levels.
3. More distal hairs associated with large sebaceous glands.
4. Saccular sweat gland.
5. Epidermis with papillae like structures.
6. Sebaceous gland in a secretory condition.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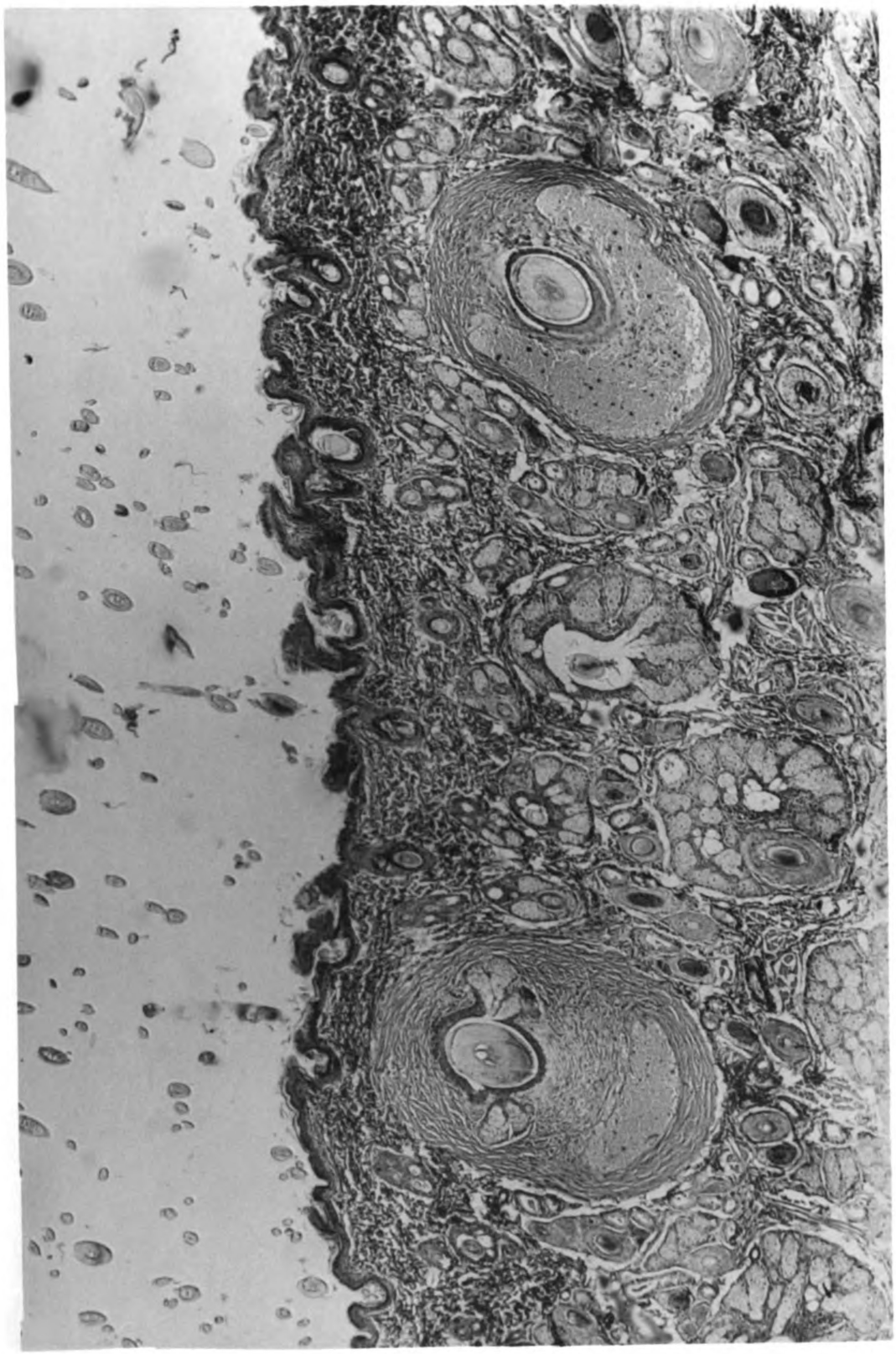
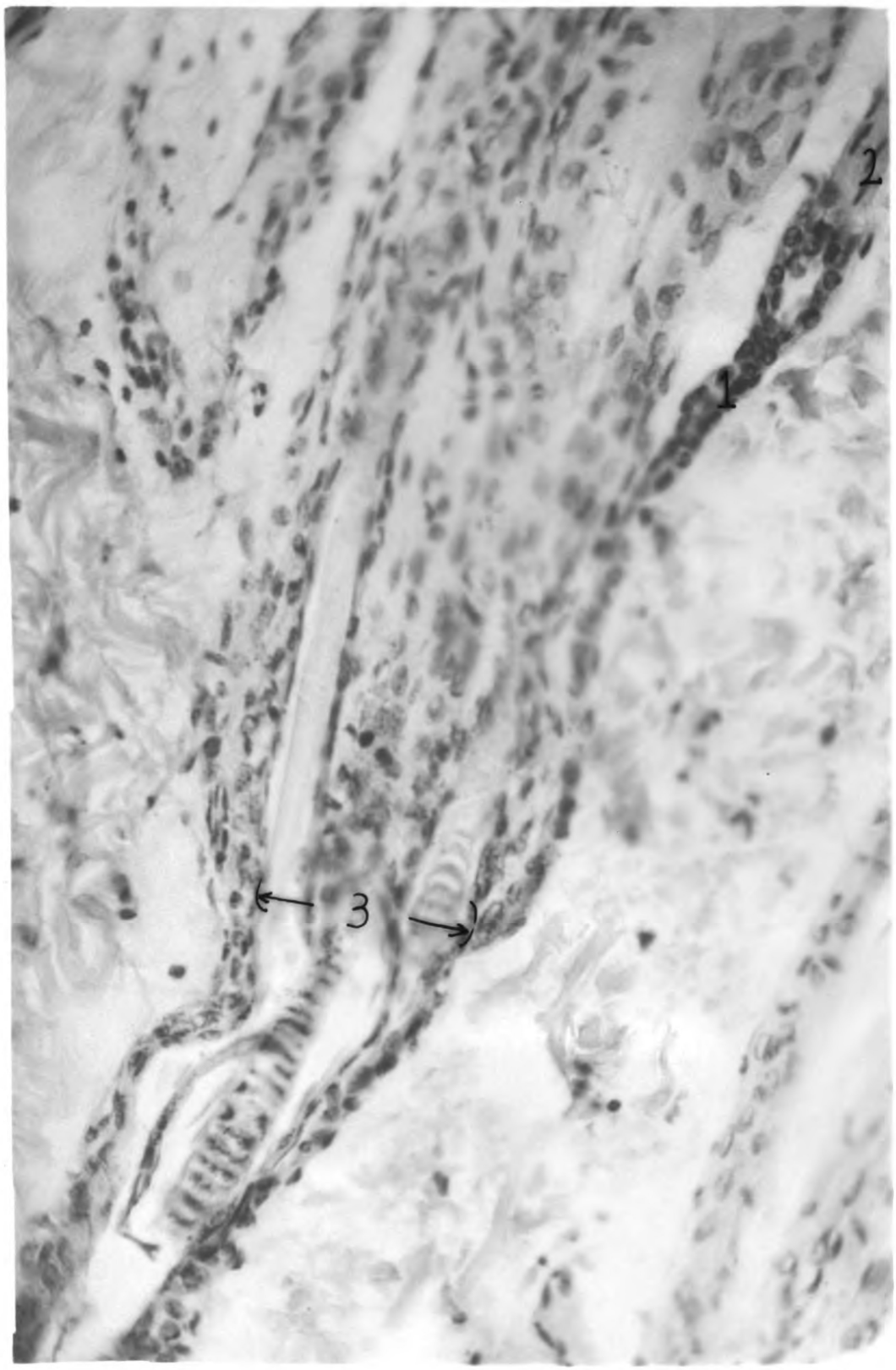


PLATE XX

Longitudinal section in the hairy skin area showing small saccular sweat gland emptying into the upper portion of the hair follicle. H. and E. 360X.

