HISTOCHEMICAL STUDIES OF HIDES IN PROCESS FROM FRESH SKINS TO TANNED LEATHERS (REPORT III), ESPECIALLY THE SWELLING AND SPLITTING OF COLLAGENOLTS FIBERS, AND THE MECHANISM OF SUFFICIENT VENTILATION IN LEATHERS

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Introduction

Histochemical studies of hides in the process from fresh skins to tanned leathers has been done on hides ripening in cold storage. They have been compared for the degree of freshness (1). Also the changes of steer skins in the processes of ripening, soaking, liming, shaving and splitting, bating, pickling, chrome-tanning, staining, and oil-liquoring have been studied. Through these results, the morphology of hides to leathers was established histochemically and pathologically.

In the present study pathological studies on the swelling and splitting of the collagen fibers has been done to clarify the mechanisms of sufficient-ventilation in leathers.

There were the desquamation of the stratum corneum, granulosum, spinosum and basale in the epidermis, depolymerization of DNA in the nuclei, disappearance of fat in the epidermis, and transudation of fat on the dermal surface; the degeneration, swelling and splitting of the transversal and longitudinal collagenous fibers, enlargement of the intercollagenous spaces and bacterial multiplication around the collagenous fibers; isolation of the internal and external hair sheaths; agglomeration, liquidation, glucoprotein-cast, bacterium and melanin masses within the hair follicles; snake-like vesiculation of the hair follicles, hollow-pit with alopecia and disappearance of the arrector muscles; large fat droplets, tubular appearance, bacterial multiplication and disappearance of fat in the sebaceous glands

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Because of these pathological changes in fresh hides to chrome-tanned leathers it might be important to observe the mechanisms of sufficient ventilation in the leathers by measuring the largest or shortest length of the epidermis, papillary and reticular layers, distances from the dermal surface to the bottom of the hair root or to the base of the sebaceous glands areas of the longitudinal or transversal collagenous fiber in some unit (it is called here a collagenon), total area of the collagenon system, area of the intercollagenous space and the electron-microscopic changes of a collagenous fibrils.

Materials and Methods for Studies

Materials used for studies were 50 steer-skins described already in the previous report (2). All hides and leathers were collected at the Nippon Hikaku manufactory plant (Leather manufacture) in Tokyo in 1964.

The total hides and leathers from these steer-skins were fixed in buffered formol, and cut into 15μ sections with a frozen microtome. Then stained with periodic acid Schiff reaction (PAS) with or without saliva digestion for glycogen and other polysaccharides, and with acrolein Schiff reaction for protein: stained with Sudan III or Sudan black B for fat and lipoid, general staining, such as hematoxylin-eosin and staining, van Gieson's staining for collagenous fibers, Bielschowsky's silver impregnation method for reticular fibers, and Weigert's procedure for elastic fibers, were done in this investigation.

The largest or shortest length of the epidermis, papillary and reticular layers, the distances between the dermal surface and the bottom of the hair root and distance between the dermal surface and the base of the sebaceous glands, were measured with a micrometer. The collagenous fibers in the reticular layer consisted of the longitudinal fibers (contained oblique ones), transversal ones and intercollagenous spaces; they were divided into a large number of units which were called the collagenon. Collagenon consisted of the transversal and longitudinal fiber-bundles and their spaces. Total area of the collagenon system and that of the intercollagenous spaces, and that of the longitudinal or transversal fiberbundles, were drawn by Abbe's Zeichen-apparat, and then measured by the planimeter.

Results

Previous reports (1 and 2) with the process of the fresh hides to tanned leathers laid the ground-work for an investigation of the degeneration of the steer-skins during their manufacture. One of the main purposes of this paper was to evalute sufficient ventilation of leathers.

1. Pathological studies on the swelling and splitting of the collagenous fibers.

According to previous work (1 and 2), on the changes of the hides to leathers,

there were pathological changes in the hides in the process of ripening, liming, shaving, bating, chrome-tanning, and staining and fat-liquoring as shown in Table 1.

In the epidermis, there were the desquamation of the stratum corneum on soaking, that of the stratum granulosum et spinosum on liming, and that of the stratum basale on bating; the depolymerization of nuclear DNA in ripening to shaving; the disappearance of fat in soaking. In the collagenous fibers, there were the degeneration of the collagenous fibers by the loss of fuchsinophility in the van Gieson's staining; swelling of transversal collagenous fibers in soaking to tanning, and that of longitudinal ones in ripening, liming, bating, pickling and tanning; splitting of collagenous fibers and enlargement of the intercollagenous space in soaking and lining to pickling and tanning; and the bacterial multiplication in soaking, shaving and bating. In the hair follicles, there were the isolation, liquidation and agglomeration of the internal and external hair sheaths like glycoprotein casts in them, at the liming, the rest of glycoprotein casts at the shaving to pickling, the hollow-pit formation with alopecia at the bating to tanning, and the disappearance of the arrector muscles at the liming. In the sebaceous glands the authors observed the large fat droplets at the shaving to pickling, the hollow pit-formation with tubular appearance at the bating to tanning, the disappearance of fat at the soaking to pickling, and the bacterial multiplication at the shaving and bating.

It seemed to be important to find the swelling and splitting of the collagenous fibers, isolation of the hair sheath, bacterial multiplication in the hair follicles, sebaceous glands and inter-collagenous spaces, removal of glycoprotein casts in the hair follicles, and hollow pit formation with tubular appearance for the clarification of the mechanisms of the well ventilation in the leathers.

2. The enlargement, desquamation and atrophy of the cell-elements in the epidermis and corium of the hides and leathers on the manufacturing processes.

Whole tissues formed the epidermis and corium of the hides and leathers on the every manufacturing processes were measured by the micrometer. The results were shown in Table 2.

The largest length of the epidermis was $52.6\pm16.0\mu$ at fresh hide, $52.8\pm24.2\mu$ at ripening hide, and $67.0\pm10.2\mu$ at soaking hide at mean values, and then 0μ at liming hide to tanned leather. The epidermis swollen relatively, and then desquamated. The smallest length of the epidermis was 22.2–15.6μ in fresh hides, $20.6\pm9.5\mu$ in ripening hides and $36.6\mu\pm13.0\mu$ in soaked ones. Accordingly the ripend hide stored in a cold store might be slightly dried in comparison with the fresh hide.

The hides contained minute folds were expressed as the number of the epidermal winding indicated the top and base of the papillary per unit length (1170μ equal to the length of 50 at ocular micrometer, OC 10×OB 10). The numbers

Table 1 Pathological changes of the hides in the ripening,

Structure		Lesions \ Process of hides to leathers	Freshness
Epidermis		Desquamation of stratum corneum	−
		Desquamation of stratum granulosum	−
		Desquamation of stratum spinosum	−
		Desquamation of stratum basale	−
		Depolymerization of DNA of nucleus	−
		Disappearance of fat in stratum	−
		Transudation of fat on the surface	−
		Change of coloring in trichrome staining	A. B.
Corium	Collagenous fibers	Degeneration of collagen (Loss of fuchsinophily)	−
		Swelling of colagenon system	−
		Swelling of transversal collagen	−
		Swelling of longitudinal collagen	−
		Splitting of collagen	−
		Enlargement of intercollagen space	−
		Bacterial multiplication	−
		Fine fibrils stained with dyes	+
		Fat deposition	−
		Fat or oil infiltration	−
		Fat necrosis with fatty crystals	−
		Changes of reticular fiber	−
		Changes of elastic fiber	−
	Hair follicles	Isolation of internal hair sheath	−
		Isolation of external hair sheath	−
		Liquidation of hair sheath	−
		Agglomeration of hair sheath	−
		Glycoprotein cast in hair follicle	−
		Melanin mass in hair follicle	−
		Bacterial multiplication	−
		Snake like vesiculation	−
		Hollow pith with alopecia	−
		Disappearance of arector muscle	−
	Sebaceous glands	Large fat droplets	−
		Hollow pit with alopecia	−
		Bacterial multiplication	−
		Decrease or disappearance of fat	−

Remarks: A. B. showed aniline blue

of epidermal windings in these unit length of 1170μ were counted 9.0±2.0 for fresh hides, 6.8±2.4 for ripening hides, 2.4±0.7 for soaked hides, 3.6±1.1 for liming hides, 2.4±0.7 for shaving hides, 3.4±1.4 for bating hides, 3.0±0.9 for pickling hides, 2±0 for chrome tanned leather, and 2±0 for stained leather. Accordingly the winding folds of the epidermis decreased in soaking to tanning because of the swelling in the water, limed water and bating solution.

