THE MICROSCOPIC ANATOMY OF THE INTEGUMENT OF MATURE FEMALE AND MATURE CASTRATED MALE YORKSHIRE HOGS

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THE MICROSCOPIC ANATOMY OF THE INTEGUMENT
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To

CLO

It is the hope of the author that the following passage by Edgar Guest will be as much help to the reader as it was to him.

When things go wrong as they sometimes will,
  And the road you're trudging seems all uphill.
When the funds are low and the debts are high,
  And you want to smile but you have to sigh.
When care is pressing you down a bit,
  Rest if you must - but don't you quit.

. . .

Success is failure turned inside out,
  The silver tint of the clouds of doubt.
And you can never tell how close you are,
  It may be near when it seems afar.
So stick to the fight when you're hardest hit,
  It's when things seem worst that you mustn't quit.

- Edgar A. Guest -

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Thousands of words are incorporated into a book, however not one of them may stand alone and have meaning. The author of this manuscript is likened to a single word. Without the gracious assistance of friends, associates and teachers this manuscript would have been as imaginary as a one word novel.

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INTRODUCTION

An abundance of information concerning human skin has been presented by Montagna (1956), Dick (1947), Pease (1951) and others. Unfortunately, the dermatology of domestic animals has been neglected. A series of studies on the integument of domestic animals in the Department of Anatomy at Michigan State University has done much to relieve this situation, namely, Webb and Calhoun (1954) dog; Goldsberry and Calhoun (1955) cattle; Strickland (1958) cat; Smith (1960) newborn swine; Holmes (1960) rat; and Fowler (1962) fetal pig.

Swine dermatology in particular has been neglected by histologists. Since hogs are a source of food and clothing necessary to our economy, an understanding of the normal histology of swine integument is important in diagnosing pathological conditions.

The purpose of this paper is to present the results of the histological study of the skin of mature female and mature castrated male hogs. The anatomy of the skin of both sexes will be discussed simultaneously, however structural differences between the sexes will be noted whenever present. References will be made to the skin of other domestic animals and to man for comparison. It is the hope of the author that this paper will serve as a useful reference for investigators requiring knowledge of normal swine histology.

REVIEW OF LITERATURE

A careful search of the literature has revealed very little information concerning the skin of swine. Most of the work on skin, of which Montagna (1956) has done considerable, has been devoted to the study of the human integument. Investigations of the latter include, the dermo-epidermal junction by Szodoray (1931), Dick (1947), Baumberger et al. (1942), Odland (1950) and Katzberg (1958); innervation by Woolard (1936), Weddel (1941), Montagna and Ellis (1952) and Winkelman (1959); electron microscope studies by Adolph et al. (1951), Pease (1951), Gray et al. (1952), Hibbs and Wallace (1958) and the histology of hair by Leblond (1951). Montagna and Ellis (1952) have devoted an entire book to the biology of hair and hair growth.

Pertinent references to the skin of domestic animals follow: Goldsberry and Calhoun (1955) and Findlay and Jenkinson (1960) cattle; Cooper and Franklin (1940), Andrew and Andrew (1949) and Holmes (1960) rat; Strickland (1958) cat; Webb and Calhoun (1954) mongrel dog; Billingham and Medawar (1947) guinea pig; Takagi and Tagawa (1961) horse; and Dixon (1961) rat, rabbit, cat and monkey.

The best information to date concerning the skin of swine was found in books by Ellenberger (1906), Wilson (1941), Sisson and Grossman (1956) and Trautmann and Fiebiger (1957). The earliest study of swine integument was made by Flatten (1896). David (1932) made a histological study of Mexican hairless swine skin (Sus scrofa). Smith (1960) and Fowler (1962) reported on the histology of newborn swine and fetal pig respectively. Special studies on swine skin include, the inheritance of hair whorles by Craft (1932), the histology of wattles by Roberts and Morrill (1944), a report on thermal injury to swine skin by Moritz and Henriques (1947), the vibrissae of Sus scrofa by Moriconi (1953), and an electron microscopic study on the cells of the pigs carpal organ by Kurosum and Kitamuro (1958). Irving (1956) classified swine as bare skinned animals and studied their physiological insulation.

Epidermis

The epidermis, which is the most superficial layer of the skin, is composed entirely of stratified squamous epithelium. The epidermis is sometimes called the cuticle, as it is the outermost covering of the skin (Dawson, 1948).

Histologists generally subdivide the epidermis into four distinct layers;

Stratum corneum
Stratum lucidum
Stratum granulosum
Stratum germinativum

Ham and Leeson (1961) further subdivided the stratum germinativum into the stratum spinosum or prickle cell layer and the stratum cylindricum or the basal cell layer. Goldsberry and Calhoun (1955) reported that in the skin of Hereford and Aberdeen Angus cattle, in most instances, only two clearly defined subdivisions of the epidermis were present--the stratum corneum and stratum germinativum.

The stratum corneum is composed of dead, clear, keratinized cells. The most peripheral cells of this layer, the stratum disjunctum, consist of dried, horny plates which are constantly being desquamated (Dawson, 1948). Pease (1951), in a study of human epidermis, observed that the stratum corneum was arranged in cuticular plates, the latter being held together by remnants of the intercellular bridges. Keratin is thought to be formed from tonofibrils (Leblond, 1951). Histologists generally agree that the stratum corneum, in human skin, is thickest on the palms and soles.

The stratum lucidum is not evident in most sections of human skin. The cells of the stratum lucidum are filled with a semifluid, eleiden, which is believed to be a transformation product of keratohyalin granules (Ham and Leeson, 1961). Smith (1960) and Fowler (1962) in their respective studies of new born and fetal swine did not observe this clear layer. Webb and Calhoun (1954) reported a stratum lucidum in most sections of mongrel dog integument.

The cells of the stratum granulosum contain characteristic keratohyalin granules. Montagna and Ellis (1952) reported a decrease in the number of mitochrondria and Golgi elements in cells possessing these granules. The epidermal cells begin to degenerate in the stratum granulosum (Ham and Leeson, 1961).

The cells of the stratum spinosum are characterized by well defined intercellular bridges projected from their surfaces. According to Odland (1958), 40 to 50 intercellular bridges may be present on a single cell of the stratum spinosum. The cell membrane of a prickle cell, which may be a double membrane, does not possess a supporting structure for the projected intercellular bridges (Pease, 1951). The intercellular bridges of adjacent cells make contact with each other, but there is no protoplasmic continuity through this bridge

(Copenhaver and Johnson, 1958). A pair of attachment plaques, one from each bridge, forms a thickening at their point of contact called a desmosome (Odland, 1958). Between these two plaques, a thin dense lamina serves as the point of attachment between the two adjacent intercellular bridges. Odland (1958) further reported that bundles of intercellular filaments (tonofibrils) converge near the attachment plaques and appear to be attached to the internal faces of these plaques without passing from one cell to another. Adolph et al. (1951) noted that the precipitated cytoplasm of these cells exhibit a fine feltwork of fibrils which are of a different size than the tonofibrils. These fibrils are laid down in a random manner and have no apparent relation to the intercellular bridges.

The stratum cylindricum (basal cell layer) rests on the basement membrane and its cells proliferate and push up into the stratum spinosum. Cowdry and Thompson (1944) found maximum cell division in the basal layer, however they further reported the level of mitosis in the epidermis is not fixed but subject to change in different physiological conditions. A diurnal rhythm exists in the frequency of mitosis in the epidermis of mice ears, a gradual increase to a maximum at

10 A.M. and a decrease to a minimum at 10 P.M. (Cooper and Franklin, 1940). Andrew and Andrew (1949) observed lymphocytes are always present in the normal epidermis of rat and man. They constitute about 1 to 4% of the cells in the stratum germinativum and are located primarily in the basal layer. These same authors theorized that the lymphocytes become recognizable as clear cells, and by differentiation of the cytoplasm are transformed into ordinary epithelial cells. According to Hibbs and Wallace (1958), the cytoplasmic membranes of the basal cells and cells of the stratum granulosum were smooth, while those of the stratum spinosum were sharply scalloped.

There has been much speculation and contradiction concerning the attachment of the dermis to the epidermis. At one time or another, reticular, collagenous and elastic fibers have been thought to bridge this dermo-epidermal junction. Baumberger _et al_. (1942) observed binding material between the dermis and epidermis exhibiting physical properties corresponding to those of collagen and therefore concluded that collagenous fibers are cemented to basal cells, presumably by an amorphous material. Dick (1947) found reticular fibers bridging this dermo-epidermal junction. Odland (1950) reported the cytoplasmic processes of basal epidermal cells inserted into the spaces of a continuous meshwork of dermal reticulum. Pease (1951) stated that the basal layer in some regions is characterized by heavy gelatinous cords (Herxheimer fibers) which are thought to connect the dermis and epidermis. The area of the dermo-epidermal junction has been thought to decrease with age. This decrease is believed to be brought about by the collapse of the dermal papillae as the involution of the vascular structures precipitates metabolic deficiencies in the dermis (Katzberg, 1958).

Dermis

The dermis, which lies directly beneath the epidermis, is divided into two layers blending into each other without a distinct demarcation--the superficial or papillary layer and the deeper reticular layer. Wilson (1941) referred to the superficial layer as the thermostat layer, however this term is not in common use.

Histologists agree the papillary layer is composed of delicate collagenous, elastic and reticular fibers having a loose arrangement. According to Wilson (1941), elastic fibers are more abundant in the papillary layer of swine integument than in the reticular layer. The elastic tissue of normal human skin consists of a superficial subepidermal network of fine fibrils and a deeper layer of large fibers (Dick, 1947). Elastic fibers are more numerous in human than porcine dermis (Moritz and Henriques, 1947). The papillary layer has numerous capillary meshes and lymphatics. A plexus of lymphatic capillaries originates in the dermal papillae. The reticular layer is composed of coarse collagenous fiber bundles situated parallel to the surface of the skin. Wilson (1941) reported hog skin differs from that of other domestic animals by possessing a reticular layer composed almost entirely of adipose tissue. He further stated castration gives a smoother and more uniform structure to the skin of domestic animals, the skin becoming tighter and more dense after castration. The skin _in vivo_ is a gel, in part composed of macromolecules, which become the elastic fibers noted in fixed tissues. Because the skin itself is elastic, the fibers may act as tightening agents of the skin (Jarrett, 1958).

The dermis of swine skin possesses a superficial and deep vascular supply. The sebaceous glands and epithelium are supplied by the superficial vascular plexus and the sweat glands derive their vascularity from the deeper plexus (Wilson, 1941).

Hair

The hair follicle is an epithelial structure surrounded by a connective tissue sheath. A bundle of smooth muscle fibers, the arrector pili muscle, is attached to the top connective tissue sheath about half way down the follicle. The arrector pili muscles of the hog average 40 microns, this being thicker than those of most domestic animals (Ellenberger, 1906). The arrector pili muscles are conspicuously thick in the sheep and often double in the pig, however they are thin on the bristles of the pig (Trautmann and Fiebiger, 1957).

There is a great diversity of hair patterns among mammals. The hair of the pig, dog, and cat occur in groups (Trautmann and Fiebiger, 1957). According to Flatten (1896) and Smith (1960) the hair of swine is usually arranged in groups of three. Flatten (1896) further reported the middle hair of the triad to be larger and extended deeper into the dermis. Norback (1951), in his study of hair, reported that Hofliger (1931) observed secondary hair follicles of sheep and hogs, which in some cases, were similar in size to the central primary follicle. Webb and Calhoun (1954) stated the hair follicles in mongrel dogs occurred in groups of three, there being up to twenty hairs in a single group. The hair of newborn swine was generally found in groups of three, with only one hair per follicle regardless of the size of the hair (Smith, 1960). Fowler (1962) occasionally observed two hairs in a single follicle. Strickland (1958) reported 12 to 20 hairs diverging from a single follicle in the skin of cats. Holmes (1960) observed the general body hair of the rat to be arranged in well defined groups of follicles, the central follicles appearing in linear form but alternating position from row to row, producing a cobblestone appearance. David (1932) discovered normal hair follicles in the skin of the Mexican hairless swine, but they extended in abnormal directions under the epidermis and the hairs were not evident on the body surface.

Goldsberry and Calhoun (1955), in a study of the integument of cattle, observed "follicular folds" which consisted of 7 to 20 folds below the opening of the sebaceous glands and projected into the lumen of the follicle. These folds were also reported by Strickland (1958) cat; Holmes (1960) rat; Smith (1960) newborn swine; and Fowler (1962) fetal pig. Montagna (1956), who called these folds "corrugations," reported their presence in rats, sheep and mice, but stated they were not present in man.

Many mammals possess sensory hairs. Winkelman (1959) differentiated sensory hair from common hair by the degree of development of the individual components and the presence of a connective tissue capsule which enclosed the sinus of the sensory hairs. He further reported the sensory hair is innervated by 2 to 5 large nerve trunks penetrating the connective tissue capsule at its base. Dixon (1961) noted vibrissal hairs were innervated by extremely thick nerve bundles passing obliquely through the connective tissue capsule at its base and spread through the epithelial root sheath of the follicle. Tactile sinus hairs have never been demonstrated in the human species (Montagna and Ellis, 1952).

Sebaceous Glands

Sebaceous glands are epidermal appendages developing from the side of the hair follicle which makes an obtuse angle with the surface with the skin. The cat and pig have apocrine glands in the ear canal similar to those of the human species (Baumann *et al.*, 1958). According to Trautmann and Fiebiger (1957), sebaceous glands are rudimentary in the pig, and Sisson and Grossman (1956) reported the sebaceous glands of the pig were small and less numerous than those of other domestic animals. Smith (1960) observed six sebaceous glands surrounding each tactile hair follicle. Montagna and Ellis (1952) stated the nuclei of the cells in the central part of the gland are pyknotic in man.