1. Excretory duct of the saccular sweat gland.
2. Arrector pili muscle at the base of sweat gland.
3. Three hairs converging toward a common opening.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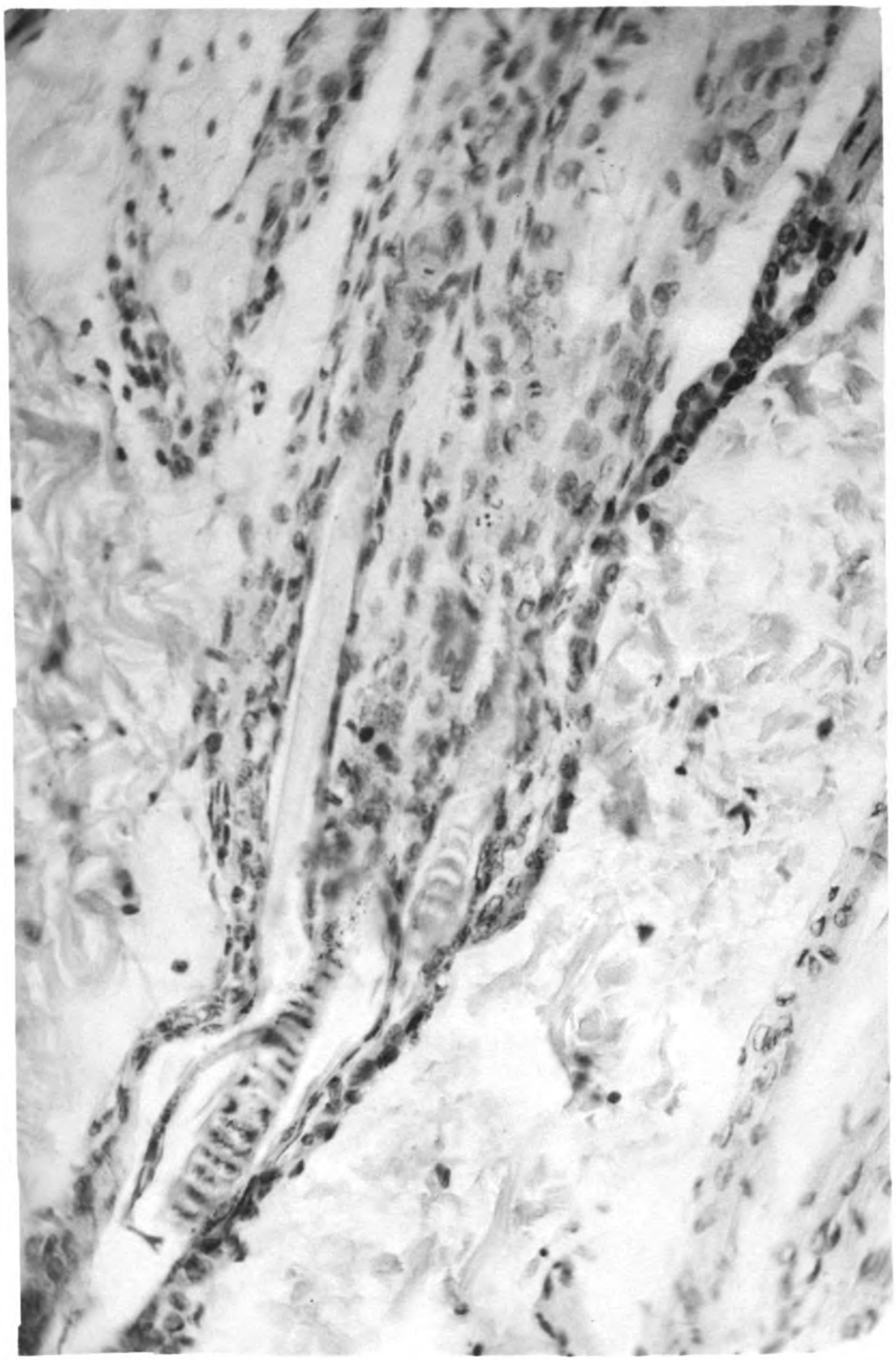