The distance between the dermal surface and hair base corresponded to the distance from the dermal surface to the hair root. The distance between the dermal

soaking, liming shaving, bating, chrome-tanning and oil-liquoring process.

Ripening	Soaking	Liming	Shaving & Splitting	Bating	Pickling	Chrome-tanning	Staining & Fat liquoring
−	+	+	+	+	+	+	+
−	−	+	+	+	+	+	+
−	−	+	+	+	+	+	+
−	−	−	−	+	+	+	+
+	+	+	+	−	−	−	−
−	+	+	+	−	−	−	−
−	+	−	−	−	−	−	−
A. B.	OR. +	−	−	−	−	−	−
−	−	−	−	+	+	+	+
−	−	−	−	−	−	−	−
−	+	+	+	+	+	+	+
+	−	+	−	+	+	+	+
−	+	+	−	+	+	+	−
−	+	+	−	−	+	+	+
−	+	−	+	+	−	−	−
−	−	−	−	−	−	−	−
+	+	+	+	−	−	−	−
−	−	−	−	−	−	−	−
+	+	−	−	−	−	−	−
−	−	F. −	−	−	−	S. −	−
−	F. −	T. −	−	F. −	−	−	−
−	−	+	+	−	−	−	−
−	−	+	+	−	−	−	−
−	−	+	−	−	−	−	−
−	−	+	−	−	−	−	−
−	−	+	+	+	+	−	−
−	−	+	+	+	+	−	−
−	−	+	+	+	+	−	−
−	−	−	−	+	+	−	−
−	−	−	−	+	+	+	+
−	−	+	+	+	+	+	+
−	−	−	+	+	+	−	−
−	−	−	−	+	+	+	+
−	−	−	+	+	+	−	−
−	+	+	+	+	+	−	−

and OR.: orange; F.: fine; T.: thick, and S.: segment.

surface and hair root at mean values was 1239±363.3μ in fresh hides 964±275.3μ in ripening hides, 1224±451.4μ in soaking ones 554±151.3μ in limings, 642.5± 99.2μ in shaving and splitting, 760.8±153.8μ in bating, 817.6±99.1μ in pickling, 1078±163.1 in chrome-tanned, and 1080±101.9μ in staining and oiling. From this above results, there was a slight decrease at ripening in comparison with the distance from the dermal surface to hair root in fresh hides because of the dryness in cold storage, and the remarkable decrease in liming, shaving, bating and pickling because of the desquamation of the epidermis, and the increase in chrome-

Table 2. Histogram of the hides and leathers of the steer skins indicating

Length \ Process / Case		Fresh hides	Ripening hides	Soaking in Water
Length of epidermis largest (shortest) (μ)	No. 1	44(15)	45(15)	58(29)
	2	44(15)	44(29)	-8(22)
	3	58(22)	88(29)	73(44)
	4	73(44)	44(15)	73(44)
	5	44(15)	44(15)	73(44)
		52.6±16	52.8±24.4	67±10.2
	Average	(22.2±15.6)	(20.6±9.5)	(36.6±13)
Number of epidermal winding/per 1170μ of unit (μ)	No. 1	11	5	2
	2	8	6	3
	3	9	4	3
	4	7	9	2
	5	10	7	2
	Average	9±2	6.8±2.4	2.4±0.7
Distance from surface to hair root (Distance from surface to base of hair) (μ)	No. 1	1020	1020	1750
	2	1095	730	820
	3	1175	1170	1170
	4	1750	730	1310
	5	1170	1170	1170
	Average	1239±363.3	964±275.3	1244±415.4
Distance from surface to base of sebaceous glands (μ)	No. 1	660	290	880
	2	438	440	730
	3	730	580	880
	4	730	440	730
	5	440	660	880
	Average	599.6±185.6	482±177.2	820±101.9
Length of zona papillae (Length of corium from base of papillary layer to muscle layer) (μ)	No. 1	580	580	1320
	2	580	580	870
	3	1020	1020	1020
	4	1170	580	1020
	5	730	580	1170
	Average	816±331.4	668±244	1080±212
Length of zona reticularis from base of papillary layer to reticular one (μ)	No. 1	4090	4380	4090
	2	3360	2480	4090
	3	2920	5110	4530
	4	3800	3070	4090
	5	3800	2630	4530
	Average	3594±56.9	3534±1432.8	4266±298.8

tanning because of the swelling.

The distance from the dermal surface to the sebaceous glands was 599.6± 185.6μ in fresh, 482±177.2μ in ripened, 820±101.9μ in soaked, 524±95μ in liming,

the enlargement, desquamation and atrophy in the epidermis and corium

Liming	Shaving & Splitting	Bating	Pickling	Chrome-tanning	Staining & Oiling
Desquamation of epidermis	Desquamation of epidermis	Desquamation of epidermis	Desquamation of epidermis	Desquamation of epidermis	Desquamation of epidermis
3	2	2	3	2	2
5	3	4	2	2	2
3	3	3	3	2	2
4	2	5	4	2	2
3	2	3	3	2	2
3.6±1.1	2.4±0.7	3.4±1.4	3.0±0.9	2±0	2±0
580	584	584	876	1020	1170
438	584	730	876	1020	1020
580	584	880	876	1020	1020
438	730	880	876	1020	1170
730	730	730	730	1314	1020
554±151.3	642.5±99.2	760.8±153.8	817.6±99.1	1078.8±163.1	1080±101.9
580	290	438	580	730	1170
440	290	730	730	876	1020
580	290	580	730	876	1020
440	430	580	730	1020	1020
580	430	440	730	1314	1020
524±95	346±95	553.6±150.3	700±114.3	963.2±274.2	663.2±274.5
292	173	730	730	1020	1170
102	146	584	876	1020	1020
102	430	870	584	1020	1020
292	730	870	730	1020	1020
146	420	730	730	1314	1020
186.8±121.1	381.8±294.6	756.8±147.9	730±12.8	1078.8±163.1	1050±83.2
6030	3070	3070	2770	4090	6030
6030	3500	3500	2770	4380	4090
6030	3500	3360	2340	4090	3500
6030	4090	3070	3070	5110	4090
5110	4090	2630	2630	6030	4230
5846±515.8	3650±543.6	3126±414.5	2716±328.1	4740±1033.5	4388±1191.9

346±95μ in shaving, 553.6±150.3μ in bating, 700±114.3μ in pickling, 963.2±274.2μ in chrome-tanning, and 963.2±274.5μ in staining. The tendencies in the decrease or increase of the dermal distance to the sebaceous glands was