Sweat Glands

The sweat glands of the pig, as in most domestic animals, are apocrine (Trautmann and Fiebiger, 1957). Moritz and Henriques (1947) observed glands in the dermis of the pig which had some resemblance to the sudoriferous glands of human skin, however they were nonfunctional. According to Trautmann and Fiebiger (1957), the secretory tubule is glomiform in the pig. The apparent size of sweat glands may vary depending on whether the skin is obtained from slaughtered or biopsied animals, being larger in the latter

(Findlay and Jenkinson, 1960). Hurley and Shelley (1954) stated the role of myoepithelium in the human apocrine sweat gland was primarily of contraction. Furthermore, they reported these contractions occurred in peristaltic waves with a definite refractory period and theorized the apocrine tubules served as a reservoir for apocrine sweat.

Carpal Glands

Trautmann and Fiebiger (1957) reported the carpal glands of the pig comprised 1 to 12 cutaneous invaginations which contained greatly branched, brownish merocrine mucous glands with many smooth muscle fibers. The carpal gland of the pig is a conglomerated sweat gland, histologically similar to the smaller eccrine gland of man (Kurosum and Kitamuro, 1958). Flatten (1896) noted carpal glands on the medial skin of the carpal joint. He further reported these glomiform glands, present in the reticular layer, flow into "superficial tubules of the dermis."

MATERIALS AND METHODS

Source of Animals

The animals used in this investigation were obtained from the Michigan State University slaughter house, and passed ante and postmortem inspection by a federal veterinarian. Three sexually mature female and three mature castrated male hogs were studied, ranging in age from six months to one year and weighing approximately two hundred and fifty to three hundred and fifty pounds.

Technique

Immediately upon slaughtering, skin specimens were obtained from twenty one body areas (Plate I) and placed in a mixture of commercial formalin, 95% ethyl alcohol, glacial acetic acid, and distilled water (Lavdowsky's mixture, Guyer, 1949). The tissues were removed from this mixture after approximately fifty hours and stored in 70% alcohol.

The specimens were dehydrated and infiltrated by the butyl-alcohol-mush method of Johnson, *et al*. (1943). The tissues were embedded in "Tissuemat" and horizontal and vertical sections were cut, 7 to 9 microns, and stained with Harris' hematoxylin and eosin, Weigert's and Van Gieson's connective tissue stain, Mallory's Triple Stain (Crossmon's modification, 1937) and Giemsa's stain. Slaughtering procedures prevented the acquisition of skin specimens from the hind limb, therefore the latter area was not included in this study.

Measurements

Epidermal and dermal thickness was measured with an ocular micrometer and recorded in microns. Every figure represents an average of six measurements. Density of mast cells and elastic fibers were estimated qualitatively. The size of sweat glands was based upon a comparative determination, only the largest and smallest being noted, since true cross sections could not be determined.

PLATE I

Body areas from which skin specimens were taken

	Section No.
A. Head	
(a) Lip - upper	1
(b) Snout	2
(c) Bridge of nose	3
(d) Eyelid - upper	4
(e) External ear	5
(f) Neck - dorsal	6
B. Thorax	
(a) Dorsal thoraco - lumbar	7
(b) Lateral thorax	13
(c) Ventral thorax	18
C. Trunk	
(a) Dorsal sacrum	8
(b) Lateral abdomen	12
(c) Ventral abdomen	20
(d) Prepuce	19
(e) Tail	9
(f) Anus	10
(g) Vulva	11
D. Forelimb	
(a) Lateral brachium	14
(b) Axilla	15
(c) Lateral carpal region	16
(d) Medial carpal region	17
(e) Interdigital skin	21

TABLE 1

MEASUREMENTS OF EPIDERMAL, DERMAL, AND TOTAL SKIN THICKNESSES
(Male 1)

AREA	EPIDERMIS		DERMIS		TS
	RANGE*	A	RANGE	A	E+D
Lip	146-234	173	873-1042	983	1156
Snout	231-348	286	2241-3007	2878	3165
Bridge of nose	127-182	159	1423-1749	1514	1673
Eyelid	60-136	91			
Ear	62-118	91	547- 858	786	877
Dorsal neck	149-226	190	1490-1836	1524	1715
Dorsal thoraco-lumbar	142-177	163	1967-2413	2224	2387
Dorsal sacrum	108-142	124	1576-1990	1741	1865
Tail	100-176	135	1273-1500	1402	1537
Anus	86-137	114	1521-1837	1638	1752
Vulva					
Lateral abdomen	64-111	84	2222-2519	2392	2476
Lateral thorax	97-132	116	2264-2703	2440	2556
Lateral brachium	175-208	189	2146-2487	2334	2523
Axilla	72-136	88	1734-2127	1921	2010
Medial carpus	100-168	140	1648-1919	1719	1859
Lateral carpus	296-378	334	1680-2001	1771	2105
Ventral thorax	127-164	114	839-1349	1176	1320
Ventral abdomen	111-140	126	1100-2298	1830	1956
Prepuce	109-131	121	1173-1826	1584	1805
Interdigital area	170-203	186	1630-2100	1809	1996

Key:

A = Average of six measurements determining epidermal and dermal thicknesses

TS = Total skin thickness

E+D = Average epidermal thickness plus average dermal thickness

* = Measured in microns

TABLE 2

MEASUREMENTS OF EPIDERMAL, DERMAL, AND TOTAL SKIN THICKNESSES (Male 2)

AREA	EPIDERMIS		DERMIS		TS
	RANGE*	A	RANGE	A	E+D
Lip	149-170	159	1140-1472	1308	1476
Snout	242-302	271	1889-2460	2173	2445
Bridge of nose	186-242	219	997-1346	1112	1332
Eyelid	62-107	70			
Ear	90-144	114	632- 900	786	900
Dorsal neck	84-142	105	1837-2229	2057	2162
Dorsal thoraco-lumbar	155-196	178	2331-2636	2426	2605
Dorsal sacrum	119-160	143	2274-2601	2420	2563
Tail	116-136	125	1097-1562	1362	1488
Anus	127-151	144	1268-1689	1553	1698
Vulva					
Lateral abdomen	72-122	104	2292-2769	2538	2643
Lateral thorax	98-162	131	2336-2612	2575	2706
Lateral brachium	112-146	129	1970-2209	2053	2183
Axilla	60- 94	77	988-1377	1193	1271
Medial carpus	120-157	138	764-1300	1102	1241
Lateral carpus	150-193	170	1366-1794	1621	1792
Ventral thorax	81-133	108	1400-1848	1675	1784
Ventral abdomen	71-117	93	1597-1880	1753	1846
Prepuce	98-146	115	1401-1777	1629	1744
Interdigital area	160-203	182	1784-2333	1955	2137

Key: A = Average of six measurements determining epidermal and dermal thicknesses
TS = Total skin thickness
E+D = Average epidermal thickness plus average dermal thickness
* = Measured in microns

TABLE 3

MEASUREMENTS OF EPIDERMAL, DERMAL, AND TOTAL SKIN THICKNESSES (Male 3)

AREA	EPIDERMIS		DERMIS		TS
	RANGE*	A	RANGE	A	E+D
Lip	123-182	157	1320-1627	1514	1671
Snout	197-261	232	2090-2791	2353	2585
Bridge of nose	139-174	159	1207-1398	1349	1508
Eyelid	86-121	99			
Ear	66-116	93	564- 834	636	730
Dorsal neck	135-162	149	1453-1802	1698	1848
Dorsal thoraco-lumbar	143-194	165	1989-2377	2116	2281
Dorsal sacrum	167-198	185	2061-2494	2249	2434
Tail	120-144	131	1200-1690	1399	1531
Anus	92-130	117	1888-2274	2009	2127
Vulva					
Lateral abdomen	122-142	126	2121-2359	2206	2332
Lateral thorax	109-121	115	2263-2777	2587	2703
Lateral brachium	130-177	152	1685-1944	1837	1989
Axilla	71-129	87	1308-1829	1617	1704
Medial carpus	99-170	134	827-1020	945	1079
Lateral carpus	136-171	155	1566-1841	1705	1860
Ventral thorax	177-209	191	1139-1394	1325	1517
Ventral abdomen	88-119	90	1447-1838	1649	1740
Prepuce	100-170	133	1500-2130	1797	1930
Interdigital area	199-294	223	2023-2490	2274	2497

Key: A = Average of six measurements determining epidermal and dermal thicknesses
TS = Total skin thickness
E+D = Average epidermal thickness plus average dermal thickness
* = Measured in microns

TABLE 4

MEASUREMENTS OF EPIDERMAL, DERMAL, AND TOTAL SKIN THICKNESSES (Female 1)

AREA	EPIDERMIS		DERMIS		TS
	RANGE*	A	RANGE	A	E+D
Lip	127-154	141	1502-1772	1652	1793
Snout	211-279	223	2033-2521	2249	2472
Bridge of nose	152-182	164	764-1246	1081	1264
Eyelid	91-125	106			
Ear	148-182	163	629- 993	823	986
Dorsal neck	144-230	189	1640-1993	1839	2028
Dorsal thoraco-lumbar	160-212	183	1539-1878	1771	1954
Dorsal sacrum	140-188	166	1430-1801	1642	1808
Tail	154-219	188	1711-1911	1874	2062
Anus	113-156	128	1720-2120	1946	2074
Vulva	120-173	141	1372-1880	1632	1773
Lateral abdomen	161-222	169	1571-1957	1766	1936
Lateral thorax	119-158	145	1840-2380	2156	2301
Lateral brachium	134-201	174	1606-1855	1756	1930
Axilla	69-136	96	1321-1740	1592	1688
Medial carpus	194-251	224	1290-1711	1536	1761
Lateral carpus	149-191	170	1116-1582	1389	1559
Ventral thorax	118-174	146	1240-1700	1572	1718
Ventral abdomen	107-149	130	1289-1597	1409	1539
Prepuce					
Interdigital area	170-211	184	1827-2249	1940	2125

Key: A = Average of six measurements determining epidermal and dermal thicknesses
TS = Total skin thickness
E+D = Average epidermal thickness plus average dermal thickness
* = Measured in microns

TABLE 5

MEASUREMENTS OF EPIDERMAL, DERMAL, AND TOTAL SKIN THICKNESSES
(Female 2)

AREA	EPIDERMIS		DERMIS		TS
	RANGE*	A	RANGE	A	E+D
Lip	176-228	205	1264-1597	1425	1631
Snout	769-968	928	2382-2808	2622	3550
Bridge of nose	271-342	308	1622-1914	1852	2160
Eyelid	82-137	105			
Ear	93-136	125	714- 937	829	954
Dorsal neck	122-173	141	2062-2571	2285	2426
Dorsal thoraco-lumbar	99-136	151	1901-2248	2003	2154
Dorsal sacrum	87-160	145	1381-1785	1680	1826
Tail	139-200	155	2049-2384	2249	2404
Anus	106-154	139	1737-2267	2116	2255
Vulva	86-160	125	1900-2178	2033	2158
Lateral abdomen	80-126	116	3212-3770	3517	3636
Lateral thorax	78-119	107	1986-2575	2227	2334
Lateral brachium	83-146	114	1655-2029	1875	1990
Axilla	61-101	85	1500-1944	1722	1808
Medial carpus	165-227	190	1276-1833	1580	1770
Lateral carpus	99-163	124	1071-1361	1220	1344
Ventral thorax	102-157	129	2040-2387	2190	2319
Ventral abdomen	82-130	107	1169-1551	1480	1588
Prepuce					
Interdigital area	206-334	271	1220-1746	1414	1668

Key: A = Average of six measurements determining epidermal and dermal thicknesses
TS = Total skin thickness
E+B = Average epidermal thickness plus average dermal thickness
* = Measured in microns

TABLE 6

MEASUREMENTS OF EPIDERMAL, DERMAL, AND TOTAL SKIN THICKNESSES
(Female 3)

AREA	EPIDERMIS		DERMIS		TS
	RANGE*	A	RANGE	A	E+D
Lip	90-179	142	1737-1920	1816	1958
Snout	689-1337	941	3223-4377	3802	4754
Bridge of nose	210-357	272	1999-2564	2499	2771
Eyelid	78-120	106			
Ear	152-194	171	876-1160	1076	1247
Dorsal neck	157-224	186	3072-3684	3475	3661
Dorsal thoraco-lumbar	148-198	170	2988-3502	3292	3462
Dorsal sacrum	130-198	176	2603-3245	2998	3175
Tail	140-237	182	1860-2551	2116	2299
Anus	112-162	130	2300-2766	2482	2612
Vulva	90-134	117	2041-2228	2146	2263
Lateral abdomen	110-157	125	1978-2443	2271	2396
Lateral thorax	86-143	119	2004-2676	2316	2436
Lateral brachium	97-152	131	1755-2294	2000	2131
Axilla	89-123	103	1639-2277	2112	2215
Medial carpus	111-159	131	1140-1500	1357	1489
Lateral carpus	99-129	115	1226-1518	1416	1531
Ventral thorax	109-163	140	1411-1716	1524	1664
Ventral abdomen	92-133	110	1632-2122	1897	2007
Prepuce					
Interdigital area	294-472	374	1470-1888	1720	2095

Key: A = Average of six measurements determining epidermal and dermal thicknesses
TS = Total skin thickness
E+D = Average epidermal thickness plus average dermal thickness
* = Measured in microns

RESULTS AND DISCUSSION

Skin Thickness

Statistical significance of the skin measurements was determined by the Sign test and by using the Kelley Statistical Tables.