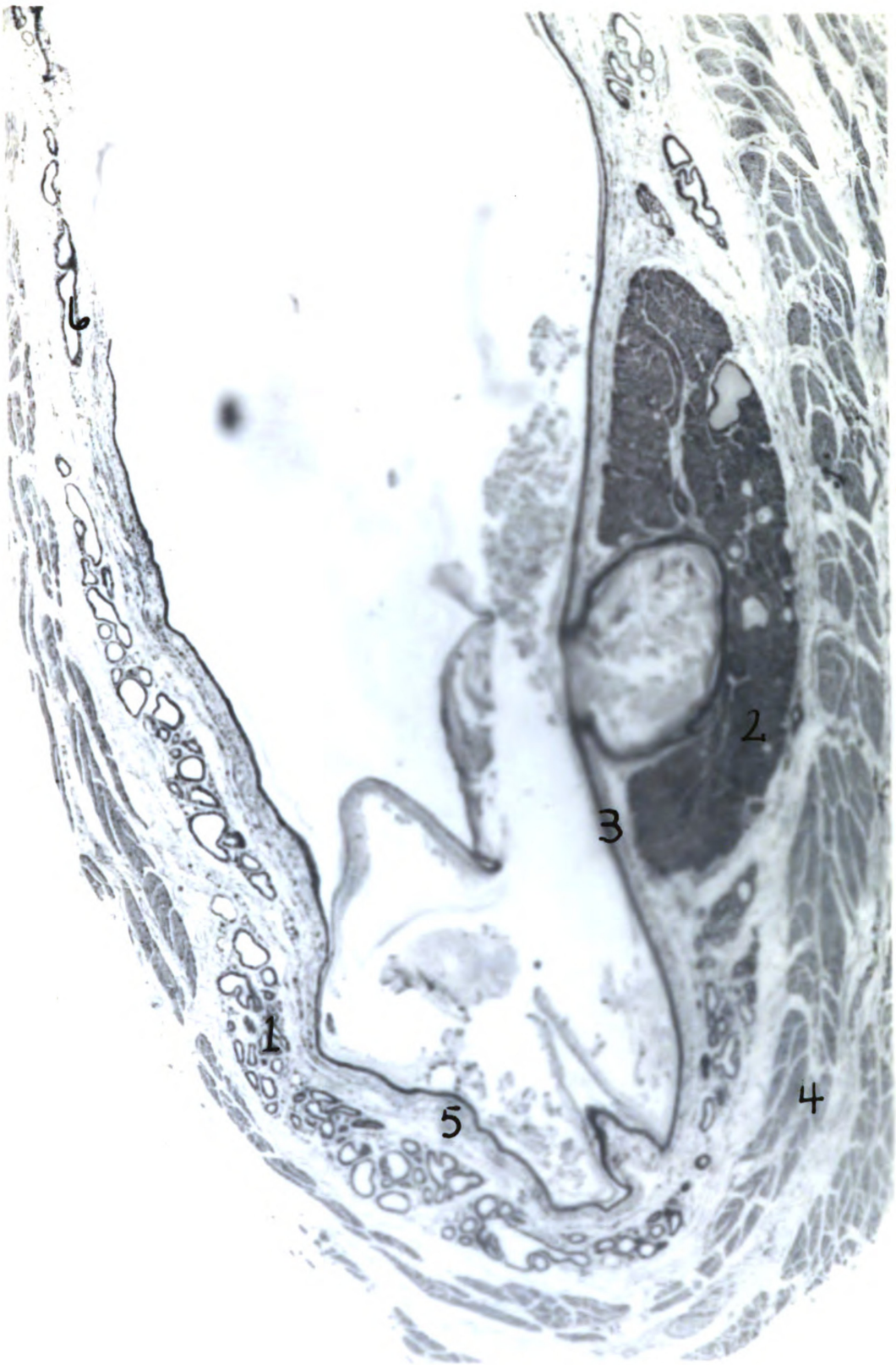


PLATE XXI

The anal sac and associated glands. Note the large coiled sweat glands, and the large cluster of sebaceous glands secreting into the anal sac lumen. H. and E. 11X.