Table 3. Histogram of the collagenon consiting of longitudinal steer-skins during the process

Collagenon system	Case number		Fresh hide	Ripening hide	Soaking in Water
Area of longitudinal fiber-bundle ($10^6\mu^2$) A	1	a	0.044	0.075	0.096
		b	0.061	0.118	0.143
	2	a	0.036	0.066	0.172
		b	0.028	0.065	0.136
	3	a	0.071	0.072	0.091
		b	0.045	0.057	0.136
	4	a	0.038	0.069	0.113
		b	0.038	0.068	0.163
	5	a	0.033	0.047	0.143
		b	0.033	0.940	0.199
	Average		0.043±0.013	0.068±0.029	0.139±0.034
Area of transversal fiber-bundle ($10^6\mu^2$) B	1	a	0.027	0.053	0.062
		b	0.053	0.069	0.133
	2	a	0.023	0.069	0.097
		b	0.027	0.019	0.043
	3	a	0.029	0.043	0.006
		b	0.028	0.054	0.116
	4	a	0.022	0.067	0.145
		b	0.016	0.080	0.256
	5	a	0.026	0.046	0.103
		b	0.030	0.062	0.090
	Average		0.028±0.010	0.056±0.017	0.105±0.069
Spaces in collagenon ($10^6\mu^2$) C	1	a	0.024	0.037	0.071
		b	0.032	0.055	0.159
	2	a	0.025	0.054	0.062
		b	0.019	0.015	0.027
	3	a	0.017	0.057	0.089
		b	0.021	0.047	0.106
	4	a	0.014	0.031	0.072
		b	0.015	0.042	0.180
	5	a	0.027	0.023	0.061
		b	0.034	0.017	0.036
	Average		0.023±0.007	0.037±0.016	0.086±0.050
Total area of collagenon system ($10^6\mu^2$) A+B+C	1		0.121	0.204	0.332
	2		0.079	0.144	0.269
	3		0.105	0.165	0.272
	4		0.072	0.179	0.469
	5		0.092	0.118	0.316
	Average		0.094	0.162	0.332

and transversal collagenous fibers in the reticular layer of the of chrome-tanning leathers.

Liming	Shaving & Splitting	Bating	Pickling	Chrome-tanning	Staining & Oiling
0.193	0.212	0.152	0.139	0.174	0.028
0.144	0.162	0.156	0.083	0.222	0.243
0.113	0.168	0.190	0.210	0.245	0.312
0.190	0.314	0.298	0.256	0.269	0.204
0.189	0.111	0.210	0.242	0.314	0.211
0.102	0.204	0.225	0.310	0.278	0.187
0.170	0.129	0.304	0.313	0.258	0.392
0.229	0.209	0.325	0.318	0.256	0.309
0.194	0.176	0.237	0.236	0.165	0.154
0.155	0.204	0.342	0.190	0.268	0.213
0.168±0.040	0.192±0.058	0.243±0.069	0.230±0.077	0.245±0.110	0.225±0.099
0.097	0.086	0.124	0.109	0.159	0.018
0.075	0.105	0.096	0.131	0.218	0.127
0.100	0.147	0.233	0.214	0.086	0.041
0.070	0.089	0.092	0.107	0.101	0.078
0.083	0.104	0.183	0.150	0.171	0.152
0.079	0.049	0.201	0.197	0.172	0.101
0.088	0.122	0.164	0.194	0.112	0.132
0.088	0.119	0.154	0.129	0.172	0.156
0.224	0.056	0.142	0.121	0.150	0.069
0.114	0.037	0.187	0.080	0.049	0.106
0.102±0.045	0.097±0.094	0.158±0.045	0.143±0.045	0.139±0.051	0.098±0.046
0.038	0.059	0.199	0.151	0.259	0.501
0.091	0.042	0.235	0.121	0.284	0.368
0.068	0.068	0.210	0.143	0.095	0.458
0.051	0.037	0.192	0.131	0.099	0.429
0.083	0.052	0.158	0.089	0.184	0.364
0.088	0.027	0.170	0.121	0.211	0.199
0.162	0.072	0.275	0.197	0.337	0.283
0.554	0.211	0.254	0.304	0.485	0.264
0.160	0.051	0.131	0.214	0.303	0.193
0.115	0.087	0.188	0.188	0.037	0.306
0.141±0.151	0.071±0.044	0.201±0.044	0.166±0.062	0.229±0.134	0.337±0.033
0.319	0.333	0.481	0.367	0.663	0.643
0.296	0.412	0.603	0.531	0.498	0.766
0.312	0.274	0.574	0.555	0.665	0.607
0.646	0.431	0.738	0.728	0.810	0.768
0.481	0.324	0.614	0.515	0.486	0.521
0.411	0.354	0.602	0.539	0.624	0.661

Table 4. Relationship between pathological changes in the process of hide

		Hide & Leather	Fresh hide	Ripening hide
Epidermis		Desquamation	—	—
		DNA-depolymerization	—	○
		Fat-disappearance	—	—
		Largest length of epidermis (μ)	52.6	52.8
		Shortest length of epidermis (μ)	22.2	20.6
		Number of epidermal winding/per 1170μ	9	6.8
Corium	Collagenous fibers	Degeneration of collagen	—	—
		Swelling of collagen	—	○
		Splitting of collagen	—	—
		Enlargement intercollagen space	—	—
		Bacterial multiplication	—	—
		Length of papillary layer (μ)	816	668
		Length of reticular layer (μ)	3594	3534
		Area of longitudinal fiber bundles ($10^6\mu^2$)	0.043	0.068
		Area of transversal fiber bundles ($10^6\mu^2$)	0.028	0.056
		Intercollagenous spaces ($10^6\mu^2$)	0.023	0.037
		Total area of collagenon system ($10^6\mu^2$)	0.094	0.162
	Hair follicles	Isolation of hair sheath	—	—
		Glycoprotein cast	—	—
		Bacterial multiplication	—	—
		Hollow pit formation	—	—
		Disapp of arrector muscle	—	—
		Distance of surface to hair-base	0.043	0.068
	Sebaceous glands	Hollow pit-formation	—	—
		Bacterial multiplication	—	—
		Fat-disappearance	—	—
		Distance of surface to sebaceous glands	0.028	0.056

similar to that of the dermal distance to the hair root.

The length of the papillary layer corresponded to that of the corium from the top of the papillary layer to the upper border of the reticular layer. These results were 816±331.4μ in fresh, 668±244μ in ripened, 1808±212μ in soaking, 1968±121.1μ in liming, 381.8±294.6μ in shaving, 756.8±147.9μ in bating, 730±128μ in pickling, 1078.8±163.1μ in chrome-tanning, and 1050±83.2 in staining. In the length of the papillary layer, there were a slight decrease at ripening because of the dryness in cold-storage, a remarkable swelling in the soaking and liming, a redecrease in bating and pickling, and an increase because of the spilitting of the fibers and cleaning of the intercollagenous spaces in chrome-tanning and staining.

The length of the reticular layer from the base of papillary layer to the reticular was 3594±56.9μ in fresh, 3534±1432.8μ in ripened, 4266±298.8μ in soaking, 5846± 515.8μ in liming, 3650±543.6μ in shaving, 3126±414.5μ in bating, 2716±328.1μ in pickling, 4740±1033.5μ in chrome-tanning, and 4388±1191.6μ in staining.

and planimetrical results in the hides and leathers and leather-manufacturing.