The epidermis of female hogs was significantly thicker than castrated males (.01 level). Montagna (1956) reported that testosterone increases the rate of mitotic activity in the epidermis and consequently the thickness of the epidermis. He further stated testosterone increases the thickness of the skin over the entire body of man. Thyroxine and testosterone are thought to be antagonistic in maintaining the epidermis of rats. Thyroxine produces a thin epidermis with decreased mitotic activity, whereas testosterone has the opposite effect (Earthy and Grad, 1951). Since the males in this study were castrated, their epidermis would be expected to be thinner than the females. Estrogens are said to have a mitogenic effect on the epidermis in the adult female mouse (Bullough, 1950).

The female dermis was significantly thicker than the castrated males (.05 level). Castor (1950) reported hog ACTH extract applied locally to the skin of adult normal rats resulted in a thinner dermis in both sexes, collagenous fibers were fused giving the dermis a homogeneous appearance, elastic fibers were not effected, and the numbers of cells in the dermis were reduced. Endocrinologists generally agree that castrated animals will produce greater quantities of ACTH than normal animals.

The hypothesis that the total skin thickness of female hogs was thicker than male hogs was rejected at the .05 level.

The thickest epidermal areas were generally found on the snout and interdigital area, and the thinnest in the axilla, eyelid and ventral abdomen. The epidermis on the snout of two of the females measured over 900 microns, due to a very thick stratum corneum.

The thickest dermal areas were usually present on the snout and lateral abdomen, and thinnest on the ear and medial carpus.

Generally the dorsal skin was thicker than the ventral in both sexes.

Epidermis

The epidermis consisted of a continuous layer of stratified squamous epithelium in which were found such epidermal appendages as hair, sebaceous glands and sweat ducts. It included only three characteristic layers since the stratum lucidum was absent (Plate II). This was in agreement with Moritz and Henriques (1947), Smith (1960), and Fowler (1962) who did not observe a stratum lucidum in their investigations of swine integument.

Stratum corneum. The stratum corneum was present in all sections studied, however its thickness varied greatly in different body areas. It was thickest in the snout, which is to be expected since swine utilize their snout as a discriminatory organ. The interdigital skin, which possessed a thick stratum corneum, was characterized by sharp epidermal projections (Plate XVIII). This cornified layer was thin in the eyelid, axilla, and dorsal areas of the abdomen and thorax. Individual cells were not apparent in most sections, and distinct cell outlines were rarely observed (Plate II). In the keratinized cells where the cell outlines remained distinct, nuclear fragments were apparent. The keratin was not always densely packed and often artifacts in the form of large spaces were seen between the layers of keratin (Plate XVIII, XV).

Stratum granulosum. The stratum granulosum generally consisted of 1 to 5 layers of flat, polygonal cells filled with basophilic granules (Plate II, XV, XIII). This layer was thickest in areas of thick skin (snout and interdigital skin), and only one layer in thickness or occasionally sporadic in thin skin (eye, axilla). Many of the cells possessed fragmented nuclei. Contrary to this work, Ellenberger (1906) reported the absence of this layer on the snout of hogs.

Stratum germinativum. The cells of the stratum germinativum varied from squamous or polygonal, in the more superficial parts, to columnar or cuboidal, at the basal portion. The cells of the stratum spinosum, which were larger than the basal cells, possessed definite intercellular bridges prominent in the snout and interdigital skin (Plate II).

"Clear cells," which were observed primarily in the stratum germinativum, possessed a clear cytoplasm and basophilic nucleus (Plate XXII).

Mitosis was limited to the basal layer and deeper layers of the stratum spinosum (Plate XVI). According to Flatten (1896) mitotic division in the deepest three layers of epidermis in the snout of the pig was noted by Flemming in 1844.

Dermis

The dermis was subdivided into two layers, which blended without a distinct demarcation (Plate XV, XXI). The papillary layer originated immediately beneath the epidermis and the deeper portion of the dermis was the reticular layer. Contrary to Wilson (1941), a definite reticular layer was observed. Beneath the reticular layer a prominent layer of adipose tissue (panniculus adiposus) was noted, which was sharply delimited from the more superficial layer (Plate XVII). Strands of connective tissue from the reticular layer extended throughout the panniculus adiposus, generally perpendicular to the surface of the skin.

Numerous eosinophils were noted throughout the entire dermis, the greatest concentrations being noted in the papillary layer of the females.

Numerous capillary plexuses were present in the papillary layer and in the surrounding connective tissue sheaths of hair follicles and sebaceous glands (Plate XIII, XVII, XXII.

According to Fowler (1962) the first elastic tissue fibers were observed throughout the reticular layer in the ventral body areas and limbs of 95-day-old fetuses. Smith

(1960) did not observe elastic fibers in the dermis of newborn swine.

Elastic fibers coursed throughout the entire dermis, forming complex networks (Plate XV). Individual fibers ranged in thickness from 1 to 5 microns. They extended between the collagenous bundles without a definite arrangement. Smith (1960) did not observe elastic fibers in the dermis of newborn swine. Delicate elastic fibers were noted in the trabecula of tactile hairs (Plate V), and in the surrounding collagenous sheath of both ordinary and tactile hair follicles (Plate V, XVI). Elastic fibers of the dermis extended into the elastic cartilage of the ear, anchoring the cartilage to the connective tissue (Plate XX). These fibers were also noted in the bulbs of hair follicles (Plate XVI). The heaviest concentration of elastic fibers was located in the preputial skin and snout. In agreement with Wilson (1941), the papillary layer possessed a heavier concentration of these fibers than the reticular layer. The dorsal body areas were more densely infiltrated with elastic fibers than the ventral areas.

Mast cells were scattered throughout the entire dermis in varying numbers. There was a greater density of mast cells in the papillary layer than in the reticular layer. This might be due to the greater concentration of collagenous bundles in the latter, which prevented their observation. In a qualitative examination, the mast cells appeared more numerous in female than male dermis. The greatest concentration of mast cells in the female dermis was observed in the anal region and axilla. Mast cells were heaviest around blood vessels of both sexes (Plate XIX). Smith (1960) did not observe mast cells in newborn swine. Holmes (1960) reported two types of mast cells in rat integument, small, polymorphous ones in the papillary layer and larger ones in the reticular layer and hypodermis, but only one type was observed in this study.

The papillary layer was composed of loosely arranged connective tissue elements. The collagenous bundles of the papillary layer were delicate and thin in contrast to those of the reticular layer (Plate XV). However, in the anal region, upper eyelid and ear the collagenous bundles of both layers were similar in thickness (Plate XXI). Usually the collagenous bundles paralleled the surface of the skin, however, they followed a perpendicular course as they extended into the dermal papillae (Plate XV).

The reticular layer was thicker than the papillary layer and generally had thicker collagenous bundles. These thick bundles, some of which measured up to 100 microns, usually extended parallel to the surface of the skin. Collagenous bundles were generally thicker and more densely arranged in the female hogs and thickest on the ventral and medial body areas of both sexes. Isolated groups of fat cells were observed in the deeper portions of the reticular layer.

Hair

The general structure of hair was in agreement with the findings of Montagna and Ellis (1952) and Trautmann and Fiebiger (1957). As Flatten (1896), Ellenberger (1906), and Smith (1960) reported, the hair was usually arranged in groups of three, however single hairs and groups of two and four were frequently seen (Plate VI, VII, VIII). Smith (1960) observed single hairs and groups of four and six. Fowler (1962) reported groups of 3 to 5 hairs. The central hair of a triad was generally larger than the two adjacent hairs, however several triads were observed in which the hairs were all the same relative size (Plate VIII). Smith

(1960) reported only one hair was found per follicle regardless of the size of the hair. This observation conflicts with those of Fowler (1962) and the author. Several follicles were noted in which two hairs projected toward the surface of the skin, one hair being larger and occupying the greater volume of the follicle (Plate VI, VII).

Arrector pili muscles were attached to the connective tissue sheath about half way down the follicle. A localized thickening of the epithelial root sheath marked the point of attachment (Plate XVII). Occasionally a single arrectores pilorum muscle extended to two of the follicles in a group and two arrector pili muscles were observed to attach to a single follicle (Plate IX, X).

"Follicular folds," evident in many of the hair follicles studied, formed one to twenty three corrugations in the outer epithelial root sheath (Plate XI, XII, XXII). "Follicular folds" were located immediately superior or inferior to the sebaceous gland openings. Folds were not observed at both sites in the same follicle as was demonstrated by Smith (1960). Fowler (1962) observed folds inferior to the sebaceous gland opening. These corrugations generally exhibited a smooth, continuous membrane-like surface at the lumenal end (Plate XI). The cells within the corrugations were smaller than those of the stratum cylindricum and irregularly placed. The shapes of the follicular corrugation cells varied from oval to a very flat, elongated type. Pyknotic nuclei were frequently observed in these cells.

Various functions have been attributed to these follicular infoldings. Strickland (1958) stated that these folds may be related in some way to the movement of sebum to the surface of the skin. Holmes (1960) attributed their presence to the relaxed position of the hair follicles. Smith (1960) stated that both these factors may be involved in making possible an "emergency" supply of sebum to the skin.

These infoldings may have been true follicular structures or artifacts. Montagna and Ellis (1952) reported the absence of these corrugations in the human species, indicating they may be specialized structures limited to domestic animals. On the other hand, the corrugations superior to the sebaceous gland opening would be an impediment to the transport of sebum toward the surface of the skin, indicating possibility of artifact. The artifact theory may be further supported by the hypothesis that when the animal was sacrificed, the supporting elements of the follicle lose their dynamic state and contract, resulting in folds.

Tactile hairs. Prominent tactile hairs were seen in the lip and snout. Smith (1960) reported tactile hairs only in the snout. Fowler (1962) observed tactile hairs on the snout, jowl and eyelids. The tactile hairs were arranged singularly in both the lip and snout, and were surrounded by a thick connective tissue sheath (Plate III). Trabeculae, composed of collagenous and elastic fibers, traversed the blood sinus of the hairs (Plate III, IV). A single large nerve appeared to innervate this structure (Plate IV). Arrector pili muscles were not observed in relation to the tactile hairs, supporting previous reports (Smith, 1960; Fowler, 1962) that the tactile hairs are not supplied by these muscles.

Sebaceous Glands

During the development of the hair follicle, epithelial cells from the side of the follicle, which made an obtuse angle with the skin, grew into the dermis to form sebaceous glands. The sebaceous glands observed were simple alveolar or simple branched alveolar glands which opened, by very short ducts, into the neck of the hair follicles (Plate XXII). These glands were composed of a secretory portion and an excretory duct. The cells of the secretory portion of the gland varied in size and structure. The basal cells were small in relation to those of the central part (Plate XI, XXII). The basal cells, which were small cuboidal, possessed definite nuclei and nucleoli. The central cells, 3 to 4 times larger than the basal cells, showed bizarre shapes and pyknotic nuclei, while the nucleus was entirely missing in some of the cells (Plate XI, XXII). The cytoplasm of these cells appeared vacuolated, indicating degeneration (Plate XI). Generally, one duct opened into the hair follicles, however in some cases two ducts were observed, one on either side of the follicle. Cellular fragments were noted in some of the excretory ducts, indicating glandular activity. In cross section, the sebaceous glands were arranged in a rosette fashion around the follicles (Plate XXI).

Sweat Glands

In agreement with Trautmann and Fiebiger (1957), the sweat glands observed were simple coiled tubular apocrine glands. The latter were found in all areas with the exception of the snout, where tubular merocrine glands were observed. Smith (1960) and Fowler (1962) reported compound tubular sweat glands in the snout of newborn and fetal swine. Flatten (1896) reported numerous sweat glands in the snout of pigs.

The secretory portion of the glands was located in the lower areas of the reticular layer and throughout the panniculus adiposus (Plate VII, XVII, XVIII), the largest glands being in the axilla and anal region and the smallest in the eyelid and external ear (Plate XXI).

Various phases of activity were observed in these glands. In many of the glands, the apical portions of the secretory cells protruded into the lumen (Plate XXIV). In other glands, the fragmented apical portion was seen in the lumen with what appeared to be secretion from these cells (Plate XXIII). Resting phases of the cells were also noted (Plate XXIII). These several anatomical observations strongly suggest that the sweat glands of Yorkshire hogs may be functional.

Carpal glands. Carpal glands were not evident in any of the sections studied. Gross observation of the medial carpus of ninety additional Yorkshire hogs also proved fruitless.

SUMMARY AND CONCLUSIONS

The skin of three mature female and three mature castrated male Yorkshire hogs was studied histologically.

The epidermis included only three characteristic layers since the stratum lucidum was absent. The stratum corneum was thickest in the snout and interdigital skin and the latter was characterized by sharp epidermal projections. The thinnest stratum corneum was found in the eyelid, axilla, and dorsal areas of the abdomen and thorax. The stratum granulosum was thickest in areas of thick skin (snout, interdigital skin) and only one layer in thickness or occasionally sporadic, in thin skin (eye, axilla). "Clear cells," were observed only in the stratum germinativum. Mitosis was limited to the basal layer and deeper layers of the stratum spinosum. The thickest epidermis was found on the snout and interdigital skin and the thinnest on the axilla, eyelid and ear.

In the dermis, prominent layers of adipose tissue (panniculus adiposus) were noted beneath the reticular layer. Elastic fibers, which coursed throughout the entire dermis, were observed in the trabecula of tactile hairs and in the bulbs of hair follicles. The heaviest concentration of these fibers was found in the snout and prepuce. The papillary layer possessed a heavier concentration than the reticular layer and the dorsal body areas were more densely infiltrated than the ventral areas.