1. Coiled sweat glands.
2. Cluster of sebaceous glands.
3. Stratified squamous epithelial lining of the anal sac.
4. Skeletal muscle.
5. Connective tissue.
6. Saccular apocrine sweat glands.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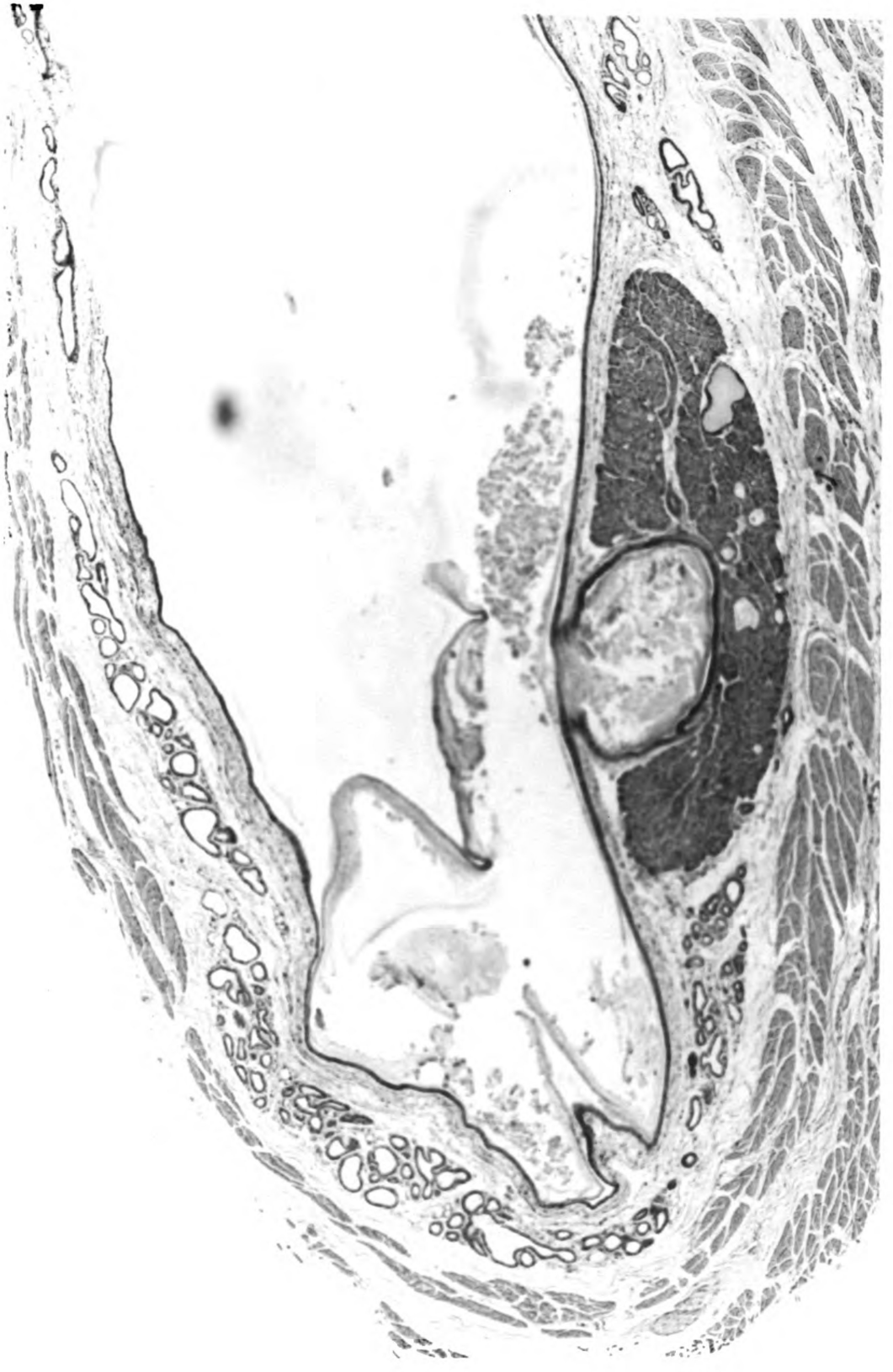
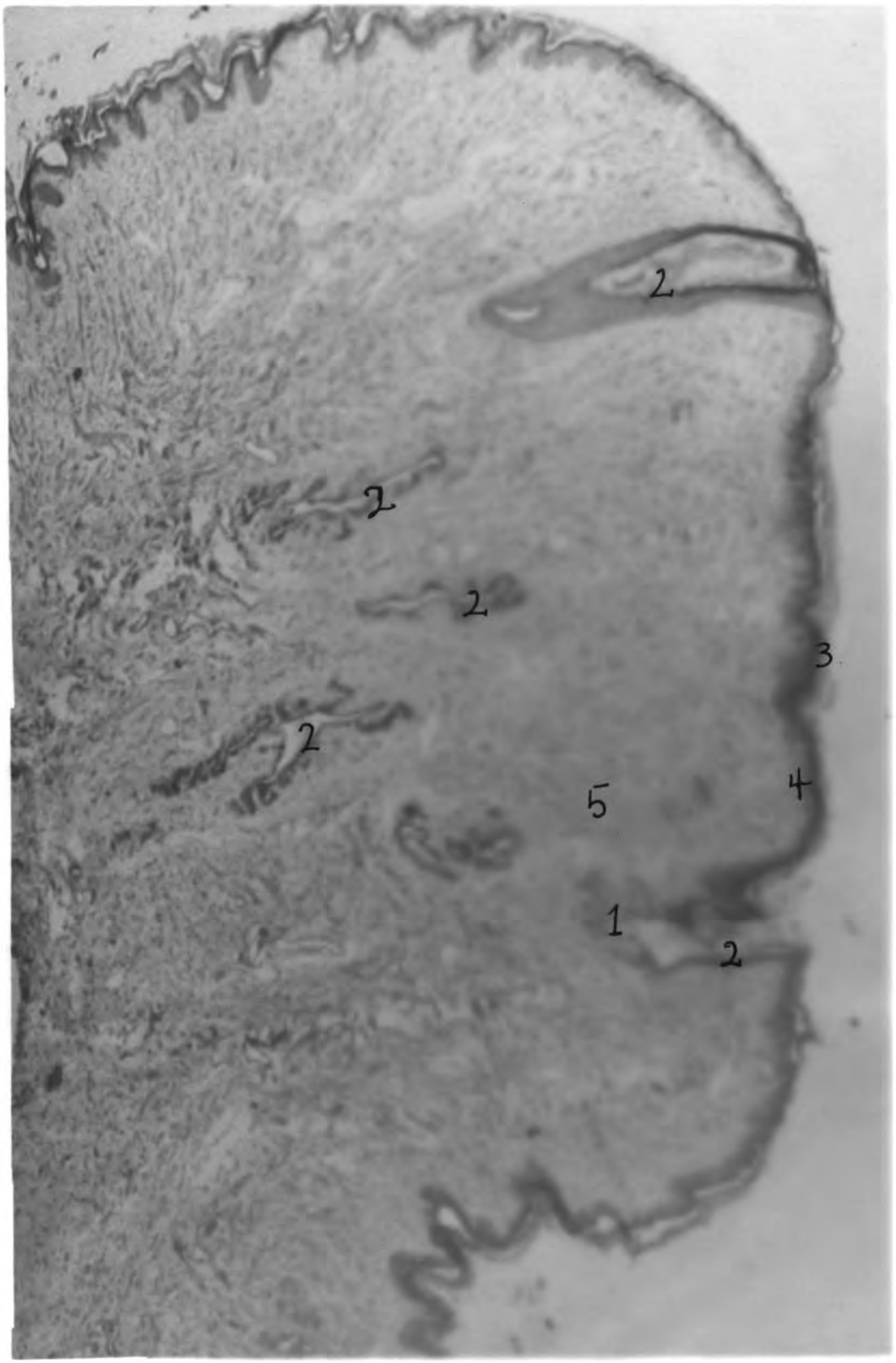


PLATE XXII

Sections of the teat. H. and E. 43X.