Soaking	Liming	Shaving & Splitting	Bating	Pickling	Chrome-tanning	Staining & Fat liquoring
○	○	○	○	○	○	○
○	○	○	—	—	—	—
○	○	○	—	—	—	—
67.0						
36.6	Desquamation at liming period to Staining period					
2.4	3.6	2.4	3.4	3.0	2.0	2.0
—	—	—	○	○	○	○
○	○	○	○	○	○	○
○	○	—	○	○	○	○
○	○	—	—	○	○	○
○	—	○	○	—	—	—
1080	186	382	757	730	1079	1050
4266	5846	3650	3126	2716	4740	4388
0.139	0.168	0.193	0.243	0.230	0.245	0.225
0.105	0.10	0.097	0.158	0.143	0.139	0.098
0.086	0.14	0.071	0.201	0.166	0.229	0.337
0.332	0.41	0.354	0.602	0.539	0.624	0.661
—	○	○	—	—	—	—
—	○	○	○	○	—	—
—	—	○	○	○	—	—
—	—	—	○	○	○	○
—	○	○	○	○	○	○
0.139	0.16	0.193	0.243	0.230	0.245	0.225
—	—	—	○	○	○	○
—	—	○	○	○	—	—
○	○	○	○	○	—	—
0.105	0.10	0.097	0.158	0.143	0.139	0.098

Accordingly fresh and ripend hides swollend in the soaking and liming, and decreased gradually, in the bating and pickling and then hypertrophied in the tanning and staining.

3. The area of the collagenon system consisted of the longitudinal and transversal collagenous fibers and intercollagenous spaces.

To clarify sufficient ventilation in leathers, it might be important to observe the enlargement of the intercolagenous spaces in every step of the manufacturing process. The area of the longitudinal fiber-bundles in a collagenon were $0.043\pm 0.013\times10^6\mu^2$ in fresh hides, $(0.068\pm0.029)\times10^6\mu^2$ in the ripend hides, $(0.139\pm0.034)\times10^6\mu^2$ in the soaked hides $(0.168\pm0.04)\times10^6\mu^2$ in the limed hides, $(0.193\pm0.058)\times10^6\mu^2$ in the shaved hides, $(0.243\pm0.069)\times10^6\mu^2$ in the bated hdies $(0.230\pm0.077)\times10^6\mu^2$ in the pickled hides, $(0.245\pm0.110)\times10^6\mu^2$ in the chrome-tanned leather, and $(0.225\pm0.099)\times10^6\mu^2$ in the stained leather. Accordingly, the area of the longitudinal collagenous fiber bundles in the fresh or ripend hides swolled rapidly and gradually in

the soaking liming, shaving, bating, pickling, tanning and staining process. The area of the transversal fiber-bundles in a collagenon were $(0.028\pm0.01)\times10^6\mu^2$, in fresh $(0.056\pm0.017)\times10^6\mu^2$ in ripened, $(0.105\pm0.069)\times10^6\mu^2$ in soaking, $(0.102\pm0.045)\times10^6\mu^2$ in liming, $(0.097\pm0.094)\times10^6\mu^2$ in chrome-tanning, and $(0.098\pm0.046)\times10^6\mu^2$ in staining. In the area of the transversal-fiber bundles there were a smaller increase in the ripening than the freshness, a remarkable increase in the soaking, liming and shaving and a most remarkable increase in the bating, pickling, and chrome-tanning because of the immersion in the water, lime-water, bating solution, acid solution and thanning solution.

The area of the spaces in a collagenon were $0.023\pm0.007\ 10^6\mu^2$ in ripend hides, $(0.086\pm0.05)\times10^6\mu^2$ in soaked hides, $(0.141\pm0.151)\times10^6\mu^2$ in limed hides, $(0.071\pm0.044)\times10^6\mu^2$ in shaved hides, $(0.201\pm0.044)\times10^6\mu^2$ in bated hides, $(0.166\pm0.062)\times10^6\mu^2$ in pickled hides, $(0.299\pm0.134)\times10^6\mu^2$ in chrome-tanned leather, and $(0.337\pm0.033)\times10^6\mu^2$ in stained leathers. Accordingly the area of the inter-collagenous spaces increased gradually in the order of soaking liming, slightly involuted in the shaving, and remarkably increased in the order of pickling bating, tanning, and staining. These enlargements of the intercollagenous spaces were produced by the swelling of the collagenous fibers, immersion into the solution such as water, lime-water, acidic solution, enzyme, tannin and dyes, and the pathological changes shown in Table 1.

Total area of collagenon system contained areas of longitudinal and transversal collagenous fiber-bundles and intercollagenous spaces. The results are indicated as follows: $0.094\times10^6\mu^2$ in the fresh hdies, $0.162\times10^6\mu^2$ in the ripend hides, $0.332\times10^6\mu^2$ in the soaked hides, $0.411\times10^6\mu^2$ in the liming hdies, $0.354\times10^6\mu^2$ in the bating, $0.539\times10^6\mu^2$ in the pickling, $0.624\times10^6\mu^2$ in the tanned leather, and $0.661\times10^6\mu^2$ in the stained and fat-liquoring leather.

4. Relationship between pathological changes and planimetrical results in the hides and leathers during the process of hide-and leather manfacturing.

The length of the epidermis increased more remarkablly in the soaking hides than in the fresh or ripening hides, and the number of the epidermal winding per 1170μ less in the soaked hides in comparison with the fresh or ripened hides. The epidermis disappeared in the soaking because of the desquamation.

The length of the papillary and reticular layers doubled in the soaking to liming, and in the chrome-tanning to staining; decreased in the bating to pickling owing to the swelling and splitting of the collagenous fibers, the enlargement of the intercollagenous spaces and the bacterial multiplication. These results were similar to the ups and downs in the area of the longitudinal and transversal fiber bundles and that of the intercollagenous spaces.

The length of the hair follicle indicating the distance from the dermal surface

to the hair root, increased gradually in the order soaking, liming, shaving, bating, pickling, tanning and staining, according to the isolation of the hair sheath, bacterial multiplication, hollow pit formation, disappearance of the arrector muscle, swelling and splitting of the collagenous fibers, and the enlargement of the intercollagenous spaces.

The length of the sebaceous glands indicating the distance between the dermal surface and the sebaceous glands, increased slightly in the order soaking, liming, bating, pickling, and tanning, according to the hollow pit formation, bacterial fibers, and enlargement of the intercollagenous spaces.

Summary and Conclusion

Histochemical studies on the process of tanning leathers has been done to clarify the mechanism of sufficient ventilation in the leathers.

The results are summarized as follows:

1. The swelling and splitting of the collagenous fibers, isolation of the hair sheath, bacterial multiplication in the hair follicles, sebaceous glands and intercollagenous spaces, cleaning of glycoprotein casts in the hair follicles, and hollow pit formation in the hair-follicles and sebaceous glands seemed to be important in clarify the mechanism of sufficient ventilation in leather.

2. The length of the papillary or reticular layer increased or decreased in every steps of the manufacturing process as follows: 816 or 3594μ in fresh hides, 668 or 3534μ in ripened hides, 1080 or 4266μ in soaked hides, 187 or 5846μ in limed hides, 382 or 3650μ in shaved hides 757 or 3126μ in bated hides 730 or 2716μ in pickled hides, 1079 or 4740μ in chrome-tanned leather, and 1050 or 4388 in stained and oil-liquored leather, according to the swelling and splitting of the collagenous fibers, enlargement of the intercollagenous spaces and bacterial multiplication.