There was a greater concentration of mast cells in the papillary layer than in the reticular layer. Qualitatively, the mast cells appeared more numerous in female than male dermis, the greatest concentration in the female dermis was observed in the anal region and axilla.

The collagenous bundles of the papillary layer were delicate and thin in contrast to those of the reticular layer. However, in the anal region and ear the collagenous bundles of both layers were similar in thickness. Usually, the collagenous bundles paralleled the surface of the skin, however they followed a perpendicular course as they extended into the dermal papillae. The collagenous bundles were generally thicker and more densely arranged in the female hogs and thickest on the ventral and medial body areas of both sexes.

The hair was usually arranged in groups of three, however individual hairs and groups of two were frequently seen. The central hair of a triad was generally larger than the two adjacent hairs, however several triads were observed in which the hairs were all the same relative size. Several follicles were noted which possessed two hairs, one hair being larger and occupying the greater volume of the follicle. "Follicular folds" formed one to twenty three corrugations in the outer epithelial root sheath. These folds were located either superior or inferior to the sebaceous gland openings. Prominent tactile hairs were arranged singly in both the lip and snout.

The sebaceous glands, which were simple alveolar or simple branched alveolar glands, appeared to be active. The central cells, 3 to 4 times larger than the basal cells, showed bizarre shapes and pyknotic nuclei, however the nucleus was entirely missing in some of the cells, indicating degeneration of the cells. The sebaceous glands were arranged in a rosette fashion around the follicles.

Simple, coiled, tubular apocrine sweat glands were observed in all body areas with the exception of the snout, where tubular merocrine glands were present. The largest sweat glands were noted in the axilla and anal region, and the smallest in the eyelid and external ear. The sweat glands appeared to be active in all areas examined.

Carpal glands were not evident in any of the sections studied. Gross observation of 90 additional Yorkshite hogs failed to indicate any sign of these glands.

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Plate II

Compact, thick, cellular, stratum corneum with nuclear remnants--vertical section of the snout.

H. and E. stain. 280X.

1. Stratum corneum

2. Stratum granulosum

3. Stratum germinativum

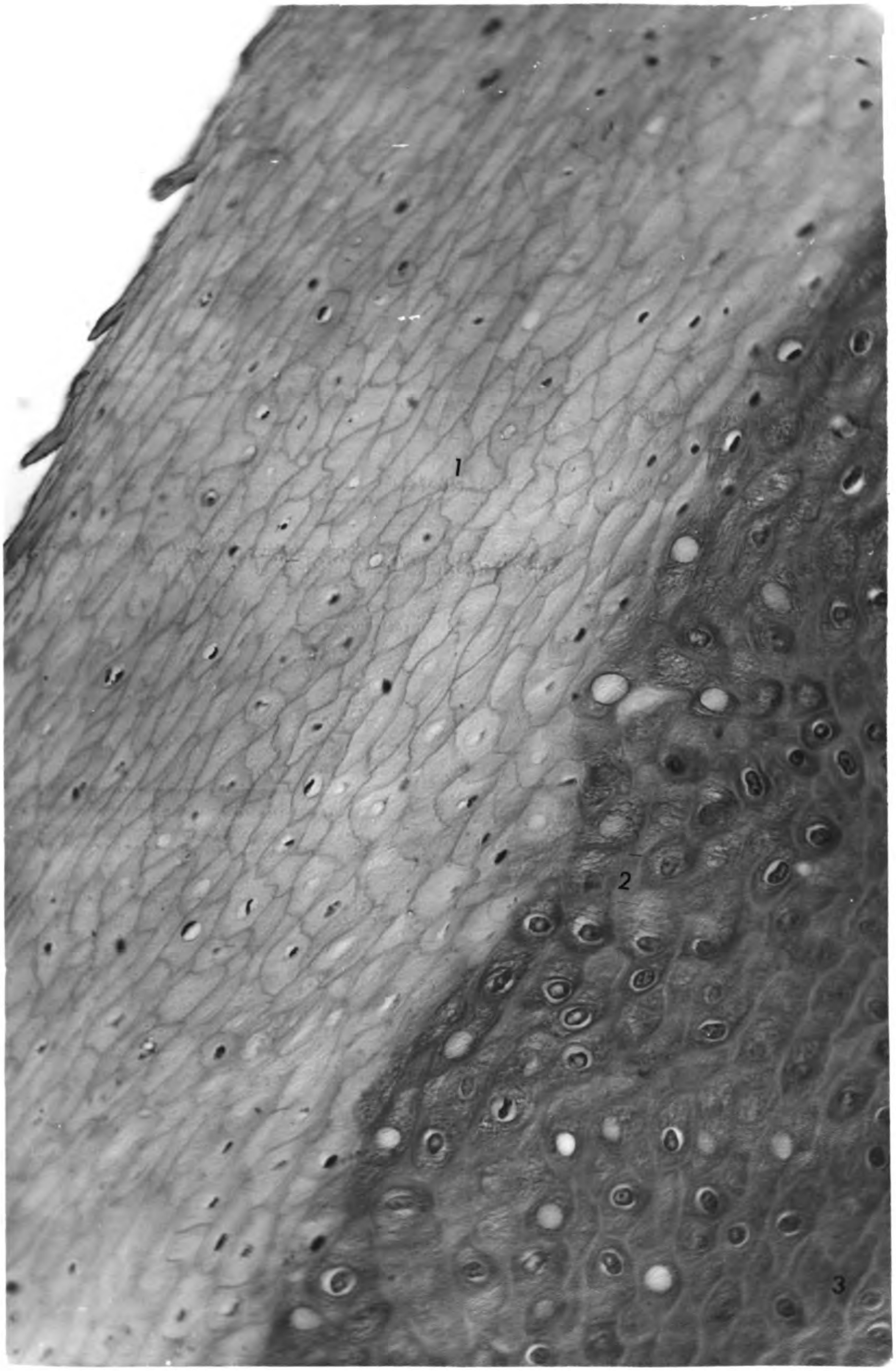

1
2
3

Plate III

The individual arrangement of tactile hairs--horizontal section of the lip.

H. and E. stain. 62X

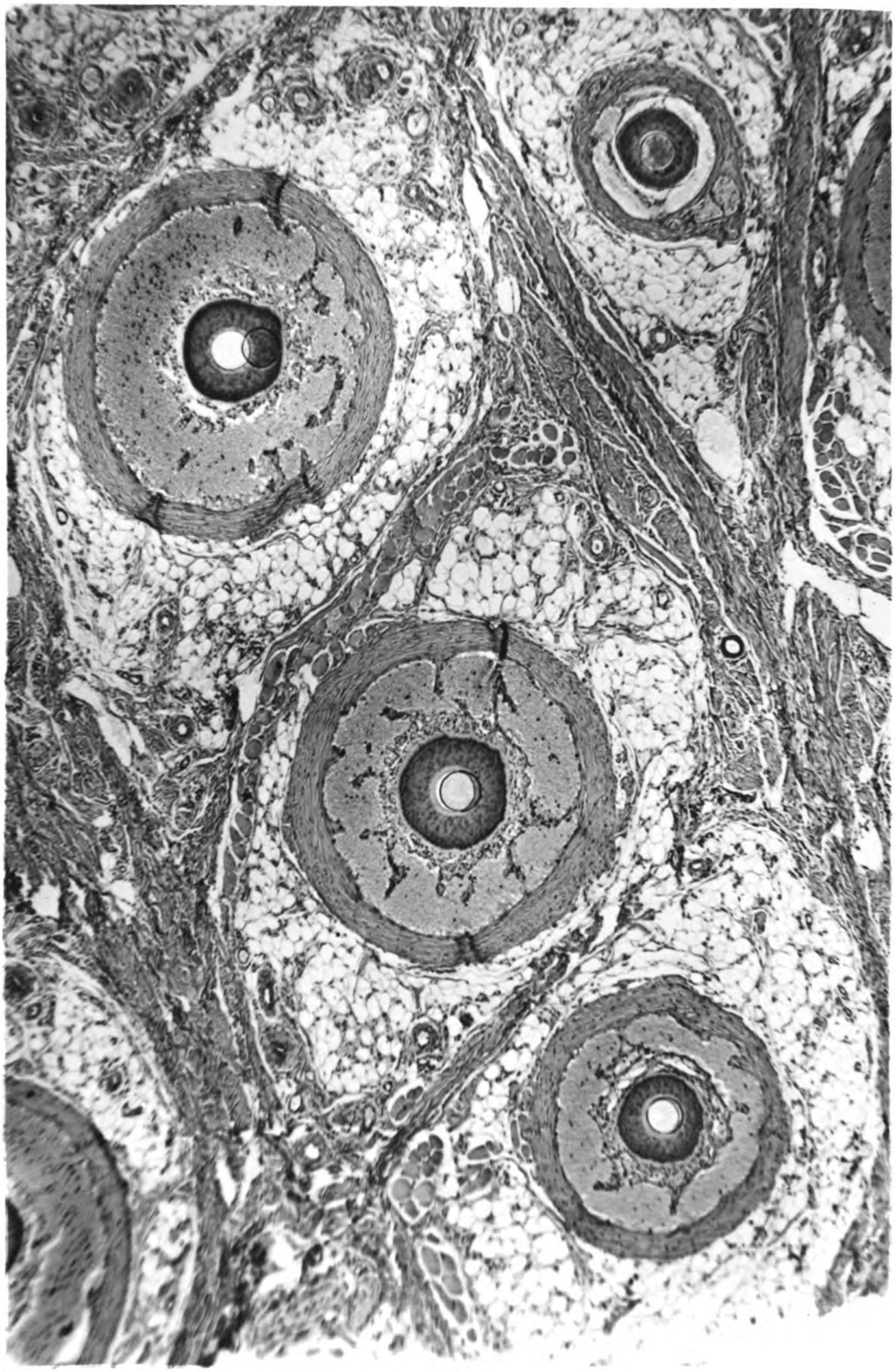


Plate IV

A single tactile hair. Note the large nerve and smaller nerve branches in the capsule--horizontal section of the lip.