1. Sebaceous gland.
2. Milk ducts.
3. Epidermis.
4. Stratum papillare.
5. Stratum reticulare.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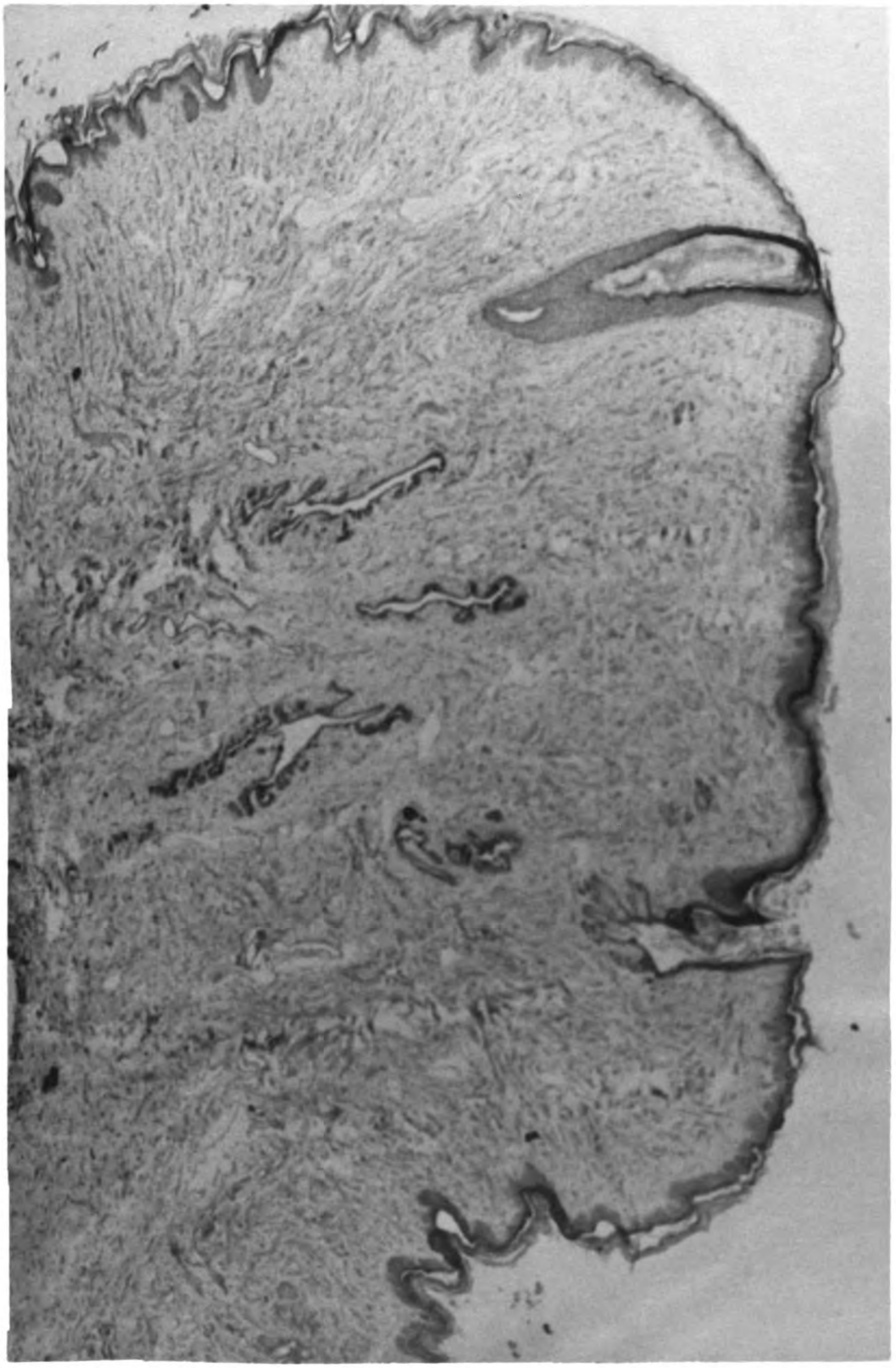

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Thesis

Strickland, James H.
The microscopic anatomy of the skin and external ear of Felis domsticus.