3. The largest or shortest length of the epidermis slightly increased or disappeared in every step of the manufacturing process as the follows: 53 or 22μ in the fresh hides 53 or 21μ in the ripened hides and 67 or 36μ in the soaked hides, and zero μ in the limed, shaving, bating, and pickling hides and tanned and stained leathers, according to the desquamation of the epidermis.

4. According to the epidermal desquamation and collagenous swelling, the number of the epidermal winding per 1170μ as a unit length decreased in every step of the manufacturing process as follows: 9 in fresh, 7 in ripened, 2 in soaked, 4 in limed, 2 in shaved, 3 in bated, 3 in pickled, 2 in chrome-tanned and 2 in stained.

5. The area of the longitudinal and transversal collagenous fiber-bundles and that of the inter-collagenous spaces enlarged in every step of the manufacturing process as follows: $0.043\times10^6\mu^2$, $0.028\times10^6\mu^2$ and $0.023\times10^6\mu^2$ in fresh; $0.068\times10^6\mu^2$, $0.056\times10^6\mu^2$ and $0.037\mu\times10^6\mu^2$ in ripened; $0.139\times10^6\mu^2$, $0.105\times10^6\mu^2$ and

$0.086\times10^6\mu^2$ in soaked; $0.168\times10^6\mu^2$, $0.102\times10^6\mu^2$ and $0.141\times10^6\mu^2$ in limed; $0.193\times10^6\mu^2$, $0.097\times10^6\mu^2$ and $0.071\times10^6\mu^2$ in shaving and splitting; $0.243\times10^6\mu^2$, $0.158\times10^6\mu^2$ and $0.201\times10^6\mu^2$ in bating; $0.230\times10^6\mu^2$ and $0.229\times10^6\mu^2$ in chrome-tanning and $0.225\times10^6\mu^2$, $0.098\times10^6\mu^2$ and $0.337\times10^6\mu^2$ in staining and oil-liquor ing, according to the swelling and splitting of the collagenous fibers, enlargement of the intercollagenous spaces, bacterial multiplication and dehairing.

Our present report described the planimetrical observations of the swelling of the collagenous fiber-bundles in the corium for the sake of clarification of the mechanism of sufficient ventilation in leather.

Moreover it is very important to solve electronmicroscopically the problems of the swelling and splitting of the collagenous fibers. This will become the subject for future investigation.

Acknowledgement

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PLATE

Plate 1

Explanation of Figures

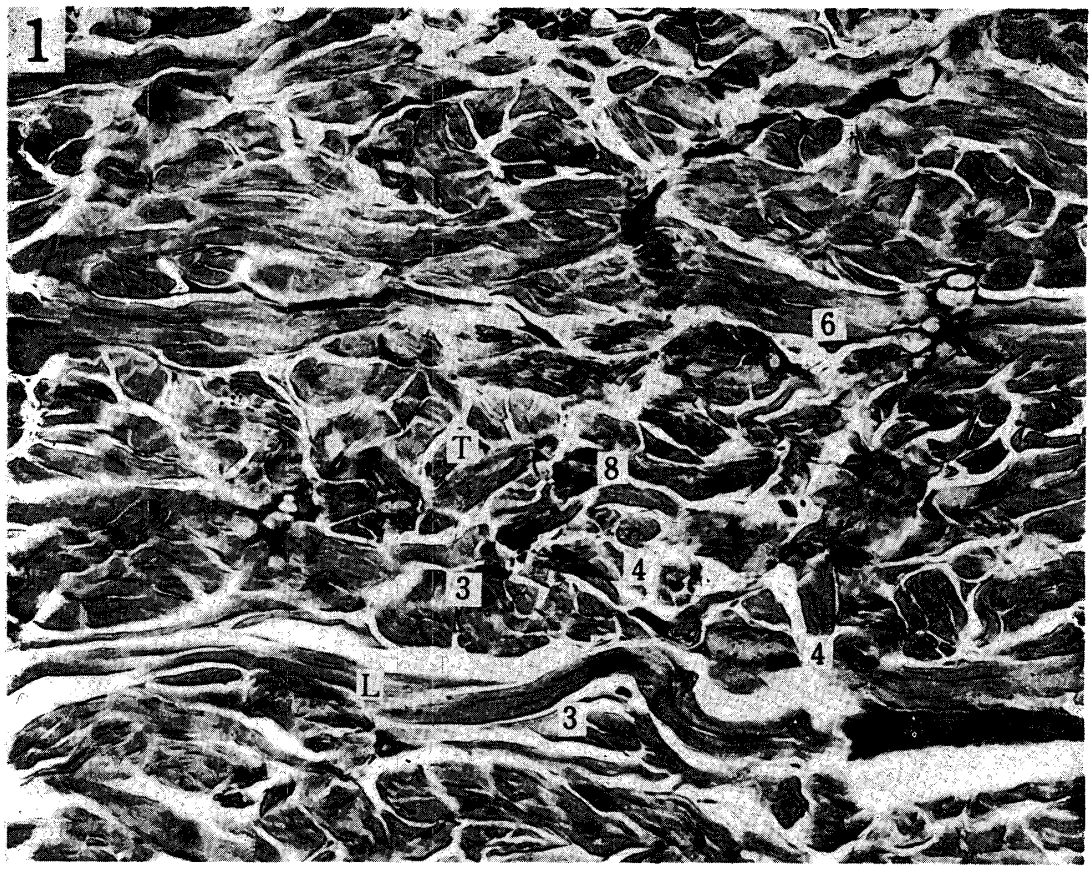
Low-power photomicrographs were taken at the same magnification and enlarged 450 times; the sections were stained with PAS reaction.

Fig. 1. Section of some collagenon in the ripening hide. The collagenon consisted of the longitudinal collagenous fiber (L) and transversal ones (T). Collagenous fiber-bundles indicated at the degree of 3–6 fibers in the longitudinal bundles and at that of 4–8 fibers in the transversal bundles.

In some collagenon, the area of the longitudinal collageneous fibers were $0.076 \times 10^6 \mu^2$, the area of the transversal collagenous fibers were $0.069 \times 10^6 \mu^2$, and the area of the interfibrous spaces were $0.054 \times 10^6 \mu^2$. The ratio of the interfibrous spaces to the total area of one collagenon was 30%.

Fig. 2. Section of some collagenon in the soaking hides. The longitudinal (L) and transversal (T) fiber-bundles swollen and split. The figures attached to the fiber-bundles slightly increased at the degree of 6–13 fibers in the longitudinal bundles and at that of 14–19 fibers in the transversal bundles.