H. and E. stain. 102X

1. Connective tissue capsule
2. Blood sinus
3. Trabeculae
4. Hair
5. Nerves
6. Blood vessels
7. Adipose tissue

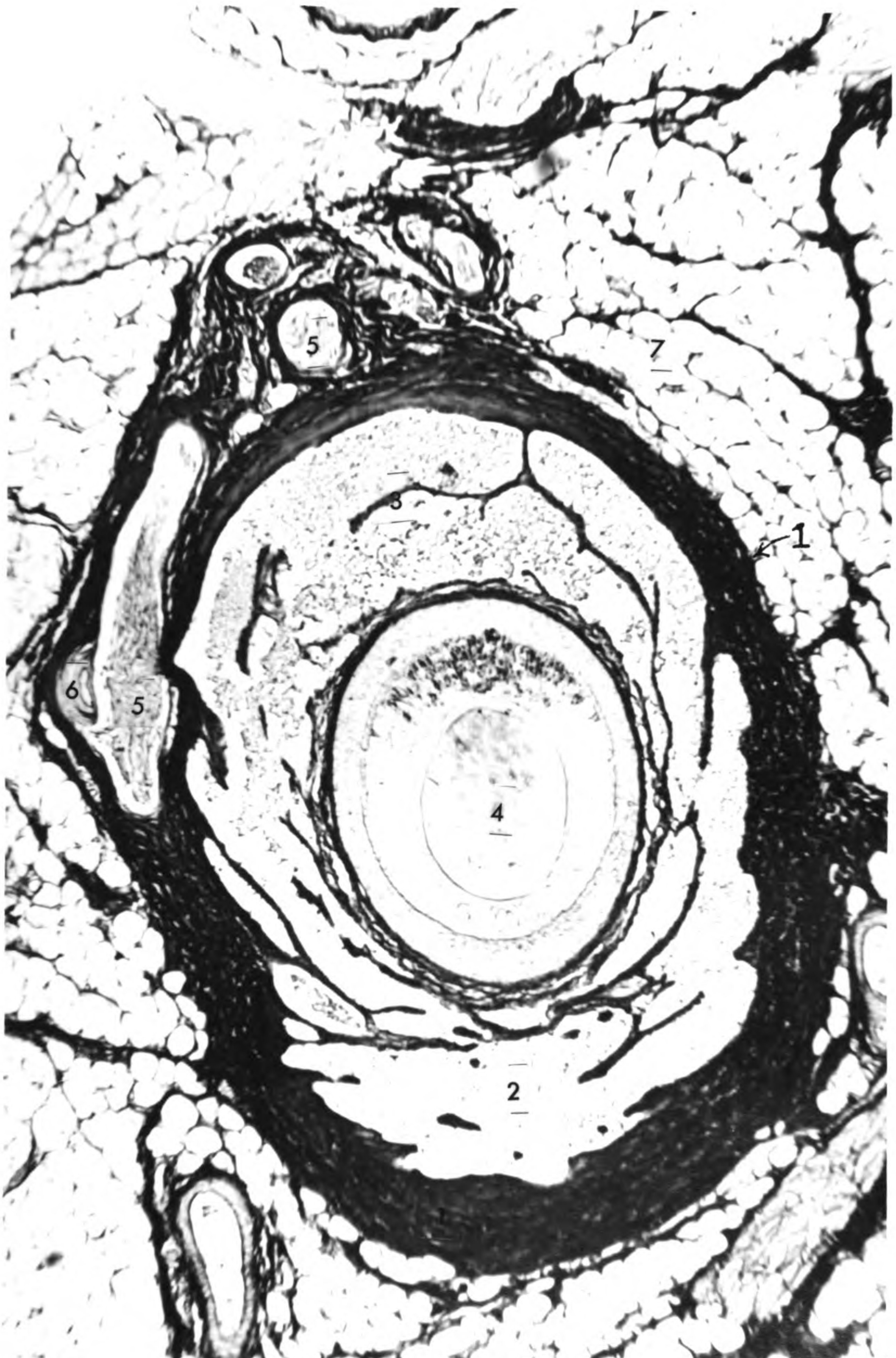
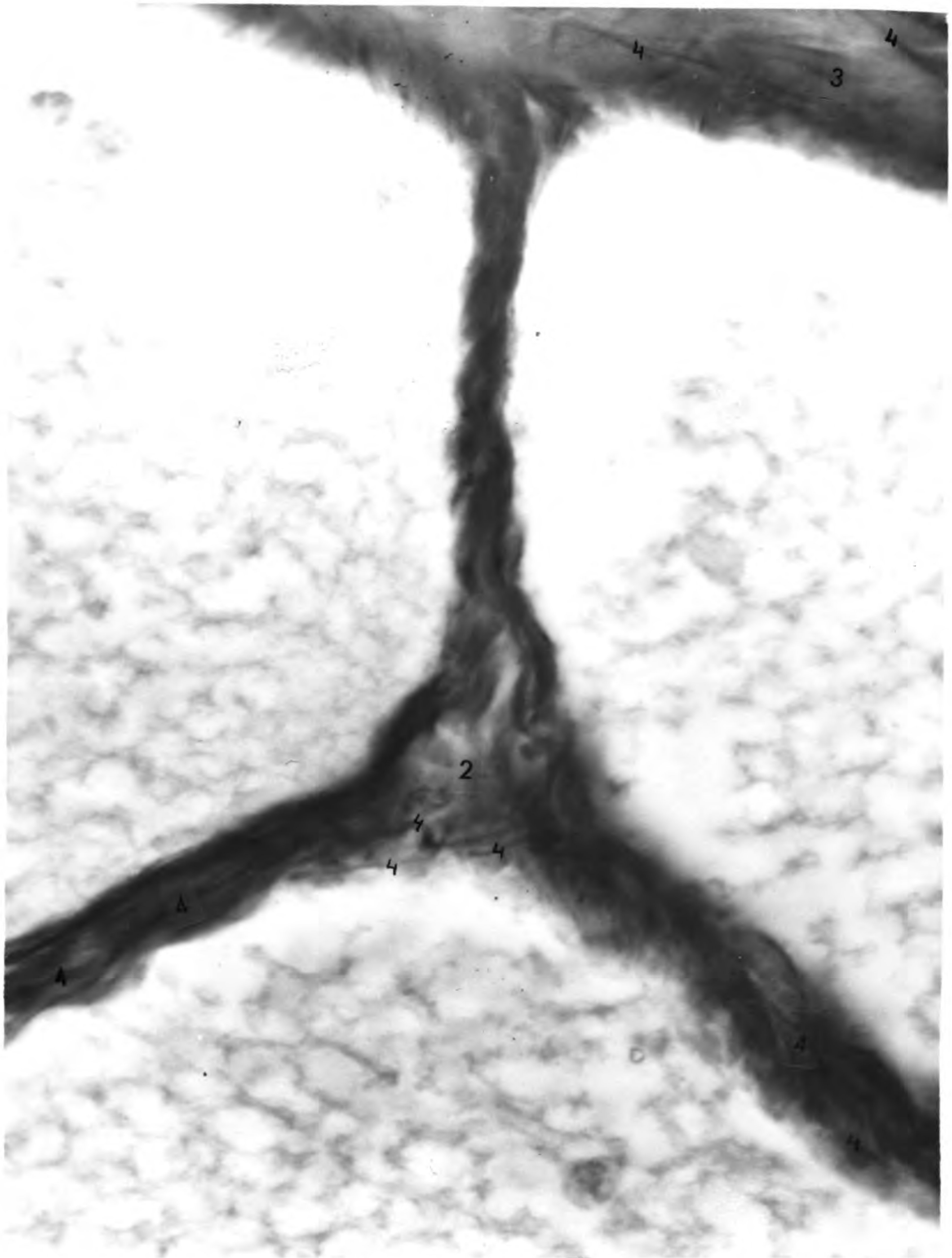

5
7
3
1
6
5
4
2

Plate V

Elastic fibers in the trabecula of a tactile hair--horizontal section of the lip.

Weigert's and Van Gieson's stain. 1083X

1. Blood sinus
2. Trabecula
3. Connective tissue capsule
4. Elastic fibers



1

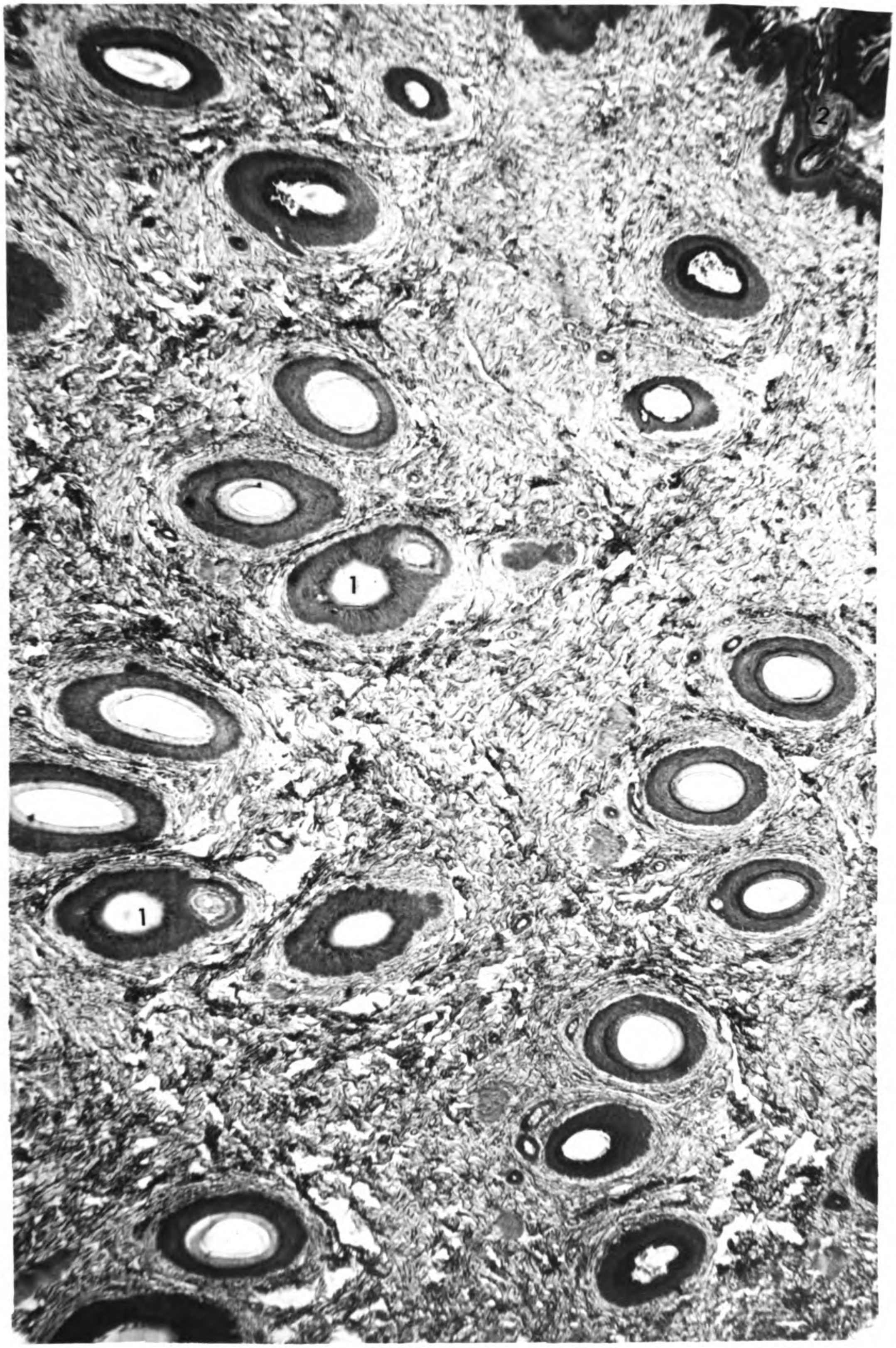
Plate VI

The hair pattern showing characteristic triads. Note the two hairs in a single follicle--horizontal section of the bridge of the nose.

H. and E. stain. 51X

1. Follicles with two hairs

2. Epidermis



2
1
1

Plate VII

The hair pattern showing triads and groups of two--horizontal section of the medial carpus.

H. and E. stain. 57X

1. Two hairs in a single follicle

2. Sweat glands

3. Adipose tissue

4. Capillaries


1
1
4
3
3
2
2
3

Plate VIII

A triad, the hairs are the same relative size--horizontal section of the lateral brachium.

H. and E. stain. 165X

1. Adipose tissue

2. Sweat glands

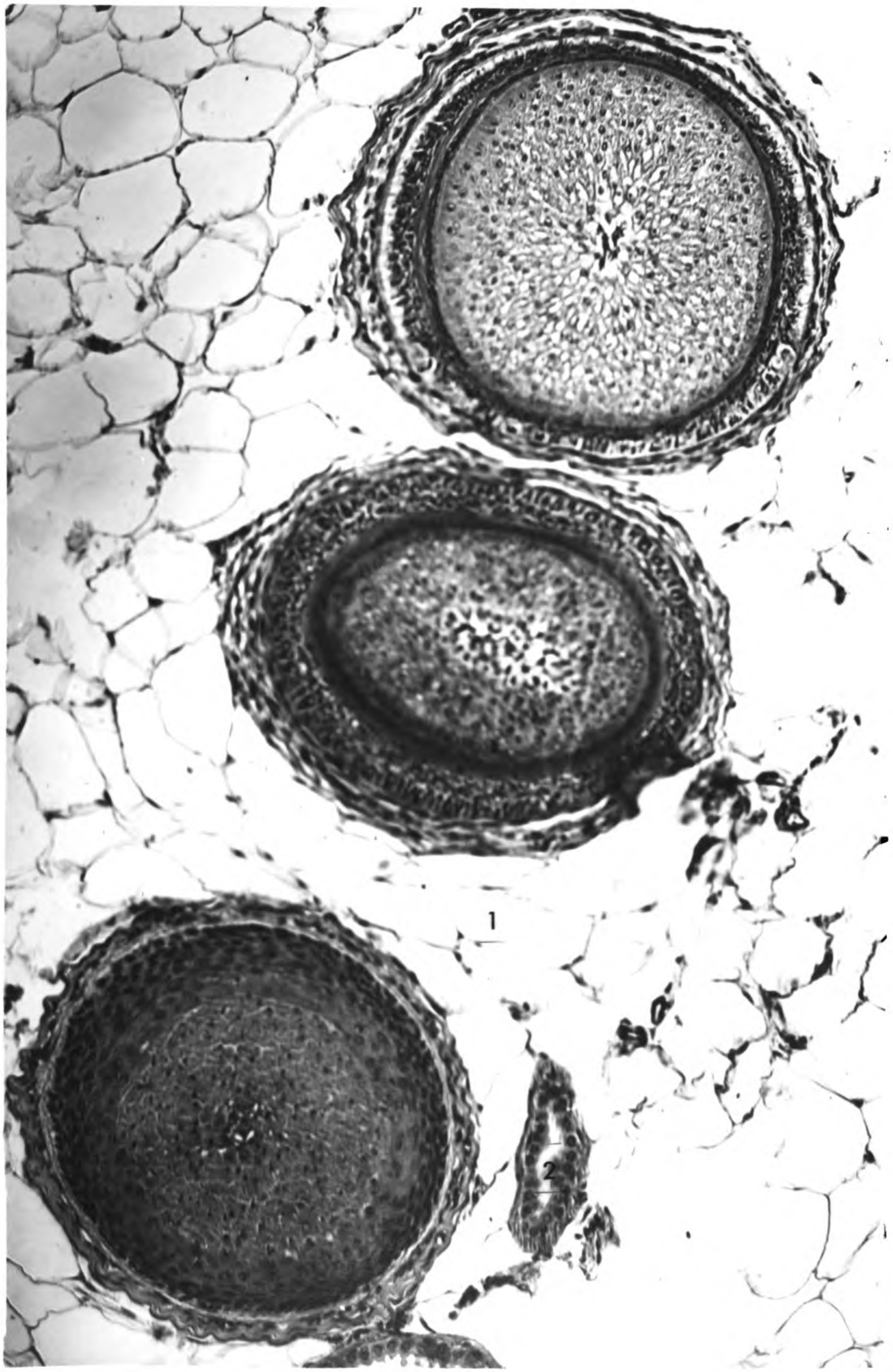

1
2

Plate IX

A single arrector pili muscle attached to two hair follicles--horizontal section of the dorsal sacrum.

H. and E. stain. 170X

1. Arrector pili muscle


1

Plate X

A single hair follicle with two arrector pili muscles--horizontal section of the dorsal thoraco-lumbar region.

H. and E. stain. 140X

1. Duct of sweat gland

2. Arrector pili muscles


2
1
2
2

Plate XI

Follicular folds and surrounding sebaceous glands. Note the cellular degeneration in the sebaceous glands--vertical section of the bridge of the nose.

H. and E. stain. 360X

1. Lumen of the follicle

2. Cuticle of the follicle

3. Follicular folds

4. Degenerating cells of the sebaceous gland

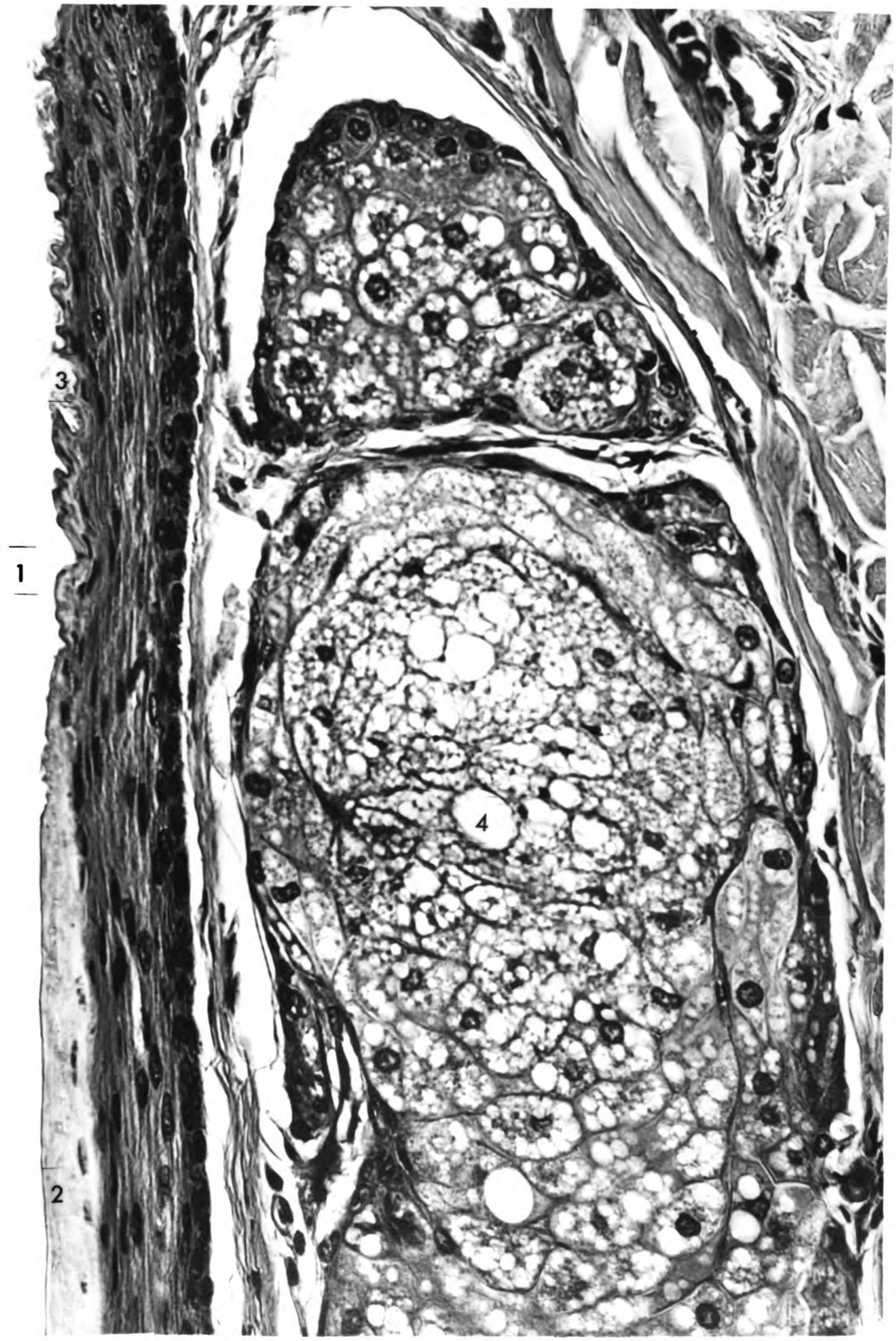

3
1
4
2

Plate XII

Follicular folds--vertical section of the bridge of the nose.

H. and E. stain. 375X

1. Lumen of the follicle

2. Follicular folds

3. Cuticle of the follicle

1

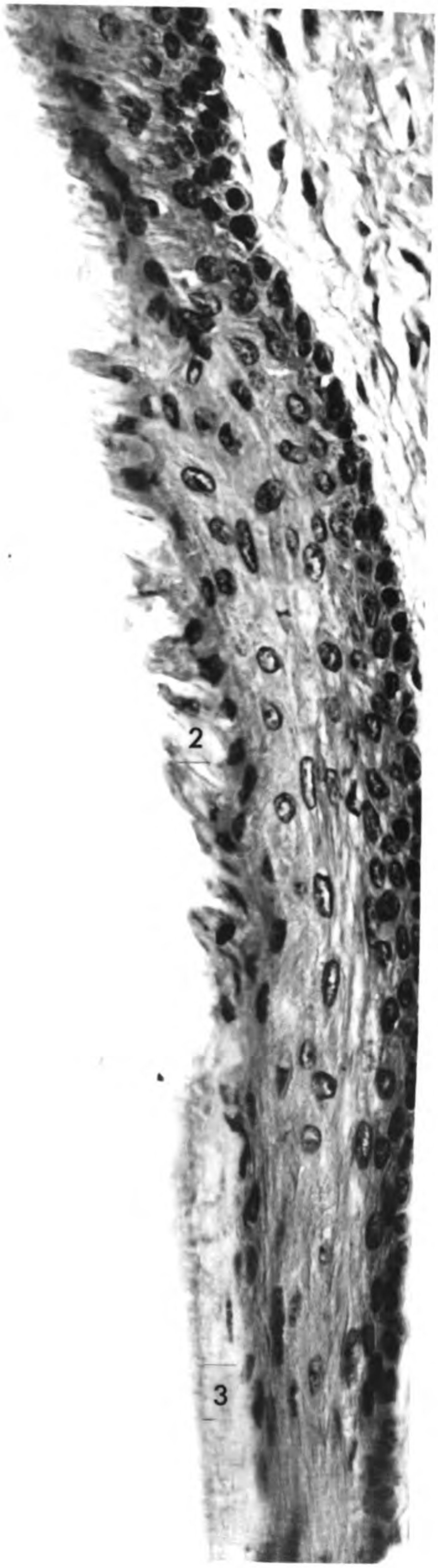


Plate XIII

Follicular fold-like structures at the bulb of the hair follicle--vertical section of the upper eyelid.

H. and E. stain. 164X

1. Cortical pre-keritinization area

2. Follicular fold-like structures

3. Cuticle of the follicle

4. Lumen of the follicle

5. Capillaries

6. Skeletal muscle

7. Clear cells

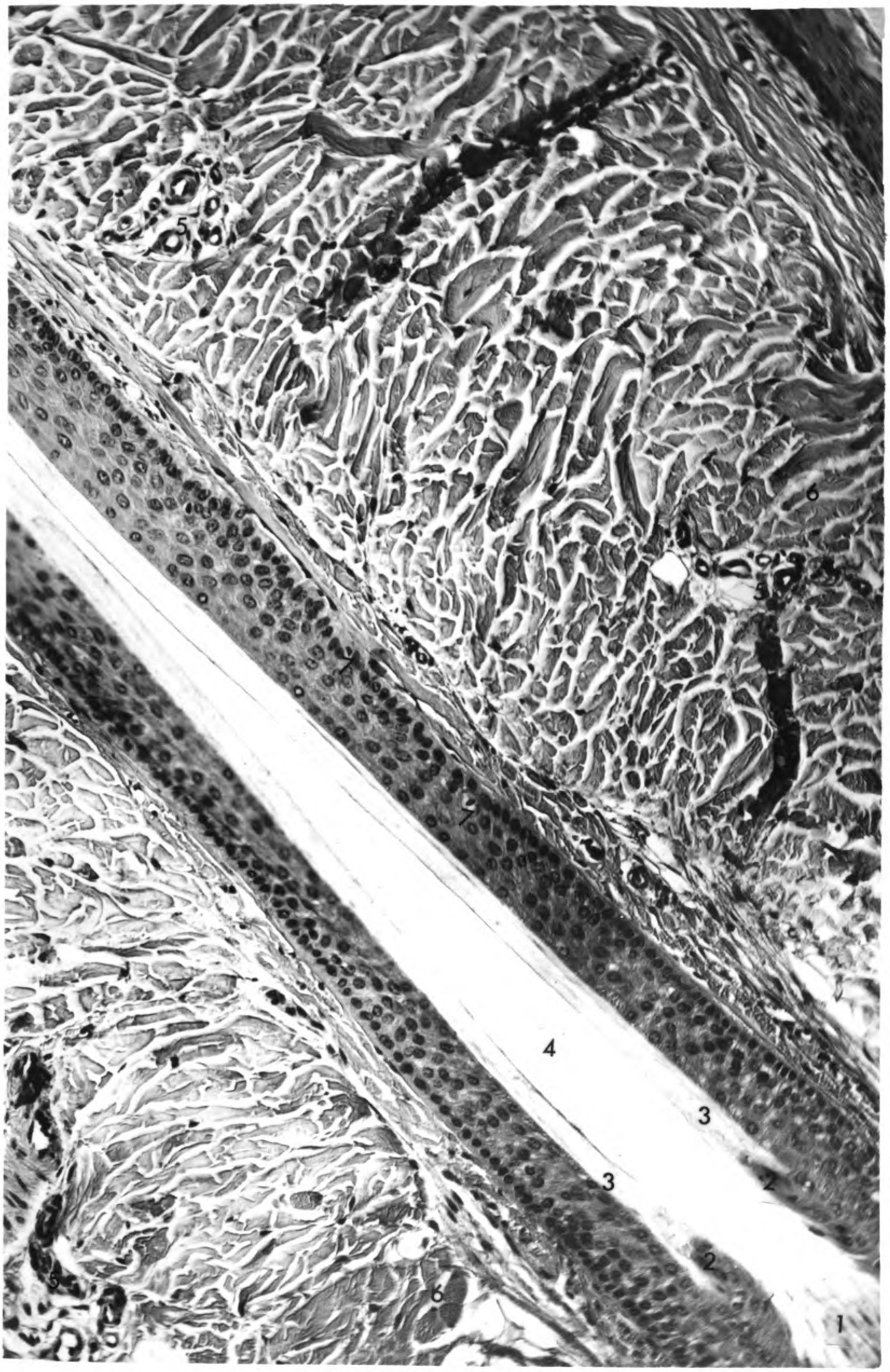

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Plate XIV

Two hairs in a single follicle--vertical section of the upper eyelid.

H. and E. stain. 140X

1. Epidermis

2. Ducts of sweat glands

3. Skeletal muscle

4. Keratin

5. Main hair

6. Smaller hair


4
4
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3

Plate XV

Arrangement of the dermal fibers showing the papillary and reticular layer. Note the elastic fibers--vertical section of the lateral thorax.

Weigert's and Van Gieson's stain. 164X

1. Stratum corneum
2. Stratum granulosum
3. Stratum germinativum
4. Papillary layer
5. Reticular layer
6. Elastic fibers
7. Collagenous fibers

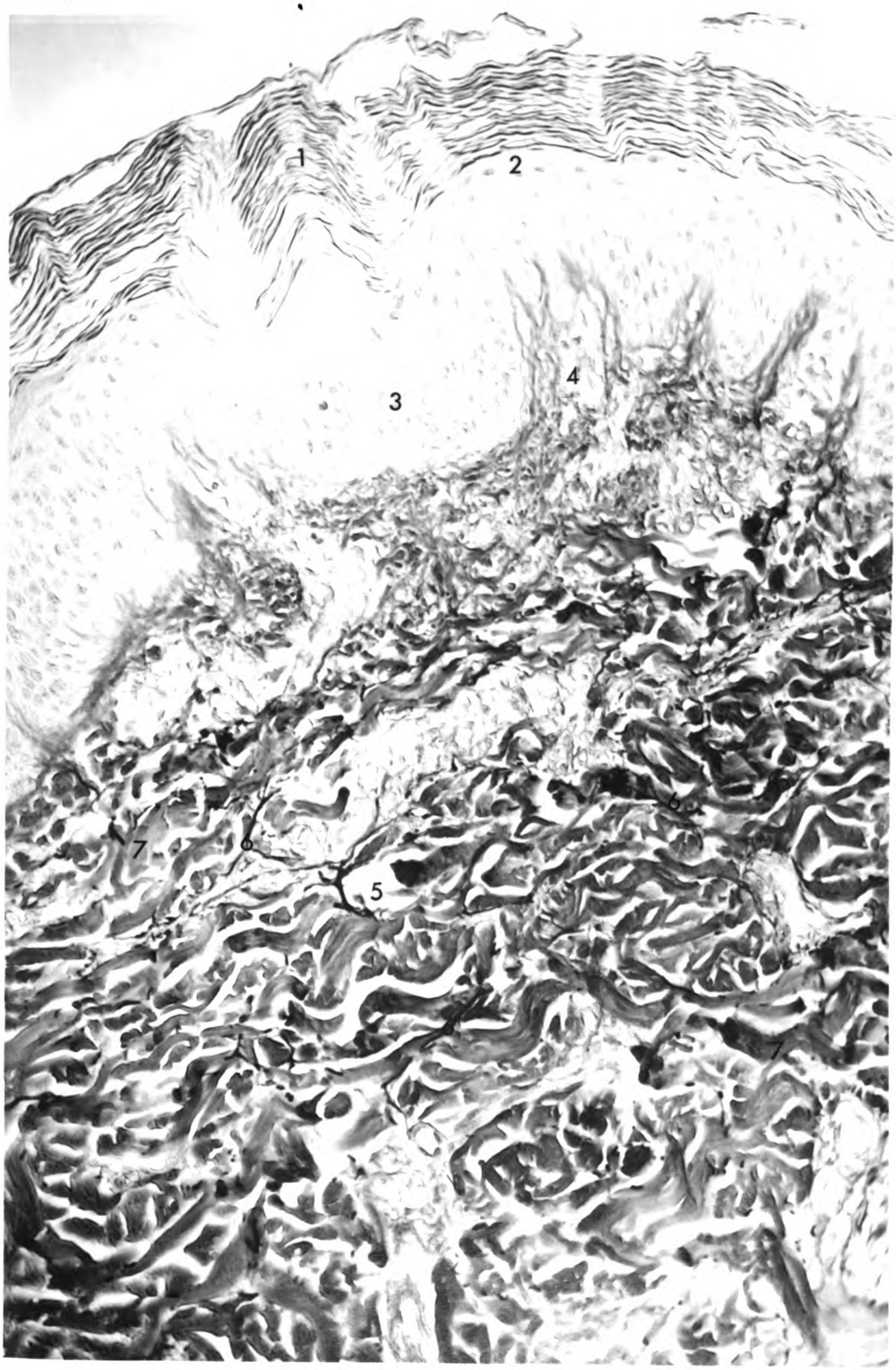
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Plate XVI

Elastic fibers in the dermal papilla of a hair follicle--vertical section of the bridge of the nose.