In some collagenon, the area of the longitudinal collagenous fibers were $0.143 \times 10^6 \mu^2$, the area of the transversal fibers were $0.133 \times 10^6 \mu^2$, and the area of the interfibrous spaces were $0.159 \times 10^6 \mu^2$. The ratio of the interfibrous spaces to the total area of one collagenon was 25%.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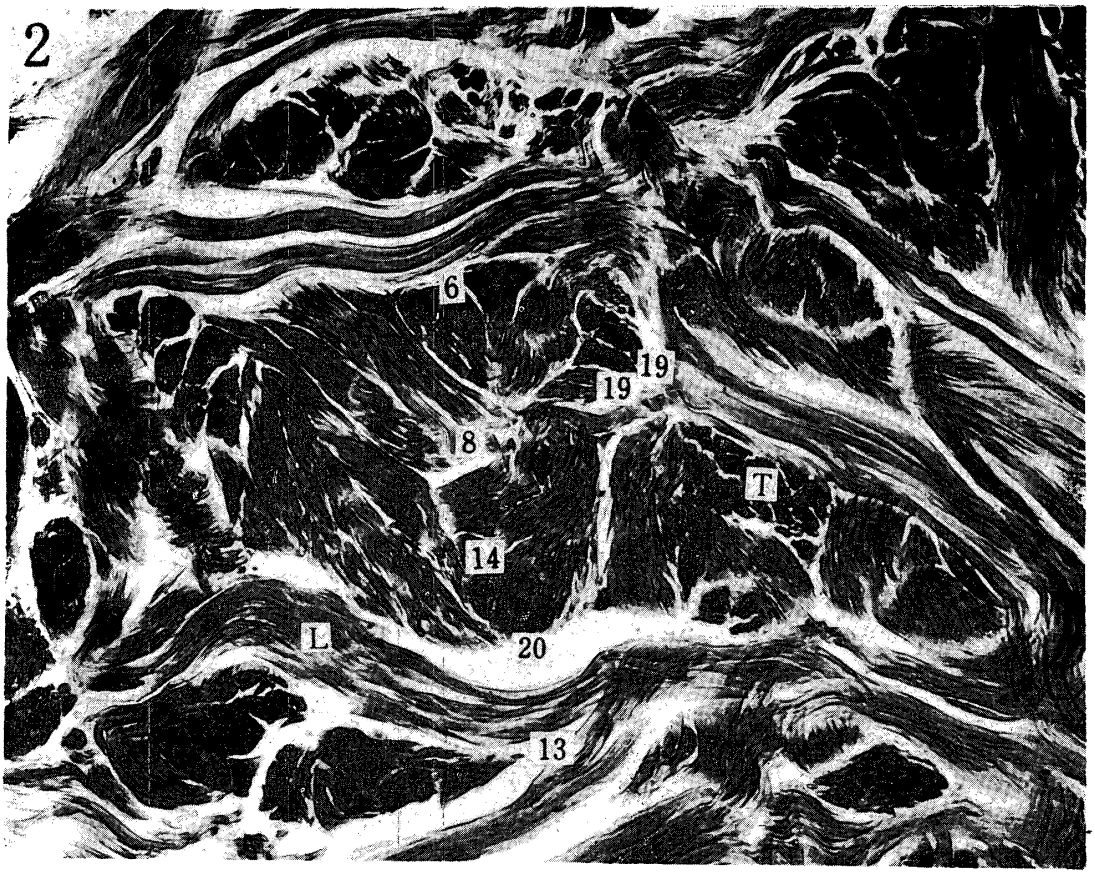
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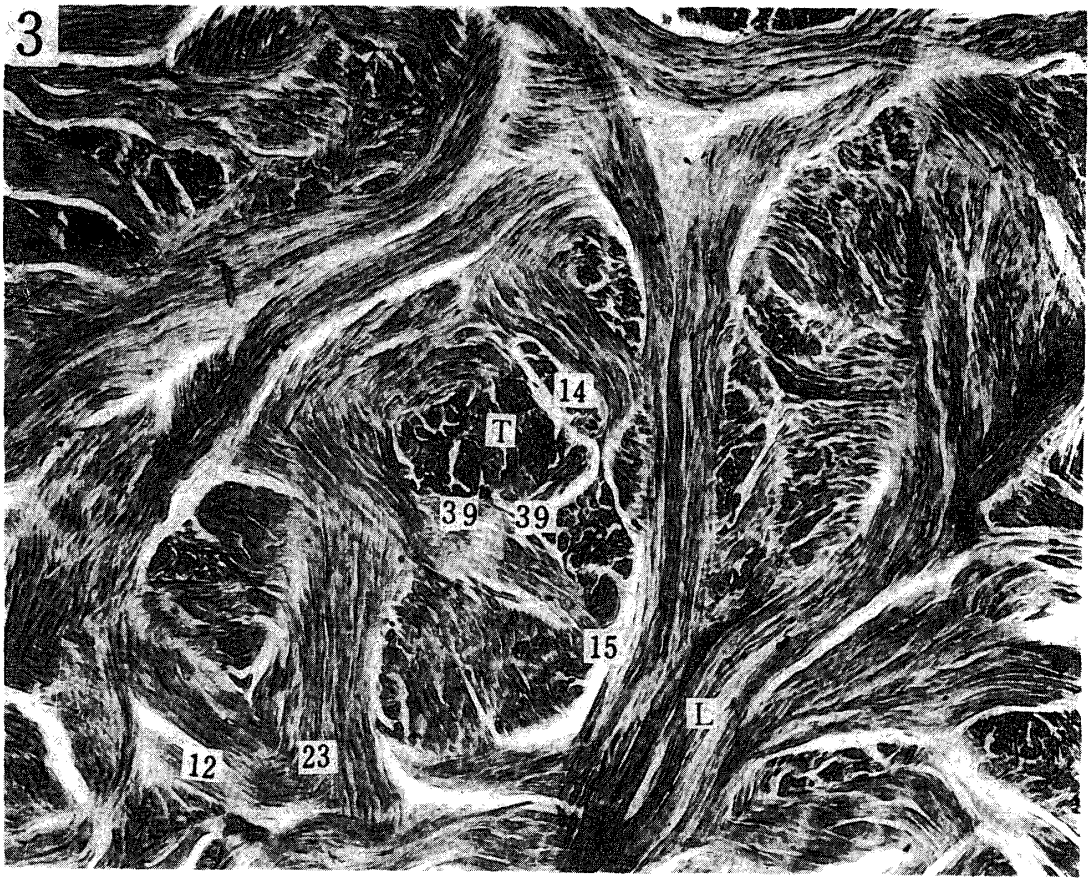
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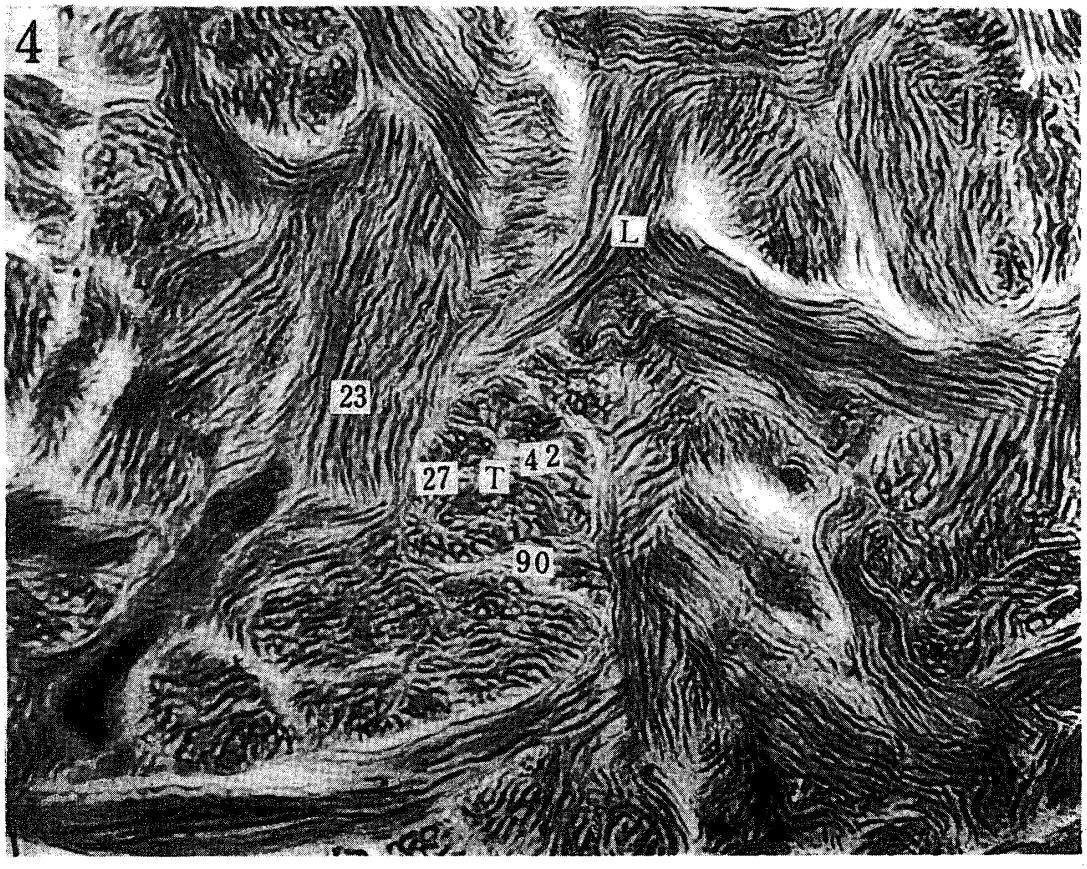
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Plate 2