Weigert's and Van Gieson's stain. 452X

1. Connective tissue sheath

2. Outer epithelial root sheath

3. Inner epithelial root sheath

4. Proliferating cortex of the hair

5. Dermal papilla

6. Various stages of mitosis

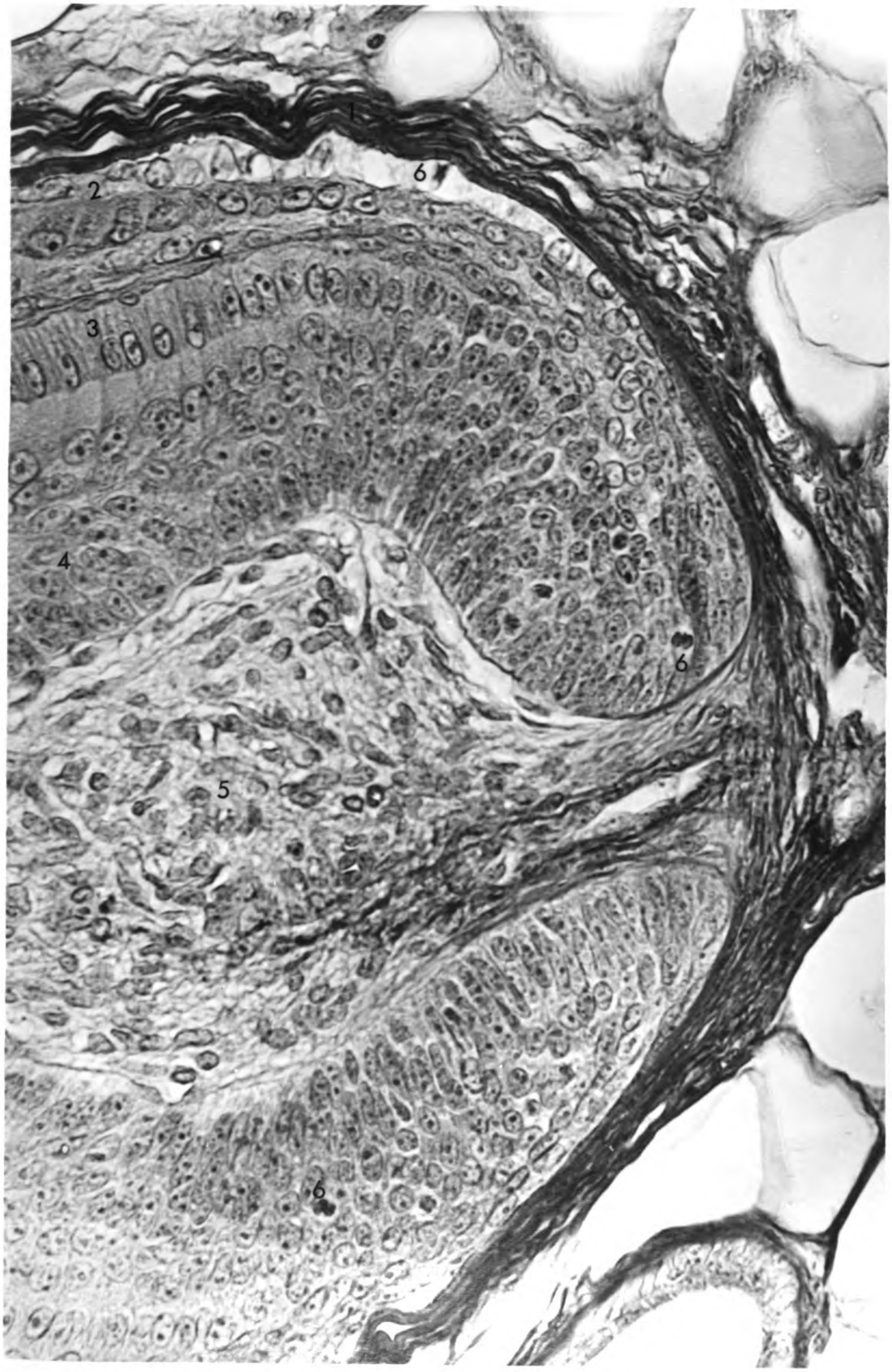
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Plate XVII

An arrector pili muscle attached to the bulge of the outer epithelial root sheath--horizontal section of the prepuce.

H. and E. stain. 74X

1. Reticular layer
2. Panniculus adiposus
3. Sebaceous gland
4. Sweat glands
5. Arrector pili muscle
6. Capillary plexus


6
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Plate XVIII

Epidermal projections of the interdigital skin--vertical section.

H. and E. stain. 110X

1. Keratin

2. Epidermis

3. Sweat glands

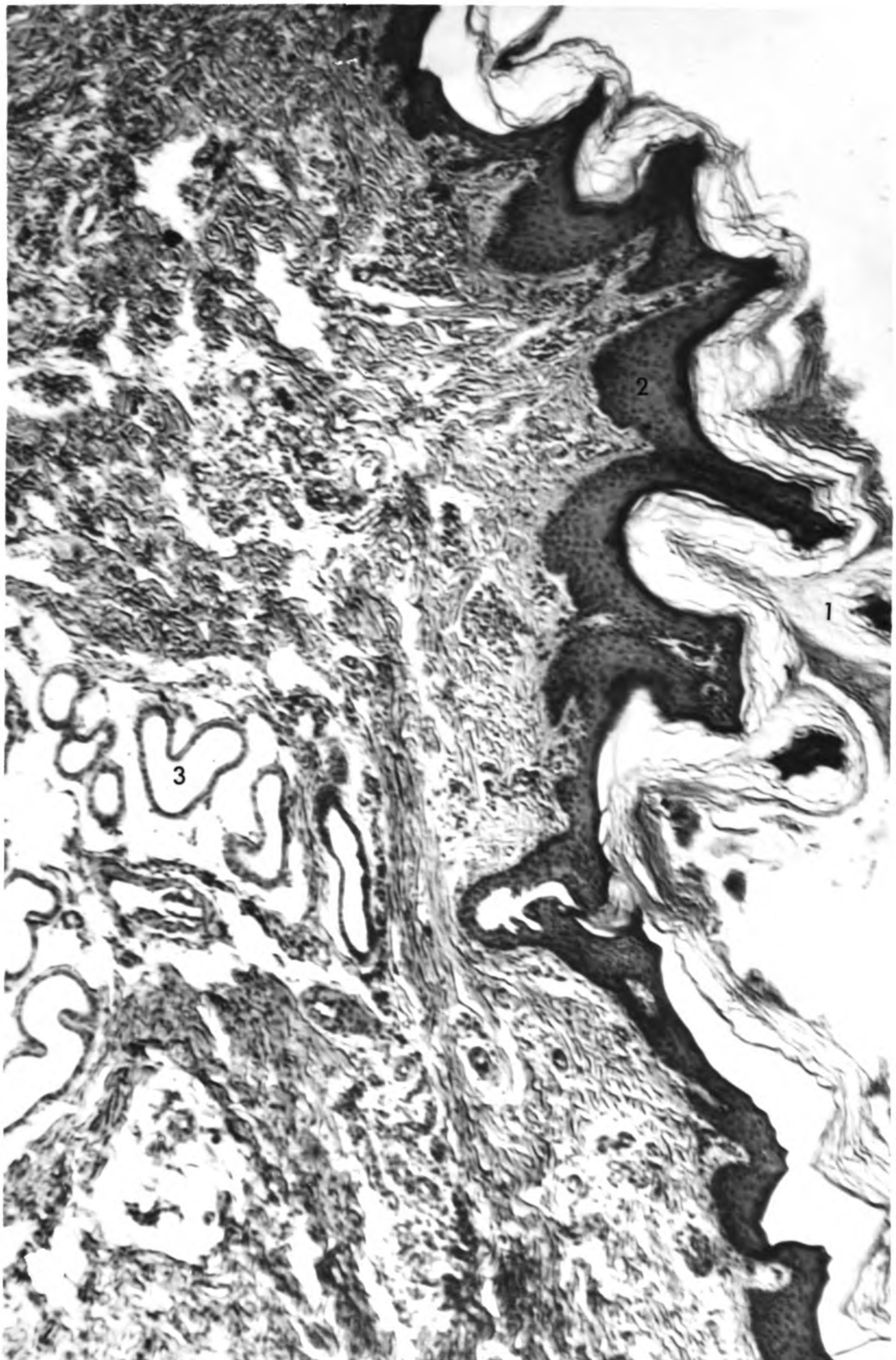
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Plate XIX

Mast cells and eosinophils in the reticular layer of the dermis--horizontal section of the ventral abdomen.

Giemsa's stain. 540X

1. Mast cell

2. Eosinophil

3. Blood vessel

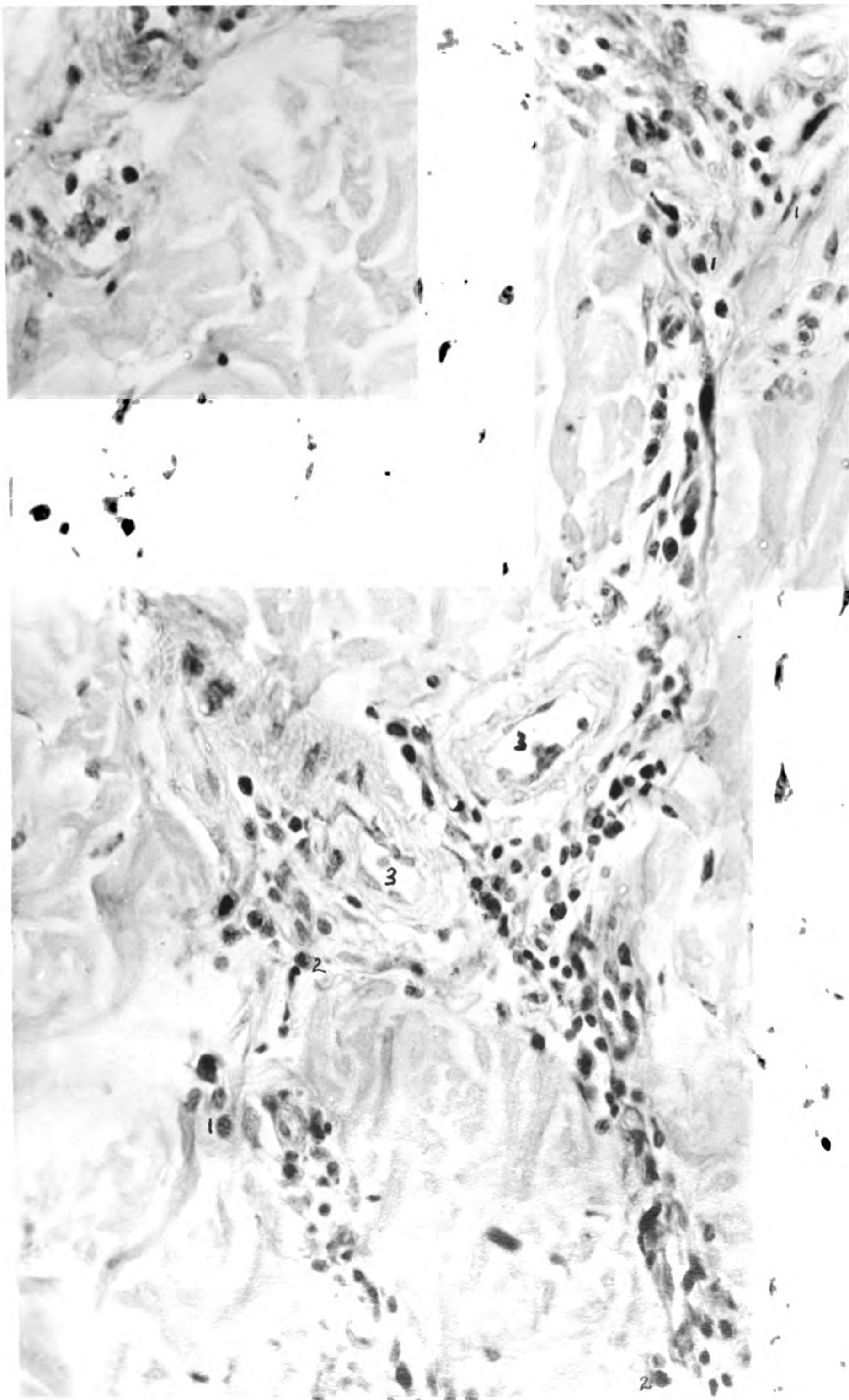
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Plate XX

Elastic fibers of the cartilage projected into the adjacent dermis. Note the absence of a panniculus adiposus--vertical section of the external ear.

Weigert's and Van Gieson's stain. 352X

1. Elastic cartilage

2. Elastic fibers

3. Capillary

4. Dermis

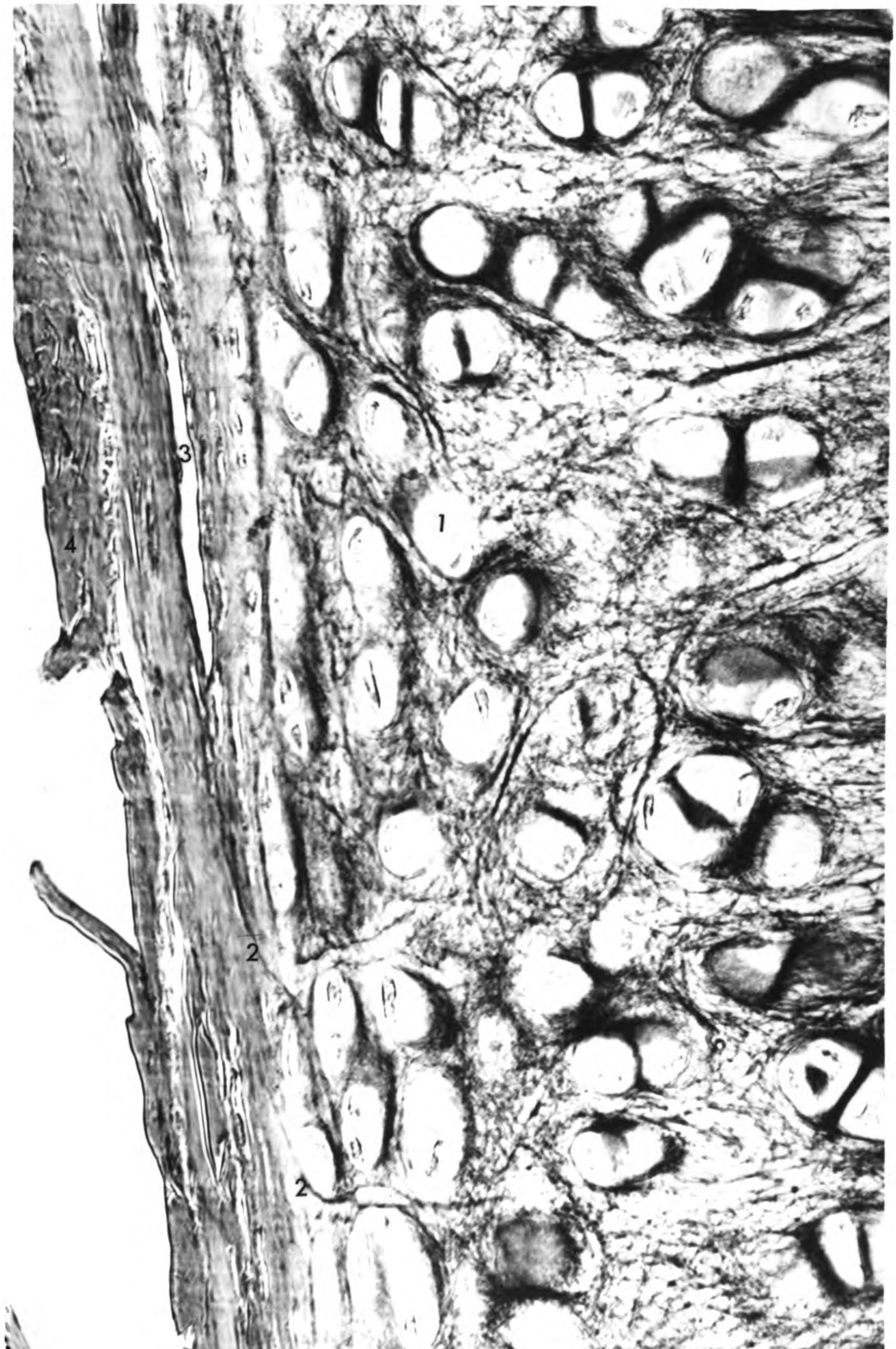
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Plate XXI

The arrangement of sebaceous glands around hair follicles. Note that there is little difference in the size of the collagenous bundles in the papillary and reticular layer, also the absence of a panniculus adiposus--vertical section of the upper eyelid.

H. and E. stain. 64X

1. Hair follicles
2. Sebaceous glands
3. Skeletal muscle
4. Sweat glands
5. Sweat gland ducts
6. Papillary layer
7. Reticular layer
8. Blood vessels

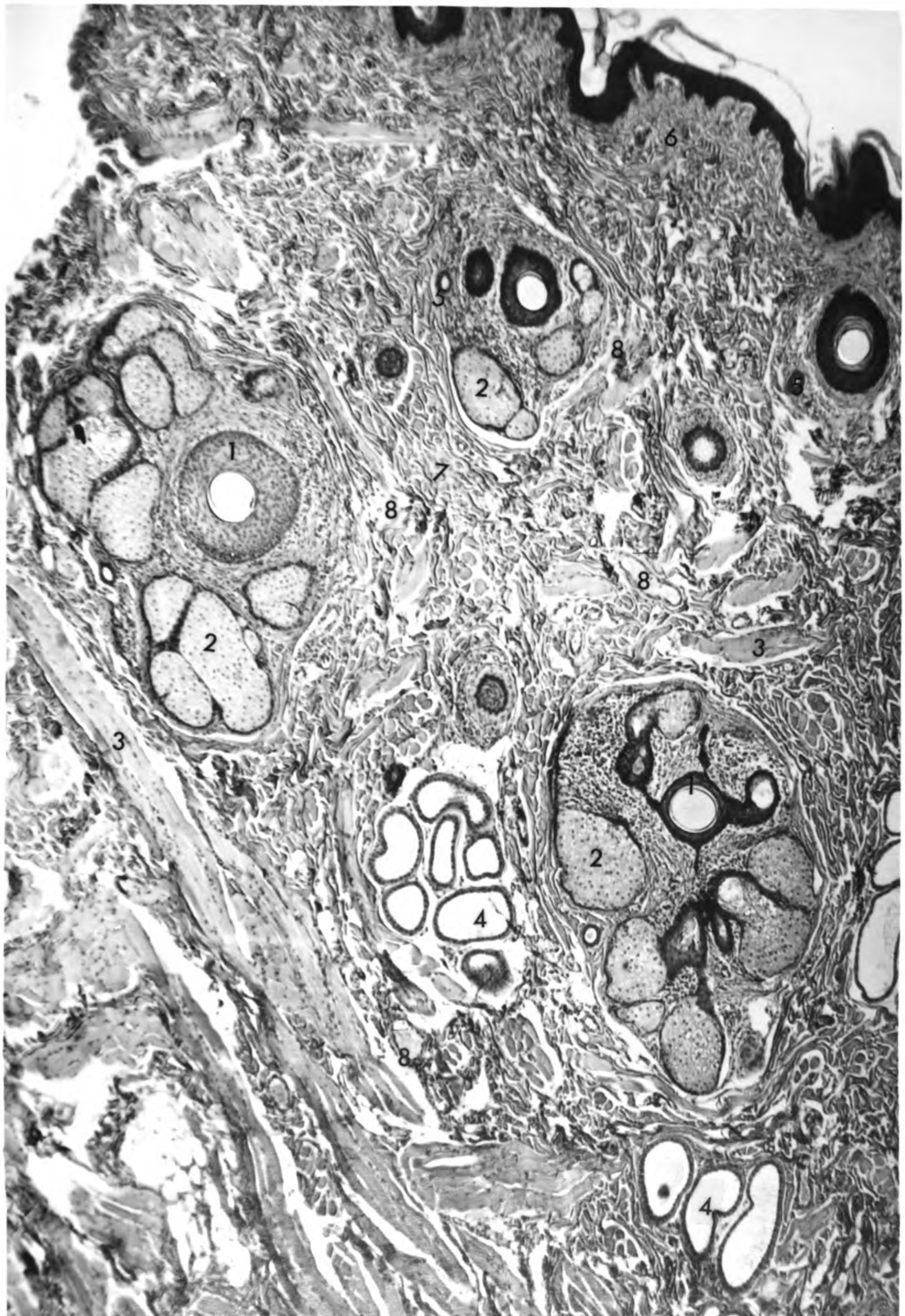
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Plate XXII

Ducts of the sebaceous gland opening into the hair follicle. Note the numerous capillaries in the surrounding connective tissue sheath--vertical section of the upper eyelid.

H. and E. stain. 200X

1. Degenerating cells of the sebaceous gland

2. Debris of the sebaceous glands

3. Follicular fold

4. Duct of sebaceous gland

5. Capillaries


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Plate XXIII

Resting phase of the apocrine sweat glands. Note the debris in the gland lumen--horizontal section of the dorsal sacrum.

H. and E. stain. 424X

1. Myoepithelium
2. Secreted debris in the lumen
3. Adipose tissue

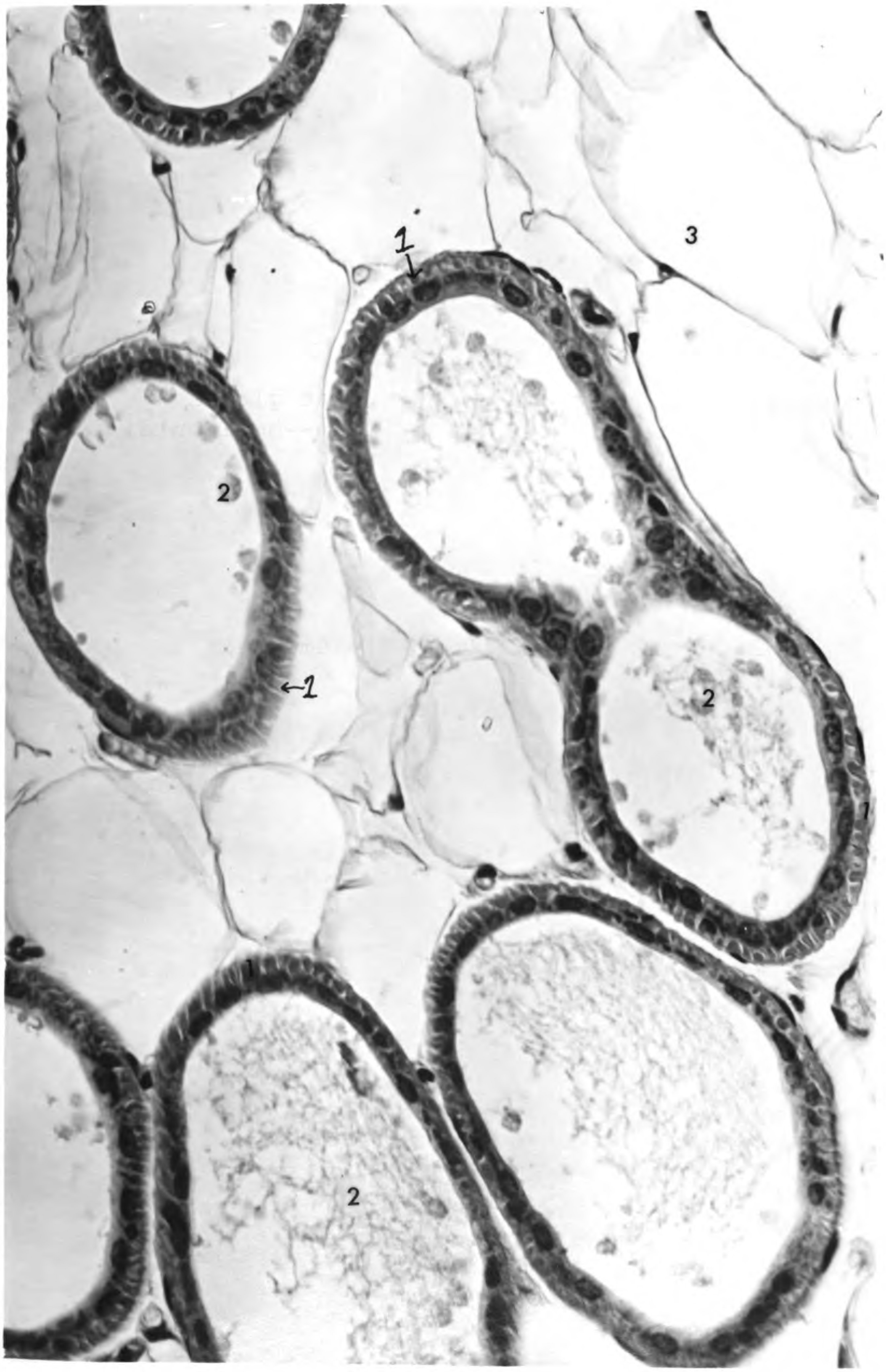
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Plate XXIV

Apocrine sweat gland in the secretory phase. Note the prominent myoepithelium--vertical section of the dorsal sacrum.

H. and E. stain. 912X

1. Myoepithelium

2. Adipose tissue

2