Explanation of Figures

Low-power photomicrographs were taken at the same magnification, and enlarged at 450 times; the sections were stained with PAS reaction.

Fig. 3. Section of some collagenon in the liming hide. The longitudinal (L) and transversal (T) fiber-bundles swollen and split. The figures attached to the fiber-bundles gradually increased at the degree of 12–23 fibers in the longitudinal bundles and at that of 15–39 fibers in the transversal bundles.

In some collagenon, the area of the longitudinal collagenous fibers were $0.155\times10^6\mu^2$, the area of the transversal fibers were $0.114\times10^6\mu^2$, and the area of the interfibrous spaces were $0.115\times10^6\mu^2$. The ratio of the interfibrous spaces to the total area of one collagenon was 21%.

Fig. 4. Section of some collagenon in the shaving and splitting hide. Swelling of tudinal (L) and transversal (T) fiber-bundles was similar to the case of the liming hide. The figures attached to the fiber-bundles indicated at the degree of 7–23 fibers in the longitudinal bundles and at that of 25–90 fibers in the transversal bundles.

In some collagenon, the area of the longitudinal collagenous fibers were $0.168\times10^6\mu^2$, the area of the transversal fibers were $0.147\times10^6\mu^2$, and the area of the interfibrous spaces were $0.068\times10^6\mu^2$. The ratio of the interfibrous spaces to the total area of one collagenon was 10%.

Plate 3

Explanation of Figures

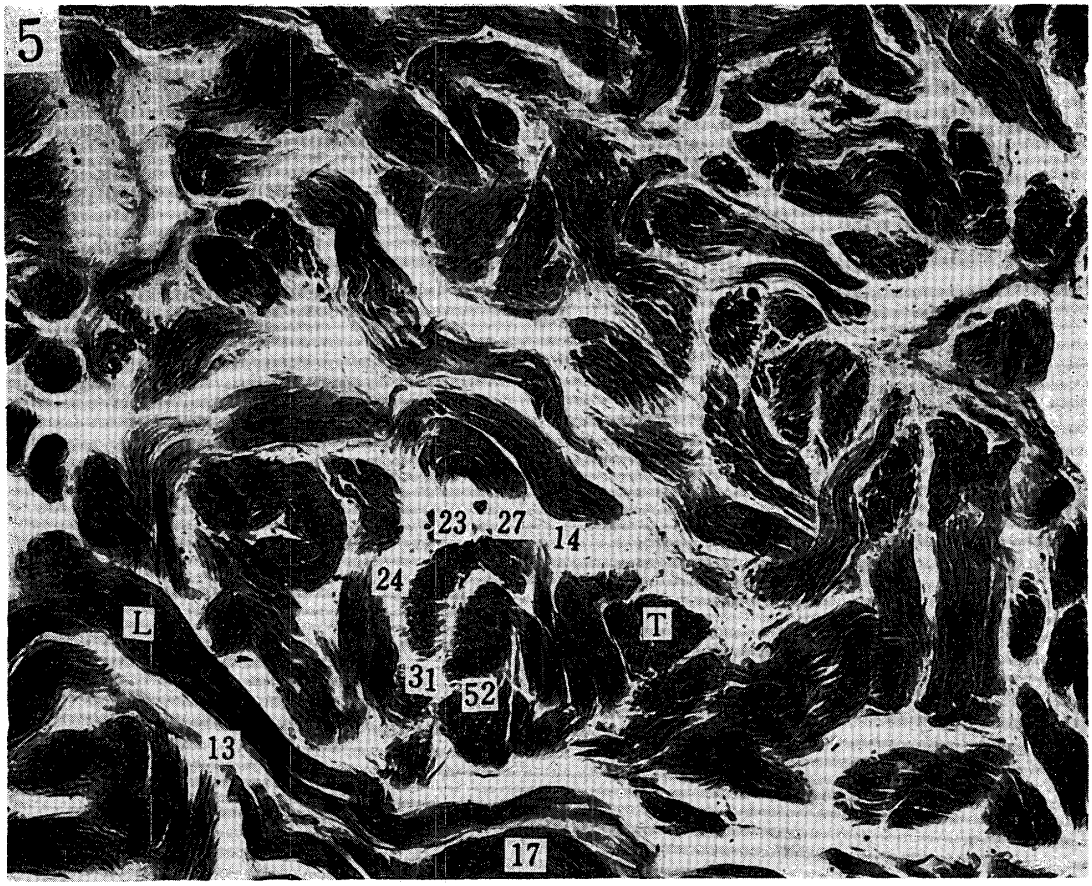
Low-power photomicrographs were taken at the same magnification, and enlarged 450 times; the sections were stained with PAS reaction.

Fig. 5. Section of some collagenon in the bating hide. The longitudinal (L) and transversal (T) fiber-bundles slightly confluenced and the interfibrous spaces enlarged. The figures attached to the fiber-bundles slightly decrease at the degree of 13–17 fibers in the longitudinal bundles and at that of 23–50 fibers in the transversal bundles in comparison with the case of the shaving and splitting hide.

In some collagenon, the area of the longitudinal collagenons fibers were $0.237 \times 10^6 \mu^2$, the area of the transversal fibers were $0.142 \times 10^6 \mu^2$, and the area of the interfibrous spaces were $0.131 \times 10^6 \mu^2$. The ratio of the interfibrous spaces to the total area of one collagenon was 37%.

Fig. 6. Section of some collagenon in the pickling hide. The longitudinal (L) and transversal (T) fiber-bundles remarkably confluenced and interfibrous spaces enlarged. The figrues attached to the fiber-bundles remarkably decreased at the degree of 7–9 fibers in the longitudinal bundles and at that of 33–45 fibers in the transversal bundles.

In some collagenon, the area of the longitudinal collagenous fibers were $0.318 \times 10^6 \mu^2$, the area of the transversal fibers were $0.129 \times 10^6 \mu^2$, and the area of the interfibrous spaces were $0.304 \times 10^6 \mu^2$. The ratio of the interfibrous spaces to the total area of one collagenon was 45%.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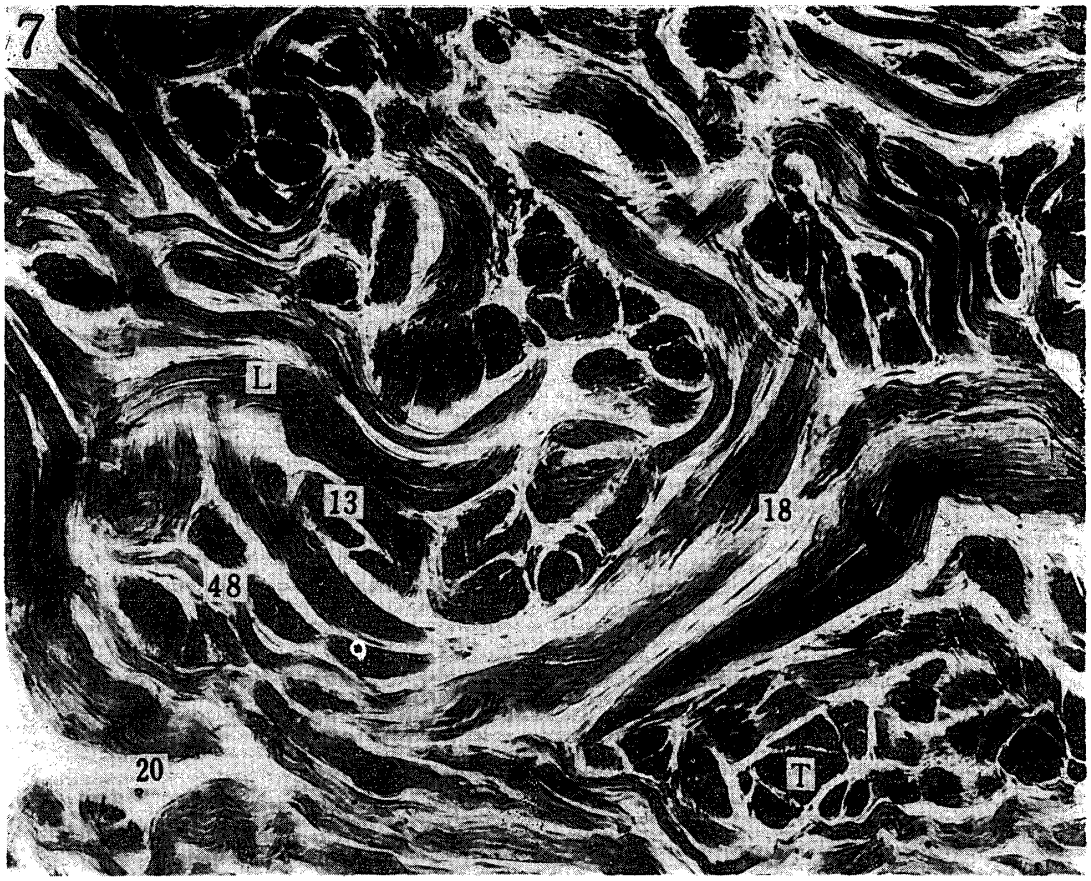
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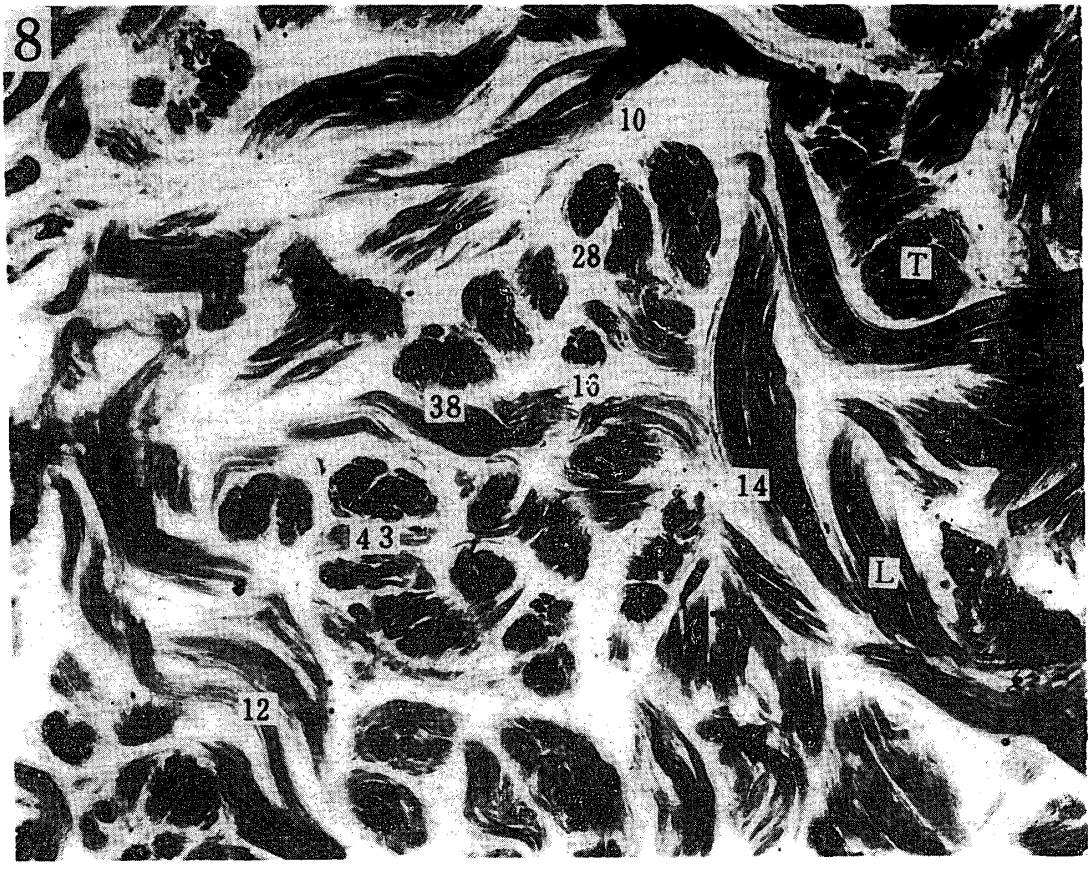
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Plate 4

Explanation of Figures

Low-power photomicrographs were taken at the same magnification, and enlarged at 450 times; the sections were stained with PAS reaction.

Fig. 7. Section of some collagenon in the chrome-tanning leather. The longitudinal (L) and transversal (T) fiber-bundles again splitted and interfibrous spaces enlarged. The figures attached to the fiber-bundles increased at the degree of 13–20 fibers in the longitudinal bundles and at that of 48 fibers in the transversal bundles.

In some section, the area of the longitudinal collagenous fibers were $0.37\times10^6\mu^2$, the area of the transversal fibers were $0.11\times10^6\mu^2$, and the area of the interfibrous spaces were $0.24\times10^6\mu^2$. The ratio of the interfibrous spaces to the total area of one collagenon was 40%.

Fig. 8. Section of some collagenon in the staining and fat-liquoring leather. The longitudinal (L) and transversal (T) fiber-bundles remarkably splitted and interfibrous spaces most remarkably magnified. The figures attached to the fiber-bundles were similar to the case of the chrome-tanning, and indicated at the degree of 10–14 fibers in the longitudinal bundles and at that of 28–34 fibers in the transversal bundles.

In some section, the area of the longitudinal collagenons fibers were $0.27\times10^6\mu^2$, the area of the transversal fibers were $0.13\times10^6\mu^2$, and the area of the interfibrous spaces were $0.48\times10^6\mu^2$. The ratio of the interfibrous spaces to the total area of one collagenon was 55%.